

VOLUME XXXVIII

GEMS & GEMOLOGY

SUMMER 2002



Featuring:
Characteristics and
Grading of Pink Diamonds

THE QUARTERLY JOURNAL OF THE GEMOLOGICAL INSTITUTE OF AMERICA



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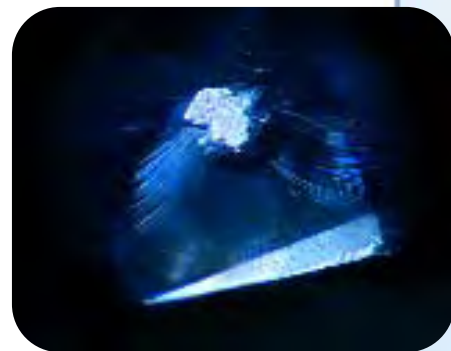
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Special annual subscription rates are available for GIA Alumni Association members and students actively involved in a GIA program: **\$59.95** to addresses in the U.S.; **\$70.00** elsewhere. Your student number must be listed at the time your subscription is entered.

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ABOUT THE COVER

Pink diamonds are known for their great beauty and rarity. The lead article in this issue, based on 1,490 natural-color pink diamonds examined by the GIA Gem Trade Laboratory, looks at the differences between type I and type II pink diamonds and discusses the color description terminology used by GIA GTL. Shown here (clockwise from top): a 13.32 ct Fancy orangy pink emerald cut from Harry Winston Inc.; a 6.10 ct Fancy Intense pink rectangular mixed cut from Rima Investors Corp.; a 10+ ct Fancy Vivid purple-pink round-cornered rectangular modified brilliant from Cora Diamond Corp.; a 12.53 ct Fancy Intense pink heart shape from Julius Klein Diamonds, Inc.; and a 7.18 ct Fancy Intense pink oval from Mona Nesseth, G.G., Custom & Estate Jewels (courtesy of a private collector). Photo © GIA and Harold & Erica Van Pelt. Due to printing fluctuations, color reproduction may not be exact.

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Remembering Gemology's Renaissance Man

John Sinkankas (1915–2002)

Gems & Gemology mourns the passing of associate editor John Sinkankas, who died in San Diego, California, on May 17 after a brief illness. John had celebrated his 87th birthday just two days before.

John Sinkankas was the quintessential “Renaissance Man” of gemology. He was a prolific author, a renowned lapidary, the undisputed bibliophile in his field, a gem and mineral connoisseur, and a successful miner. He was also an accomplished artist in watercolor, and several of his paintings of gems and minerals appeared in his books. Add to that his more than two decades of contributions to *G&G*, and it is safe to say that there will never be another John Sinkankas in gemology.

A native of Paterson, New Jersey, John began collecting minerals from the local quarries by the age of seven. After graduating in 1936 from the New Jersey State Teachers College (later William Paterson University), John started his 25-year career as a Navy pilot. He married his college sweetheart Marjorie Jane McMichael in 1940. John rose to the rank of captain before retiring in 1961, whereupon he and Marge settled in San Diego's Pacific Beach community. This positioned him well for his many forays into the local gem pegmatites.

John's childhood interest in gems and minerals continued throughout his naval career. After World War II, he enrolled in correspondence courses from GIA and the American Gem Society (AGS). A self-taught lapidary, John began cutting gems in 1947. Today two of his most important gem carvings, a 7,478 ct quartz egg and the world's largest faceted golden beryl (2,054 ct), are on permanent display at the Smithsonian Institution in Washington, DC.

Inspired to light the way for others, he began writing an amateur lapidary column for *Rocks & Minerals* magazine in 1951. His first book, *Gem Cutting—A Lapidary's Manual*, was published in 1955. More than a dozen books followed, including *Emerald and Other Beryls* (1981), *Gemology: An Annotated Bibliography* (1993), and the three-volume series *Gemstones of North America* (1959, 1976, and 1997).

John once described his approach to writing: “It's really quite a thrill when you find little bits of information that you didn't know, that you've never seen before. And you have a great deal of satisfaction in putting it down in black and white so everybody else can share that information.”

As John's writing projects expanded, so did his and Marge's private library. At the time GIA purchased their

14,000-item library in 1988, it was the world's finest private collection of gem and mineral literature. Now housed in the Institute's Richard T. Liddicoat Library and Information Center in Carlsbad, California, the Sinkankas collection includes thousands of rare and important books (see D. Dirlam et al., “The Sinkankas Library,” Spring 1989 *G&G*, pp. 2–15).

In 1982, John was awarded an honorary doctorate from William Paterson University. Two years later, a new pegmatitic phosphate mineral was named *sinkankasite* in recognition of his extraordinary contributions to the field. John received the Carnegie Mineralogical Award in 1988, and was named an Honorary Lifetime Member of the American Gem Trade Association (AGTA) in 1992.

John's contributions to *Gems & Gemology* were immeasurable. A member of the editorial review board from 1981 to 1983, and associate editor since 1984, he not only contributed numerous articles and book reviews, but he also diligently reviewed (and sometimes even rewrote) dozens of manuscripts.

As a friend of John's for more than 25 years, I treasured his dry wit and unassuming personality. He was generous with his encyclopedic knowledge and had a unique ability to take complex concepts, such as crystallography, and put them in terms that a layperson could understand. His influence was global, especially in the lapidary arts, where many who never even met John spoke of him as their mentor.

John Sinkankas is survived by his wife, Marjorie; daughters, Sharon J. Tooley of San Diego and Marjorie E. Coates of Virginia; sons, John W. Sinkankas of Los Angeles and George M. Sinkankas of Tennessee; nine grandchildren; and six great-grandchildren.

At the request of the Sinkankas family, GIA has established the John Sinkankas Library Fund. If you would like to contribute to the fund, please send your donation to: Dona Dirlam, Liddicoat Gemological Library and Information Center, 5345 Armada Drive, Carlsbad, California 92008 (ddirlam@gia.edu).

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LETTERS

COMMENTS ON THE GIA ANALYSIS OF DIAMOND "FIRE"

This article from GIA's study of the impact of proportions on the appearance of a round brilliant cut diamond (Reinitz et al., Fall 2001, pp. 174–197) is a work of admirable dedication, intelligence, and technology and represents a huge commitment of resources.

It is unfortunate that this huge effort has two major gaps. First, it confines the study of entering rays to the vertical, ignoring the vast majority of rays that enter the diamond from directions other than the perpendicular, and therefore result in very different emerging light patterns.

Second, the "fire" (dispersion) calculations are taken from the total of emitted rays impacting on a virtual hemisphere that encloses all of the diamond above the girdle. In the real world, diamonds are viewed from individual points of view, so that the "fire" of the diamond can be judged only from those points. Thus, the study uses only one illumination direction, where in actuality diamonds are illuminated from an infinity of positions. Conversely, simultaneous viewing from an infinity of positions over an entire hemisphere could never occur, as diamonds can be seen from only one location at a time.

Thus, the two fundamental bases for this study do not reflect what actually happens when diamonds are illuminated or viewed.

If we were to add three other entering beams of light—say, at 20°, 40°, and 60° from the vertical—the light emissions resulting from these new sources would likely be very different from the purely vertical rays used in the study. They would also more closely approach realistic illuminating positions.

Again, diamonds are never actually viewed from a complete hemisphere, but from single points of view within that hemisphere. The two systems of viewing are not identical, or even similar.

To get representative views of rays emerging from the diamond, at least four viewing positions—say at 0°, 20°, 40°, and 60° from the vertical—would seem the minimum necessary to sample "fire" for each of the above illumination sources by an actual observer. Thus, we would have four illuminating positions, with four viewing positions for each.

A comparison of the intensity of light (brightness) and

color emissions (fire) for each of these 16 viewing positions for a variety of diamond proportions would more closely represent the real-world observation of diamonds.

The GIA Study Is a Huge First Step. This first step includes the ability to measure and compare the number, color distributions, and intensity of rays entering and emerging from diamonds of differing proportions. Although not included in the GIA articles (see also T. S. Hemphill et al., "Modeling the appearance of the round brilliant cut diamond: An analysis of brilliance," Fall 1998 *Gems & Gemology*, pp. 158–183), it seems reasonable and important to combine the diverse brilliance and fire measurements into a single "metric."

Table 2 of the Fall 2001 article (p. 179), which compares "Proportions and Calculated Metric Values for 28 Diamonds" from the study, is the only place where the fire metric is examined in actual (as opposed to virtual) diamonds. Note that within this group of 28 diamonds, five of the eight that most closely adhere to both the American Ideal Cut (AGS "0") and the Tolkowsky cut* show DCLR (dispersed colored light return, the metric for fire) of over 3.75 and a combined WLR (weighted light return, the metric for brilliance) and DCLR of over 4.03.

Those stones are:

No.	Crown angle	Pavilion angle	Table	WLR	DCLR	Combined WLR and DCLR
1	34.3°	40.6°	54%	0.283	3.97	4.25
8	33.4°	41.2°	58%	0.279	3.79	4.07
10	34.9°	40.9°	54%	0.281	3.89	4.17
13	33.7°	41.1°	52%	0.281	4.01	4.29
16	33.8°	40.4°	54%	0.281	3.77	4.05

So, of the 28 actual (not virtual) stones examined by GIA for this study, five that had the highest DCLR and a high combined WLR and DCLR—that is, five that exhibited the most fire, and high combined brilliance and fire—were the five that most closely resembled both the AGS "0" and Tolkowsky proportions.

This fits the claims of the "Ideal" adherents that this cut is high in dispersion, and represents the best combination of brilliance and fire.

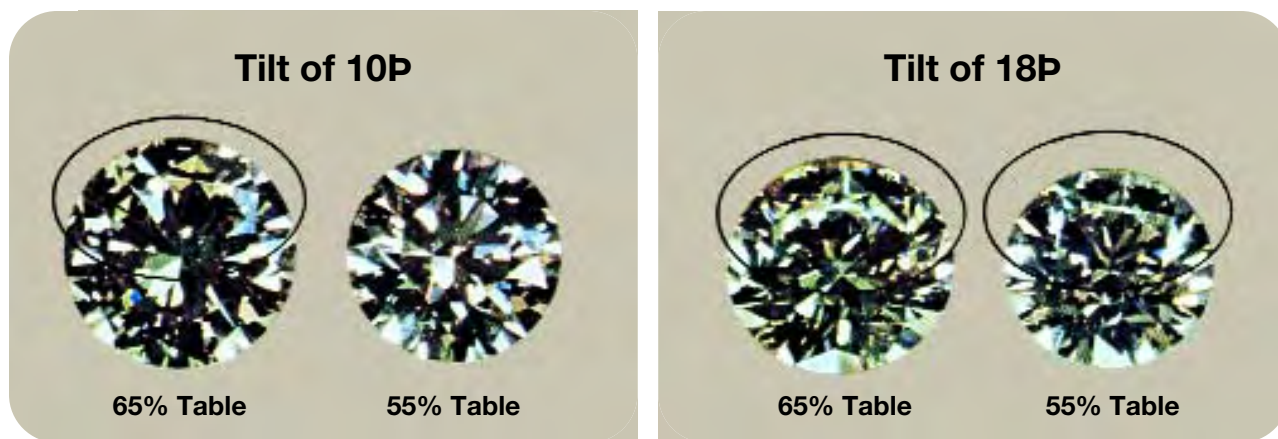


Figure 1. In these photos of two $\frac{3}{8}$ ct round brilliants, which were identical except for the size of their tables, the diamond with the 65% table begins to show dull girdle reflections at a 10° tip, whereas the one with the 55% table does not show any girdle reflections until it has been tipped to 18° .

A New Concept: Examination of the Quality of Emitted Light—The “Cone of Beauty.” GIA equates excellence of cut with the amount of light emissions, but one must also consider the quality of light emissions being viewed. Some light emissions actually detract from the diamond’s appearance, or “beauty.” For example, dull (fish-eye) reflections of the girdle seen at the edge of a tipped table contribute to the total of light emissions, but they certainly detract from the diamond’s beauty. Likewise, pavilion height, crown height, and table size all affect the amount a diamond can be tipped before ugly, dull girdle reflections become visible.

Therefore, not only is this study of fire relevant to only a tiny minority of the possible illumination sources (and not to real-life viewing positions), but it also measures only the quantity, not the quality (the uniform beauty), of the emitted rays of light. This uniformity of high brilliance and fire, that is, the absence of dull areas, is an essential factor in the diamond’s beauty.

“Fish-eye” diamonds are the dullest, the least desirable of all. Yet it is possible, by sufficiently tipping any conventionally cut brilliant, to view these dull girdle reflections at the table edges.

What causes increased visibility of these ugly girdle reflections? First, the larger the table, the easier it is to see girdle reflections. Second, visibility of the girdle reflections varies directly with insufficient pavilion angles.

To illustrate this concept, we prepared two $\frac{3}{8}$ ct round-brilliant-cut diamonds—each with 41° pavilions and 34° crown angles—which were identical except for the size of the table: 55% in one, 65% in the other. As figure 1 illustrates, at a 10° tip, the 65% table began to show dull girdle reflections; the 55% table showed none at all. It was necessary to tip to 18° before the 55% table showed any girdle reflections at all; at 18° , the diamond with the 65% table showed a large dull area of girdle reflections.

I refer to the angle over which a stone can be tipped before the girdle reflections significantly impact the appearance of the diamond as the “cone of uniform beauty.” For the diamond with the 55% table, the “cone of uniform beauty” is 36° ; for the diamond with the 65% table, it is only 20° (figure 2).

As one tips the stone further, the dull area in the 65% table continues to be much larger than in the 55% table. This is a significant difference in beauty and brilliance.

So we see that measuring the total quantity of brilliance and dispersion of emitted light is only part of the picture. One must also consider the *quality*, the *uniform beauty*, of the perceived rays.

Similar cause-and-effect relationships should become apparent when other individual entry and emerging rays are analyzed, as suggested above. It is this diamantaire’s opinion, that at the end of such a research study the “Ideal cut” diamond will emerge as the most beautiful, in keeping with its rapidly growing popularity in recent years.

In conclusion, I hope that GIA will add a cut “grade” to their well-respected diamond grading reports. And I recommend that any such information take into consideration additional illumination and viewing angles, as well as the “cone of uniform beauty” concept introduced above. An objective evaluation would allow the cutter or buyer to make an informed decision about the desired style of cutting. Those who want maximum “spread” and weight will be able to gauge the consequent loss of “fire” and decreased “cone of brilliance.” However, table 2 of

*Following are the proportions specified for the AGS “0” and Tolkowsky cuts.

	AGS “0”	Tolkowsky
Table	52.4%–57.5%	53%
Pavilion angle	40.16° – 41.22°	40.75°
Crown	33.7° – 35.8°	34.5°
Girdle	0.51%–2.95%	Omitted
Culet	Very small	Omitted

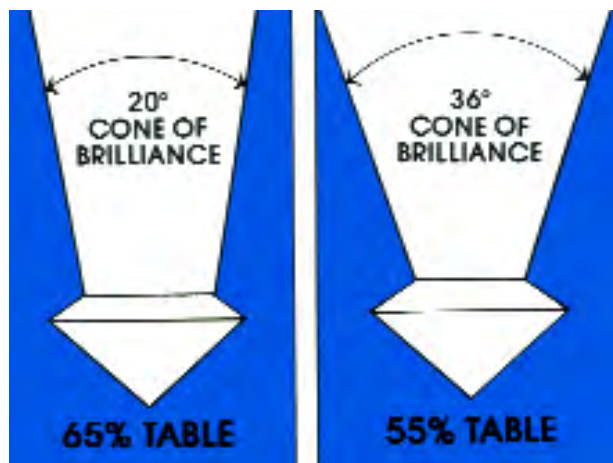


Figure 2. The “cone of uniform beauty”—that is, the angle to which a diamond can be tipped before the girdle reflections negatively impact the appearance—is 36° for the diamond with the 55% table, but only 20° for the one with the 65% table.

the “fire” article indicates that those who prefer maximum beauty will choose the “American Ideal” make.

George Kaplan
Lazare Kaplan International
New York City

Reply:

Mr. Kaplan makes some excellent points about the lighting and observation conditions we chose for DCLR. (Others have made similar comments about WLR.) Both of these metrics were preliminary explorations into the appearance aspects of a round brilliant cut diamond, and we have since experimented with other combinations of illumination and viewing conditions. Mr. Kaplan suggests examining 16 conditions altogether, and we will keep these suggestions in mind as we continue our research.

We must, however, point out something about “actual,” or typical, lighting and observing conditions. In typical mixed lighting, each polished round brilliant displays a complex visual array that combines brilliance, fire, scintillation, and aspects pertaining to the pattern, such as contrast and symmetry. All these appearance aspects are displayed simultaneously in most common lighting. We think that this complexity underlies the continuing disagreement in the trade about cut issues. More than 80 years of debate has not resulted in worldwide agreement of what constitutes the best proportions, although it has produced several successful marketing niches.

Thus, our first step was to look at these appearance aspects individually. When separating these optical effects from one another, it can be advantageous to choose

extreme lighting and/or observing conditions, rather than typical ones, so that only one appearance aspect is displayed, while the others are minimized. With regard to fire, we stated (on p. 181 of the Fall 2001 article): “This combination of lighting and observing conditions tests the *maximum extent* to which a round brilliant with a particular choice of proportions can disperse light into its component colors.” Thus, this set of conditions offered us a means to effectively differentiate sets of proportions from one another.

Despite his reservations about the conditions for DCLR, Mr. Kaplan suggests that this metric, added to WLR, is useful for assessing diamonds. As these metrics are defined, however, the scale of DCLR is about 10 times larger than the scale of WLR. Thus, in the sums provided by Mr. Kaplan, DCLR counts for about 10 times as much as the WLR contribution. So the diamonds that have a high sum really have higher DCLR than the other stones, rather than “the highest combined brilliance and fire.” We do not consider the research published so far to be directly usable as a grading system; as we stated on page 175 (of the article on fire), “We plan to address practical applications of our research to date in our next article.”

Mr. Kaplan also suggests that the results of the DCLR and WLR metrics, however flawed, nevertheless demonstrate the superiority of the “American Ideal Cut” (i.e., the AGS “0”) and the Tolokowsky Cut. When we look at the same data, however, we see support for our contention that the combination of proportions is more important than the particular value of any one of them. Based on the proportions shown in our table 2, of the five diamonds Mr. Kaplan chose as examples, only two would get a grade equivalent to AGS “0”; three would get a grade of “1”. Another diamond, no. 23, has high DCLR and a high sum, but it would get a grade equivalent to an AGS “3”. We would also like to note that one diamond that would get a grade equivalent to AGS “7” shows both

Stone no. ^a	Equivalent AGS grade	WLR	DCLR	Sum
13	1	0.281	4.01	4.291
1	0	0.283	3.97	4.253
23	3	0.269	3.92	4.189
10	0	0.281	3.89	4.171
8	1	0.279	3.79	4.069
16	1	0.281	3.77	4.051
22	7	0.274	3.75	4.024
20	2	0.279	3.63	3.909
12	0	0.274	3.52	3.794
7	2	0.271	3.46	3.731

^aSamples are listed in order (highest to lowest) of the sum of WLR and DCLR. The numbers boldfaced are the ones in Mr. Kaplan’s table.

a DCLR value and a sum greater than another diamond that would be graded as a "0".

We agree completely with Mr. Kaplan's excellent point that the "quality" of light emerging from a round brilliant is important as well as the quantity of it. After exploring fire, a significant portion of our research effort turned in this direction, toward examining the face-up pattern displayed by a diamond. Some aspects of this pattern are important for scintillation, and some aspects (not necessarily the same ones) can affect human perception of brilliance. Since hearing Mr. Kaplan's presentation at the 1999 AGS Conclave, we have thought much about how tilting of the diamond (motion with respect to the light source and observer) reveals more about the cut than can be seen in only one viewing position. Viewing distance is also an important variable. However, we think his phrase "uniform beauty" may be even more appropriate to describe aspects of this pattern beyond the lack of girdle reflections. Two appearance problems that readily come to mind are a dark-appearing table and the visibility of the culet through the bezel facets.

Mr. Kaplan's comments are very welcome as we continue with this complicated research, even if we think his conclusions are premature. Now that we have embarked on the next phases of our research, which include real-world verification and research into scintillation (which requires movement and tilt), his comments are timely and appreciated.

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and Al M. Gilbertson
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More on jeremejevite from Namibia

In response to "Jeremejevite: A gemological update" (K. Scarratt et al., Fall 2001, pp. 206–211), I am writing to clarify a few points about the recent production of jeremejevite from Namibia. From December 1998 to February 2001, I was the mine manager of Khan River Mining & Exploration (Pty.) Ltd.'s jeremejevite project at Mile 72 on the Namibian coast (72 miles north of the coastal city of Swakopmund). Mile 72 often has been reported in the literature as "Cape Cross," although it is some 16 km south of Cape Cross. The coordinates of the discovery outcrop are 21° 52' 76"S, 14° 04' 51"E. This location lies within 700 m of the state-run recreational fishing campground at Mile 72.

The production of jeremejevite from Mile 72 dates back to the 1974–1976 mining efforts of Sid Pieters, a Windhoek gem and mineral dealer. Facetable blue jeremejevite, like the stones pictured in figure 2 of the Scarratt et al. article, was obtained during this time. The most recent production occurred in March 1999, within



Figure 1. This jeremejevite crystal specimen (25 ↔ 20 mm) was recently recovered from the Erongo Mountains in Namibia. Courtesy of C. Johnston.

the first two weeks of mining by the Khan River joint venture. The pocket contained some 300 crystals, mostly terminated, that were transparent and "straw" yellow; it also yielded the rough from which the 4.54 ct yellow stone pictured in the Scarratt et al. article was undoubtedly cut. The largest crystal we found measured 51 ↔ 6 mm. The contents of the pocket were delivered to joint-venture partner Bryan Lees of The Collector's Edge in Golden, Colorado. Subsequently, Mr. Lees sold the bulk of the crystals to rare-stone dealer Mark Kaufman of San Diego, California, from whom they presumably have migrated into circulation.

After mining some 4,000 tonnes of rock without further production, we terminated our mining activities and reclaimed the area. It is extremely doubtful that there will be future production of jeremejevite from Mile 72.

Most recently, in March 2001, there was a substantial discovery of blue, gem-quality jeremejevite in the Erongo Mountains (see, e.g. figure 1). Given the extent of the Erongo production, gemologists would be well advised to revisit the gemological data for this fascinating mineral, as the probability of their encountering one has increased significantly.

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CHARACTERIZATION AND GRADING OF NATURAL-COLOR PINK DIAMONDS

By John M. King, James E. Shigley, Scott S. Guhin, Thomas H. Gelb, and Matthew Hall

The GIA Gem Trade Laboratory (GTL) collected gemological data on 1,490 natural-color pink gem diamonds—both types I and II. While there was some overlap in gemological properties between the two diamond types, they did show differences in their color ranges, ultraviolet fluorescence, absorption spectra, and microscopic features. The color description terminology used for pink diamonds on GIA GTL grading reports is discussed and illustrated, with a separate commentary on red diamonds.

Known for their great beauty and rarity, pink diamonds have long been sought after by jewelers, collectors, and consumers (figure 1). Notable pink diamonds such as the Darya-i-Nur (reported to weigh more than 175 ct), the Agra (known historically to weigh 32.24 ct and recently recut to 28.15 ct), and the 20.53 ct Hortensia (figure 2) add to and sustain interest in these gems (Balfour, 2000). Table 1 lists a number of larger “named” faceted pink diamonds that have contributed to our fascination with them over the years. As with blue diamonds, however, the infrequency with which pink diamonds were encountered in the trade (prior to the discovery of the Argyle mine in Australia) or were documented by gemological laboratories resulted in a scarcity of published information on them.

This article presents data for an extensive population of nearly 1,500 pink diamonds examined in the GIA Gem Trade Laboratory (GTL) over a specific period during the last few years. To the best of our knowledge, this report is the first gemological study of a large sample of pink diamonds that are representative of what currently exists in the marketplace. Following some comments on the history of pink diamonds and their geographic sources, this article will focus on expanding the database of information on this important group of colored diamonds by documenting and reporting on their range of color and

other gemological properties. In particular, we looked for correlations of characteristics or properties with the two type classifications in which pink diamonds occur: those with a relatively high nitrogen content (type I), and those with virtually no nitrogen (type II). Note that, throughout this article, the term *pink* is used generically, when appropriate, to refer to the entire color range of pink diamonds. This includes those having brown, purple, or orange modifying components. In all these instances, however, the predominant color appearance is pink; thus, *pink* is the last term in the diamond’s color description. For a discussion of “red” diamonds, see box A.

BACKGROUND

Historical and Geographic Origin. Over the centuries, pink gem diamonds have been recovered from several localities. Some historic diamonds, such as the Agra, originated in India (Balfour, 2000);

See end of article for About the Authors and Acknowledgments.

*Note that this article contains a number of photos illustrating subtle distinctions in color. Because of the inherent difficulties of controlling color in printing (as well as the instability of inks over time), the color in an illustration may differ from the actual color of the diamond.

GEMS & GEMOLOGY, Vol. 38, No. 2, pp. 128–147.

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Figure 1. The fascination with pink diamonds dates back centuries. For the contemporary diamantaire, the range of colors—such as those shown here—offers many possibilities for different tastes. The diamonds in the two rings are a Fancy Intense purplish pink (left, 5.04 ct) and Fancy Intense pink (right, 3.75 ct); the round and triangular loose diamonds (0.38 and 0.54 ct) are Fancy Intense purplish pink, and the 1.12 ct oval is Fancy Deep orangy pink. The rings are courtesy of Rima Investors Corp. (left) and Mona Nesseth, Custom Estate Jewels (property of a private collector). Photo © GIA and Harold Erica Van Pelt.

their exact geographic sources in that country remain uncertain, although the Golconda region is one likely area. A number of pink diamonds—some quite large—have been found sporadically in alluvial workings along the interior rivers of Brazil, particularly in the region called Triangulo Mineiro (“Mining Triangle”; also known as Alto Paranaíba, near the city of Uberlandia; see Svisero et al., 1984; Cassedanne, 1989) in the state of Minas Gerais. A 78 ct pink diamond crystal was found at an undisclosed location in Minas Gerais in 1999 (Hart, 2000). Beginning in the 1940s, the Williamson mine in Tanzania produced a small number of pink diamonds, the most famous of which was a 54.5 ct crystal section that was fashioned into a 23.6 ct round brilliant (the “Williamson Pink”) and presented to then-Princess Elizabeth on the occasion of her wedding (“Pink diamond gift ...,” 1948; Balfour, 1982). Another occasional source is Kalimantan, Indonesia, on the island of Borneo (Ball, 1934; reported to be along the Kapuas River—see Fritsch, 1998), although no large or deeply colored pink diamonds are known from there. On occasion, the Premier mine near Johannesburg in South Africa has produced pink diamonds (L. Wolf, pers. comm., 2002).

From the late 1980s on, however, the supply coming from the Argyle mine in Australia greatly increased the availability of pink and, on rare occasions, red diamonds (Hofer, 1985; Shigley et al., 2001). Even with this production, from April 2000 to April 2001 pink diamonds represented fewer than

10,000 carats of the 25 to 30 million carats of rough production from this one mine. Of these, fewer than 10% weighed more than 0.20 ct (Michelle, 2001). The most important of the pink Argyle diamonds are offered at special auctions (“Argyle Diamond’s Pink Diamond Tender, 1985–1996,” 1997; Roskin, 2001a).

Figure 2. The 20.53 ct Hortensia was included in the 1791 inventory of the crown jewels of France, but was one of several pieces stolen from the Grande Meuble palace in 1792. It was recovered shortly thereafter, and later became associated with the family of Napoleon. It is currently displayed in the Galerie d’Apollon at the Louvre Museum in Paris. Photo courtesy of Art Resource.



Noted Auction Sales. In recent history, pink diamonds have been important components of high-profile sales by auction houses. In November 1994, Christie's (Geneva) sold a 19.66 ct Fancy pink diamond for \$377,483 per carat; a year later, in November 1995, Sotheby's (Geneva) sold a 7.37 ct Fancy Intense purplish pink diamond for \$818,863 per carat. More recently, in May 1999, Christie's (Geneva) auc-

tioned a 20.83 ct Faint pink for \$474,000 per carat, and a 5.74 ct Fancy pink for \$665,000 per carat (Blauer, 2000).

Past Studies. Except for occasional discussions of famous examples and/or historical geographic sources, there have been few published studies of the gemological properties of pink diamonds as a group. Some information on them can be found in Orlov (1977), Liddicoat (1987), Harris (1994), Webster (1994), and Hofer (1998). Most recent discussions have been on the type I pink diamonds found at the Argyle mine (see, e.g., Chapman et al., 1996; Shigley et al., 2001). Less information has been documented on type II pink diamonds, although two exceptions are Anderson (1960) and Scarratt (1987).

There have also been some shorter reports on "pink" diamonds:

- General information (Henry, 1979; Kane, 1987; Shigley and Fritsch, 1993; Fritsch, 1998; Balfour, 2000; Roskin, 2001b), and absorption spectra and fluorescence reactions (Scarratt, 1987; Fritsch, 1998)
- Descriptions of particular diamonds in the GIA Gem Trade Lab Notes section of *Gems & Gemology* (e.g., Crowningshield, 1959, 1960)
- Reports on the photochromic behavior of some pink diamonds, in which they change color under different conditions (Van Royen, 1995; Liu et al., 1998; Van Bockstael, 1998; Koivula and Tannous, 2001)
- Treated "pink" diamonds and their identification (Crowningshield and Reinitz, 1995; Kammerling et al., 1995; King et al., 1996; Reinitz and Moses, 1998)
- Treated synthetic red diamonds and their identification (Moses et al., 1993)
- Information on auction sales (Blauer, 2000)

Color and Color Origin. The cause of color in type I and type II pink diamonds (figure 3) is still the subject of scientific investigations (see Collins, 1982; Chapman and Humble, 1991; Fritsch, 1998; Chapman and Noble, 1999). There is no evidence that this coloration is due to any trace element (such as nitrogen or boron) in the crystal structure of the diamond (although early work erroneously suggested that manganese was responsible for the pink color; see Raal, 1958). The cause appears to be similar to that which produces brown coloration in diamond,

TABLE 1. Notable named faceted pink diamonds, weighing more than 9 ct.^a

Weight (ct)	Shape	Color ^b	Name
242.31 ^c	Flat oblong	"Light pink"	Great Table
175 to 195 ^d	Rectangular step	"Light pink"	Darya-i-Nur
140.50	Cushion brilliant	"Pink"	Regent
72	Cushion brilliant	"Rose pink"	Nepal Pink
70.39 ^e	Pear brilliant	Fancy Light pink	Empress Rose
60.75	(Not stated)	"Light rose"	Cuiaba
60 ^f	Oval brilliant	"Rose pink"	Nur-ul-Ain
56.71	Table	"Light pink"	Shah Jahan
40.30 ^g	Pear brilliant	Fancy Light pink	Carlotta
34.64	Cushion brilliant	Fancy pink	Princie
29.78	Pear brilliant	"Pink"	Pink Sun Rise
28.15 ^h	Rectangular modified brilliant	Fancy Intense pink	Agra
24.78	Pear brilliant	"Light pink"	Peach Blossom
24.44	Emerald-cut	"Pink"	Mouawad Lilac Pink
23.60	Round brilliant	"Light pink"	Williamson Pink
22.84 ⁱ	Marquise brilliant	Fancy pink	Winston Pink
21.06 ^j	Rectangular modified brilliant	Fancy pink	Mouawad Pink
21.00	Square	"Rose"	Mazarin no. 7
20.53	Shield	"Pink"	Hortensia
17.00	Square	"Reddish pink"	Mazarin no. 12
15	Pear brilliant	"Pink"	Kirti-Nur
13.35	Cushion brilliant	"Pink"	Paul I
9.93	Rectangular step	"Pink"	Orchid
9.01	Pear brilliant	"Light pink"	Grande Conde

^aSources of information: GIA Gem Trade Laboratory grading reports, as well as Henry (1979), GIA Diamond Dictionary (1993), Hofer (1998), and Balfour (2000).

^bColor descriptions in quotation marks are taken from the literature. GIA GTL fancy grade descriptions represent the terminology in use at the time of the report (modifications to this terminology were introduced in 1995; see King et al., 1994).

^cWeight in old carats.

^dEstimated weight range.

^eExamined by GIA in 2001.

^fEstimated weight.

^gExamined by GIA in 1978.

^hExamined by GIA in 1998. The Agra was known historically to weigh 32.24 ct but was subsequently recut.

ⁱExamined by GIA in 1974.

^jExamined by GIA in 1989.

that is, a *color center* (or centers)—an atomic-level lattice defect that can selectively absorb light in the visible region of the spectrum (Collins, 1982; Jackson, 1997). In type I and some type II diamonds, this color center is often concentrated along parallel slip planes, so that pink or brown planes (i.e., colored graining) are seen in an otherwise near-colorless diamond (figure 4). This similarity of color origin is supported by observations that diamonds can vary from pink through brown-pink to brown, and that all of these hues have some similar features (i.e., banded internal colored graining and a visible spectrum dominated by a broad 550 nm absorption band of varying intensity; Collins, 1982).

When the coloration is planar, it is thought to have been the result of plastic deformation of the diamond while it was in the earth (Collins, 1982). During this deformation, layers of carbon atoms that are parallel to the orientation of the applied stress are displaced slightly with respect to one another along parallel gliding or slip planes. As mentioned above, this situation gives rise to the creation of a color center of unknown structure along these slip planes that can in turn produce the spectral feature responsible for the pink or brown color.

GIA Color Description Nomenclature for “Pink” Diamonds. Colors appear different in a given hue range depending on their tone and saturation. The color description GIA gives for colored diamonds on grading reports is based on the hue designation on the color wheel (figure 5) or on the tone and saturation on the color wheel (figure 5) or on the tone and saturation of that hue (see, e.g., King et al., 1994). At certain saturations and tones, the term *pink* is used to describe diamonds in the hue range from reddish purple to orange. Although at higher saturations the hue is clearly reddish purple to orange (as indicated by the solid circle next to the hue name in figure 6), at lower saturations and lighter tones the overall color appearance is predominantly pink (i.e., *pink* is the only or final word in the color description, such as *purple-pink*, *purplish pink* or *orangy pink*—or any of these color terms with a “brownish” modifier, as well as *brown-pink*). Even at some relatively higher saturations and darker tones, diamonds in the purple-red, purplish red, red, and orangy red hue ranges also appear predominantly pink.

Because the GIA Gem Trade Laboratory uses the term *pink* to refer to certain combinations of tone/saturation attributes for a range of color hues, it is always applied independently of the term *red*. This means that our terminology system for colored

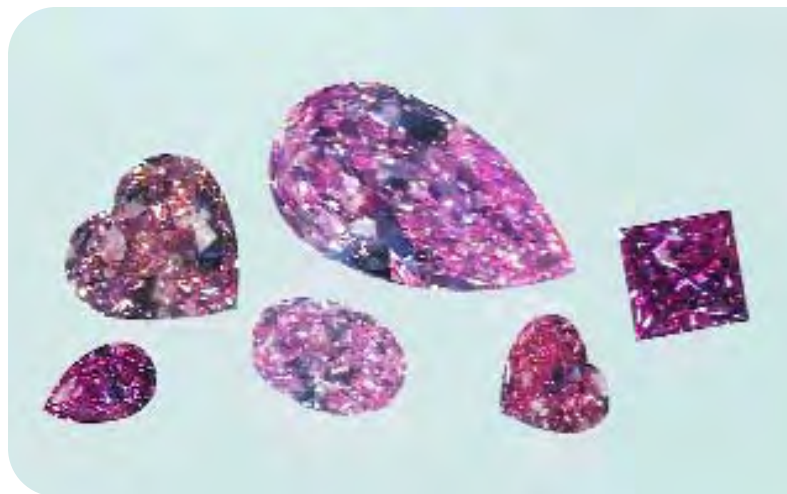


Figure 3. Pink diamonds may be either type I or type II. In this photo, two type I pink diamonds, the smaller 0.41 ct Fancy Deep pink pear shape on the left and the 1.53 ct Fancy Deep pink square on the right, are juxtaposed with four type II pinks. The type II pink diamonds range in size from the 1.03 ct Fancy Intense orangy pink heart shape on the lower right to the 8.01 ct Fancy Vivid pink pear shape in the center. Photo by Elizabeth Schrader.

diamonds does not use the descriptions “reddish pink” and “pinkish red” (this would be similar to the use of color names such as “strong bluish blue” or “pale yellowish yellow,” which are not part of

Figure 4. In many “pink” diamonds, especially those that are type I, the pink color is distributed unevenly, and is concentrated along parallel bands. These bands are oriented along the octahedral {111} planes; they probably are the result of plastic deformation of the diamond during its geologic history in the earth. Photomicrograph by John I. Koivula; magnified 15 \times .





Figure 5. This diagram illustrates the relatively wide range of hues in diamonds (indicated by the arrows) that GIA GTL associates with the term pink.

Because pink is used to indicate a color appearance for diamonds, and is not a true hue term, this range also includes orange, where pale colors can appear pink. The arrows used here to note the range of occurrence of

pink diamonds also indicate the distribution of the two types in our sample. While there is overlap throughout the hues, a larger quantity (shown by the wider size of the arrow) of type I pinks are often “cooler” in appearance than type II. The opposite was noted for type II diamonds, which tend to be “warmer” in appearance.

Figure 6. Each of the eight tone/saturation grids shown here relates to one of the hues in figure 5 with color appearances described as pink in the GIA GTL system. Each square in a grid (which is actually a three-dimensional box in color space) represents a range of appearances associated with a color term. The shaded areas in each hue indicate boxes that would be associated with a description that is predominantly pink. It is important to remember that these boxes include pink descriptions modified by orangy, purplish, purple, brown, and brownish, as well as simply pink.

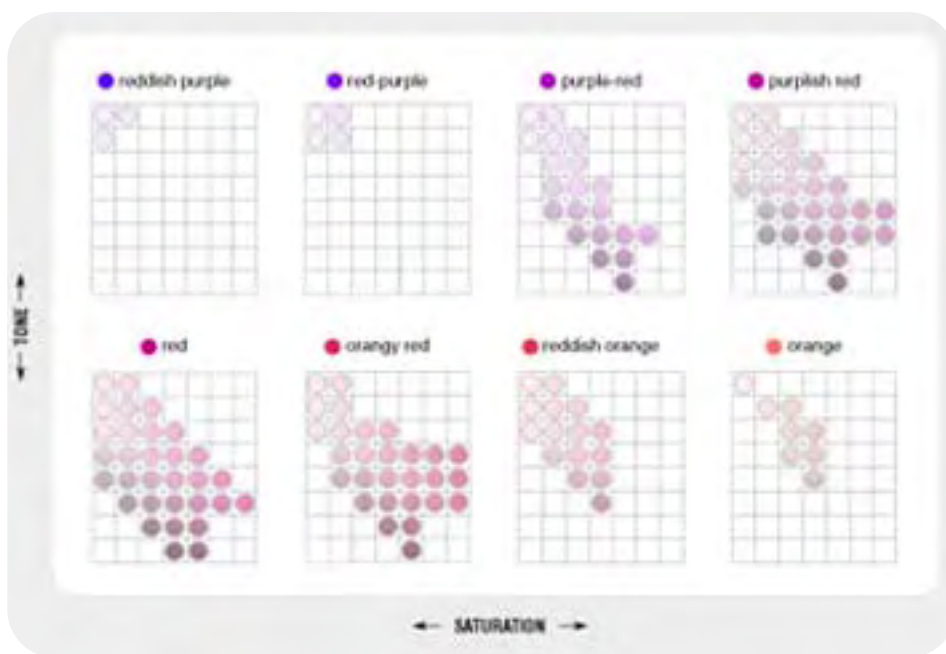


TABLE 2. Distribution of the sample pink diamonds by fancy grade and diamond type.

Grade	Overall		Type I		Type II	
	No.	%	No.	%	No.	%
Faint	114	8	64	5	50	15
Very Light	78	5	49	5	29	9
Light	170	11	99	8	71	22
Fancy Light	156	10	104	9	52	16
Fancy	488	33	402	34	86	26
Fancy Intense	282	19	257	22	25	8
Fancy Deep	147	10	142	12	5	2
Fancy Vivid	55	4	49	5	6	2
Total	1,490	100%	1,166	100%	324	100%

our grading terminology either).

It is also important to note that color nomenclature systems are not universal, so the visual appearances associated with terms such as *pink* and *red* in diamonds are not necessarily the same as for color naming systems for other materials, such as fabrics, paints, or other gemstones.

MATERIALS AND METHODS

Samples. Since the 1950s, many thousands of colored diamonds have been submitted annually to the GIA Gem Trade Laboratory for identification and/or grading reports. For the present study, we gathered data on a group of 1,490 diamonds (see table 2; for specific data within each group, please see the *Gems & Gemology* data depository on the Internet [www.gia.edu/gandg/ggDataDepository.cfm]), the total number submitted to GIA GTL during a spe-

cific period within the past few years. Each of these diamonds was described on our laboratory reports as being predominantly pink in color appearance (i.e., *pink* was the final term in the color description; table 3 indicates the color breakdown for the four stronger grade ranges, which represent the largest number of samples). The diamonds in the overall group ranged from 0.06 to more than 50 ct (92 weighed more than 5 ct, and 30 of these weighed more than 9 ct). Some gemological observations could not be made on all the diamonds in this group because of time constraints in the grading service or the type of service (e.g., a less comprehensive “identification and origin” report) requested by the client.

Grading and Testing Methods. We used the GIA Gem Trade Laboratory methodology for color grading colored diamonds to describe all of these study samples (see King et al., 1994). Trained laboratory staff evaluated each of the diamonds using a standardized D65 “daylight” lighting environment (as provided by the Macbeth Judge II illumination box). Typically from three to six staff members independently compared the overall face-up characteristic color of each diamond to GIA colored diamond color references within this viewing box.

Equipment used for the gemological examinations included a standard gemological microscope, a GIA Gem Instruments ultraviolet unit with long-wave (365 nm) and short-wave (254 nm) lamps, and a desk-model prism spectroscope. For a representative group of stones, we recorded visible absorption spectra with a Hitachi U4001 spectrophotometer (350–750 nm) at cryogenic (liquid nitrogen) temperatures, and infrared spectra with a Nicolet 510 FTIR

TABLE 3. “Pink” color descriptions in the sample diamonds for the four stronger grade ranges.

Color description	Fancy		Fancy Intense		Fancy Deep		Fancy Vivid		Total no.
	No.	%	No.	%	No.	%	No.	%	
Purple-pink	33	7	10	3	2	1	5	10	50
Purplish pink	70	14	140	50	35	24	38	69	283
Pink	115	24	112	40	54	37	9	16	290
Orangy pink	81	17	20	7	19	13	3	5	123
Brownish purple-pink	7	1	0	0	1	1	0	0	8
Brownish purplish pink	11	2	0	0	0	0	0	0	11
Brownish pink	64	13	0	0	2	1	0	0	66
Brownish orangy pink	47	10	0	0	19	13	0	0	66
Brown-pink	60	12	0	0	15	10	0	0	75
Total	488	100%	282	100%	147	100%	55	100%	972

BOX A: UNDERSTANDING THE RELATIONSHIP OF PINK AND “RED” DIAMONDS IN GIA’S COLOR GRADING SYSTEM

Diamonds described as predominantly red are among the most intriguing and highly valued gems in the world, both because of the richness of their color and their extreme rarity (figure A-1). Trade and public recognition of red diamonds expanded greatly following the record \$926,316-per-carat price paid for a 0.95 ct purplish red diamond (known as the Hancock Red) at a Christie’s auction in New York in 1987 (Kane, 1987; Federman, 1992). A decade later, in 1997, Christie’s Geneva offered a 1.75 ct diamond crystal that was described by GIA GTL as purplish red (figure A-2). Typically, rough diamonds are not offered at auction, because the outcome of their color appearance after cutting would still be in question. Nonetheless, diamonds described as being predominantly red are so rare that it was feasible in this instance. At auction, this 1.75 ct crystal sold for \$805,000 (we do not know if it was subsequently faceted). The staff of the GIA Gem Trade Laboratory first examined this diamond crystal 20 years earlier, when they confirmed its natural color. As recently as December 2001, Phillips (New York) sold a 1.92 ct Fancy red diamond for approximately \$860,000 per carat, the second highest per-carat price paid at auction for a gemstone.

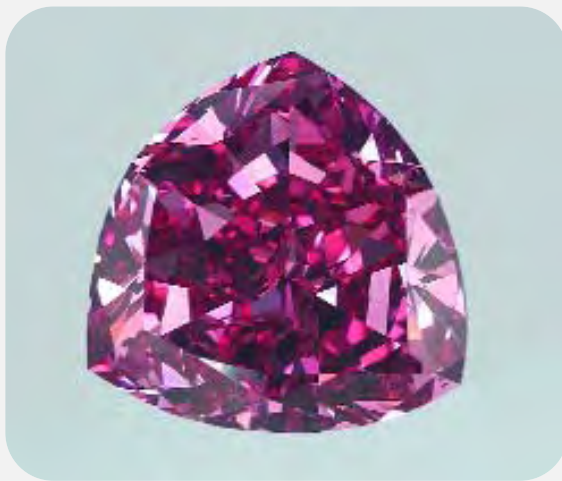


Figure A-1. This 5.11 ct Fancy red shield shape is an example of this rare color in diamonds. In the experience of the GIA Gem Trade Laboratory, and as seen in table A-1, most of the diamonds described as predominantly red are “cooler” in appearance and termed purplish red. This diamond, which is “red” without any modifier, is quite unusual. Courtesy of William Goldberg Diamond Corp.; photo by Elizabeth Schrader.

Although occasional reports have been published, very few red diamonds have been documented in detail (see, e.g., Kane, 1987). Table A-1, which lists diamonds in the public domain that have been given a “red” color description by GIA GTL since the sale of the Hancock Red in 1987, gives some perspective on the rarity of predominantly red diamonds (as we have done throughout this article, we refer here to diamonds for which the predominant color appears red: orangy red, red, purplish red, purple-red, brownish red, and brown-red).

There are two aspects of the GIA Gem Trade Laboratory’s colored diamond color grading system that, when combined, describe a diamond’s color appearance. One is the fancy grade, which represents regions of the combined effect of tone and saturation on the face-up appearance of a colored diamond. The other is the color description, which locates the hue range and, at times, more specific areas within the fancy grade. For example, within the grade range of Fancy Deep (which describes diamonds that are moderate to dark in tone and moderate to strong in saturation) are areas described as pink, brownish pink,

TABLE A-1. “Red” diamonds in the public domain documented by GIA.^a

Weight (ct)	Shape	Color grade	Featured by ^b	Year last examined by GIA GTL
5.11	Shield	Fancy red	William Goldberg	1997
1.92	Rectangle	Fancy red	Phillip’s New York	2001
1.78	Oval	Fancy purplish red	Argyle Tender	1997
1.75	Rough	Purplish red ^c	Christie’s Geneva	1997
1.12	Square	Fancy purplish red	Christie’s Geneva	2001
1.06	Oval	Fancy purplish red	Argyle Tender	1998
1.00	Pear	Fancy purplish red	Christie’s New York	1997
0.95	Round	Fancy purplish red	Christie’s New York	1987
0.75	Rectangle	Fancy purplish red	Christie’s Geneva	1998
0.73	Rectangle	Fancy red	Christie’s Hong Kong	2001
0.59	Oval	Fancy purplish red	Christie’s Hong Kong	2000
0.54	Emerald	Fancy purplish red	Argyle Tender	1998
0.42	Emerald	Fancy purplish red	Argyle Tender	1997
0.41	Round	Fancy purplish red	Christie’s New York	2001
0.25	Oval	Fancy red	Christie’s New York	1996

^aWhile many people in the industry may describe a diamond as red, the lack of a systematic approach to that determination makes such statements difficult to substantiate. Because of this, the table presents only GIA-documented red diamonds in the public domain. Not all diamonds graded red by GIA are included in this table because of client confidentiality.

^bCompany that has promoted or otherwise placed the information in the public domain.

^cRough diamonds are not given “Fancy grades”; rather they are only given a color description.



Figure A-2. "Red" diamonds are so rare that this 1.75 ct purplish red crystal sold at the Christie's Geneva November 1997 auction for \$805,000. Courtesy of Christie's.

brown-pink, and pink-brown. A Fancy Deep pink diamond is located in the moderate to lighter toned, more saturated portion of the Fancy Deep range, whereas Fancy Deep pink-brown diamonds are in the darker, weaker portion of the range.

This relationship of fancy grade and color descriptions in GIA's system is also consistent with the term *red*. In our experience to date, diamonds described as *red* or *reddish* occur in a limited range of tone and saturation. Consequently, we have applied only one fancy grade thus far: "Fancy." Since the range of color depth in which red diamonds are known is not wide, additional fancy grades have not been required.

As with the transition from one grade to the next for pink diamonds, the transition in appearance between pink and red is smooth (figure A-3). The majority of diamonds described as red to date tend to cluster near the pink/red description boundary (in the GIA GTL system, the typical transition is between either Fancy Deep or Fancy Vivid "pink" and Fancy "red"). As is the case throughout the system, diamonds near a boundary may have a similar appearance yet be described differently. While the appearance difference between pink and red may be subtle at times, the tone and saturation of color that results in the face-up appearance associated with red is seldom encountered.

A special problem with red diamonds is that few people in the trade ever have the opportunity to see significant quantities of them. Just as for pink diamonds, a red "determination" requires the use of consistent methodology and comparison to known references. Without examples readily available in the market, opinions can vary greatly regarding what a "red" diamond should look like. Dealers impas-

sioned about the prospect of having a diamond of this color often believe that moderately dark, moderately strong pinks are red because they lack points of reference. Alternatively, some dealers feel diamonds that are described as red are too pale because they don't look like rubies; although "red" diamonds represent the strongest, darkest color appearances in their hue range, they may not look like other "red" gemstones. Or, only having seen a purplish red diamond, a dealer may incorrectly feel that a warmer red is "brownish" (similar situations also have been encountered with warmer pink diamonds). In the GIA GTL system, the appearance associated with the description "red" should be and is related to diamond, not other gems, so the color appearance of red in diamond may be very different from red in garnet, ruby, or spinel.

From the limited number of predominantly red diamonds seen by GIA, it appears their cause of color is the same broad 550 nm absorption band, with an associated band at 390 nm, that is found in the spectra of pink diamonds, except that in red diamonds it is considerably stronger. Our observations over the last several years have not revealed any distinctive gemological features associated with diamonds described as red as compared to their pink counterparts.

Figure A-3. This illustration reproduces the darker, most saturated (lower right) area of the pink grid in the fold-out chart accompanying this article. The transition in color appearance between diamonds described as "pink" and "red" is smooth, if often subtle. Nevertheless, the tone and saturation necessary to yield a face-up color appearance described as predominantly red is rarely encountered.



spectrometer (6000–400 cm^{-1}) at room temperature. Diamond type was determined by one or more methods, including absorption spectra (by use of the prism spectroscope or an infrared spectrometer), short-wave UV transparency, and photoluminescence (PL) spectroscopy using a Renishaw laser Raman spectrometer. It should be mentioned that these two type categories (I and II) are not completely distinct (i.e., there

Figure 7. These two pie charts illustrate the distribution of the 1,166 type I and 324 type II pink diamonds in the sample by several weight categories. Note that type II pink diamonds tend to be larger than their type I counterparts.

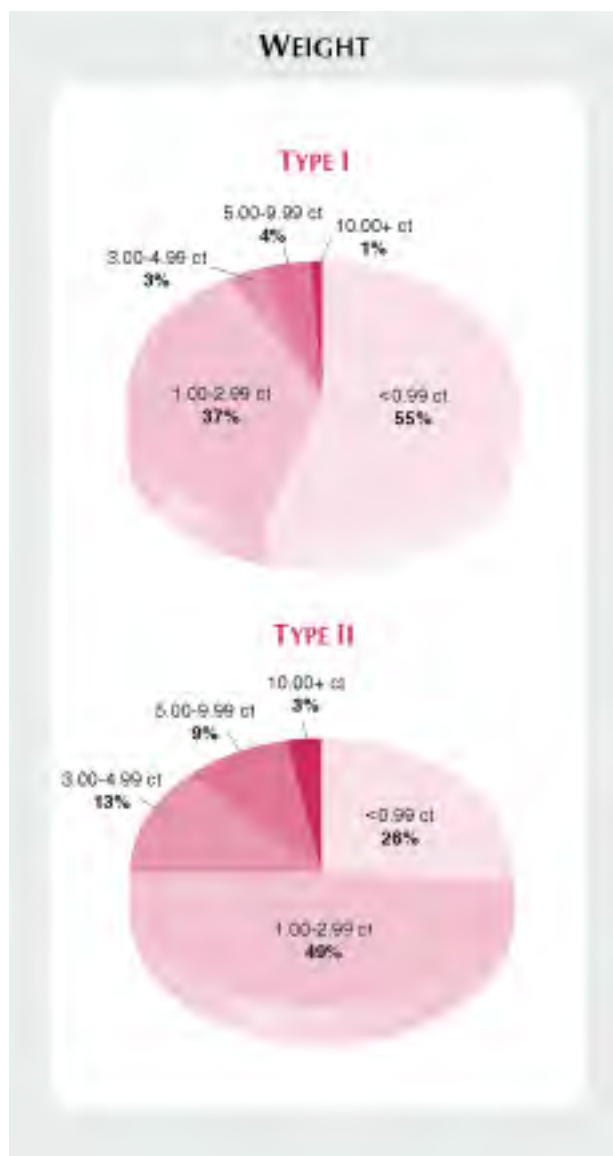


Figure 8. As indicated in figure 7, type II pink diamonds tend to be larger than type I pinks. This unusually large (50.08 ct) Fancy orangy pink diamond is a type II. Courtesy of Julius Klein Diamonds, Inc.; photo by Elizabeth Schrader.

is no strict boundary between them). As the nitrogen content decreases, the two types become less easy to distinguish. Historically, the type II category was defined simply by the lack of nitrogen-related features in the infrared spectrum of a diamond (Robertson et al., 1934). With the increased sensitivity of newer infrared spectrometers, weak nitrogen-related spectral features can be detected more easily. Consequently, the number of diamonds considered type II has tended to decline (for a discussion of diamond type, see Fritsch and Scarratt, 1992).

DATA ANALYSIS AND RESULTS

Diamond Type. Of the 1,490 diamonds examined for this study, 1,166 were type I and 324 were type II.

Weight. Twelve percent of our type II samples were 5 ct or larger, whereas only 5% of our type I diamonds were in this category (see figure 7). This is consistent with observations made over the years that large diamonds (in colors other than yellow) frequently are type II (see figure 8).

Color Appearance. The three diagrams in the fold-out chart illustrate the wide range of color appearances associated with pink diamonds at three positions on the hue circle (i.e., purplish red, red, and orangy red). Each diagram shows the lighter, less-saturated colors in the upper left, and the darker,

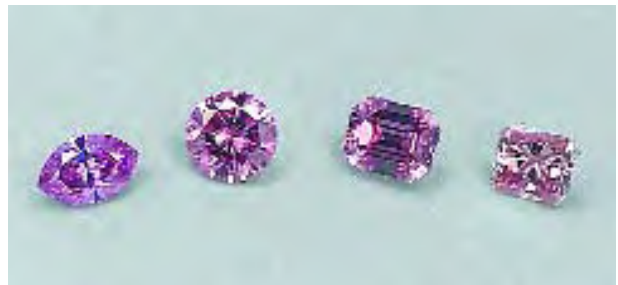
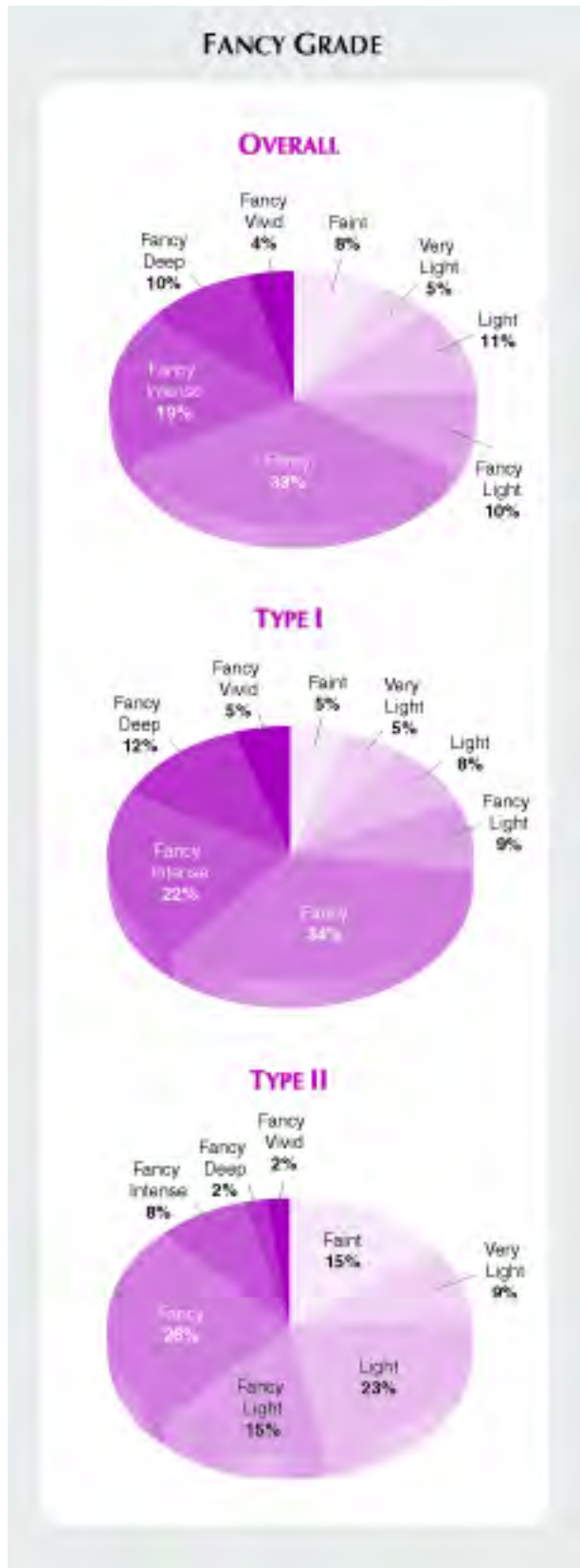


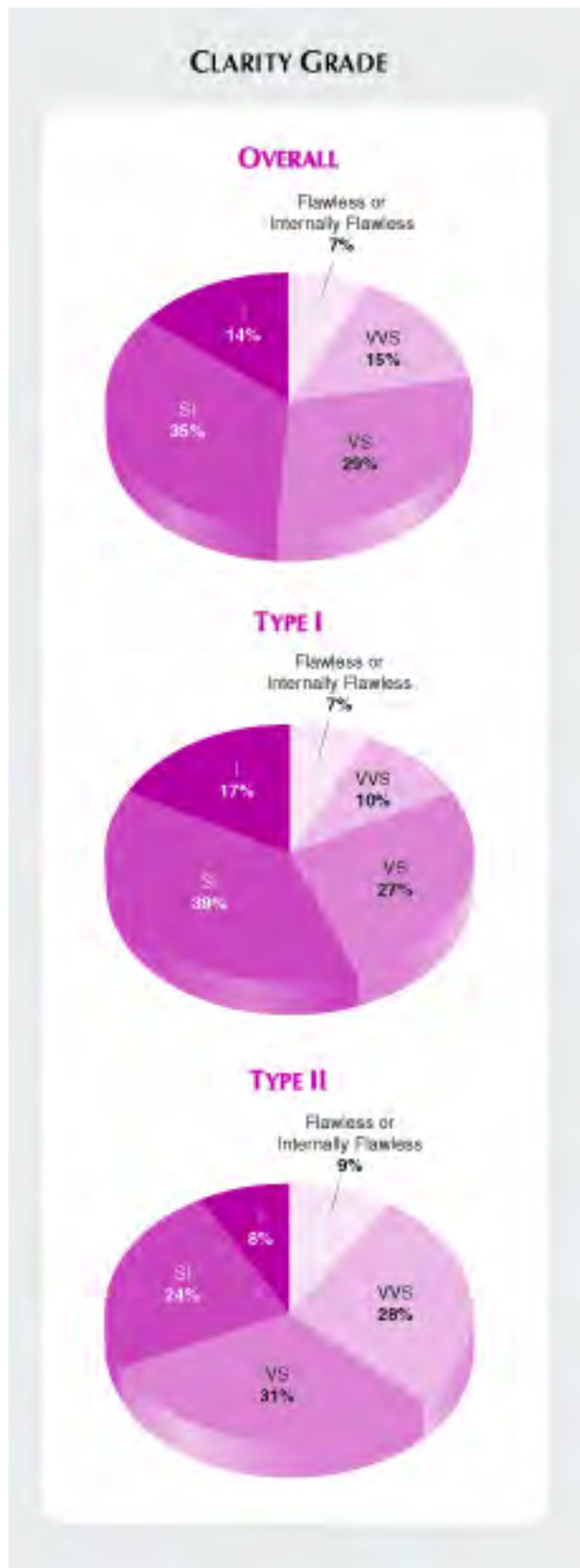
Figure 10. The colors of pink diamonds transition smoothly from one hue to the next. The diamonds shown here illustrate four of the more typical hue appearances encountered in this study. The 0.28 ct marquise on the left is Fancy Intense purple-pink, the 0.41 ct round brilliant is Fancy Intense purplish pink, the 0.48 ct emerald cut next to it is Fancy Intense pink, and the 0.33 ct rectangular diamond on the far right is Fancy Intense orangy pink. Photo by Jennifer Vaccaro and Elizabeth Schrader.

more-saturated colors toward the lower right. The transitions among hue, tone, and saturation for pink diamonds are relatively smooth, with subtle differences in appearance typically encountered between neighboring colors. Understanding the appearances of pink diamonds is challenging because they occur in such a wide range of hues (again, see figure 5). This is very different from the situation of, for example, blue diamonds (King et al., 1998), where the hue range is very limited.

GIA GTL Fancy Grade Terminology. The 1,490 study samples covered all of the GIA GTL fancy grades except Fancy Dark. For pink diamonds, this color grade usually is dominated by brown (and therefore typically results in descriptions of pink-brown, pinkish brown, or brown). Figure 9 shows how the 1,490 diamonds fell into the remaining eight grade categories used by GIA GTL.

Hue. There is a smooth gradation from one hue to the next in pink diamonds (figure 10). While there was complete overlap of the color ranges for both types I and II in the study samples, type I pink dia-

Figure 9. These pie charts illustrate the percentages of the 1,490 pink diamonds studied in each of the GIA GTL fancy grade categories. Note that a higher percentage of type I pink diamonds (1,166 samples) were found in the more saturated grade ranges of Fancy Deep, Fancy Intense, and Fancy Vivid.



monds more commonly exhibit “cooler” hues (i.e., toward purple), whereas type II pink diamonds more commonly occur in the “warmer” hue ranges (i.e., toward orange). Of the 324 type II diamonds, 42% were in the warmer hues (with descriptions such as brownish orangy pink, brown-pink, and orangy pink), whereas of the 1,166 type I diamonds, only 29% were in that range.

Tone and Saturation. The tone and saturation ranges of pink diamonds can vary greatly depending on their hue (again, see figure 6). As illustrated in figure 9, 66% of the 1,490 diamonds fell into the four stronger-saturation and darker-tone categories (Fancy, Fancy Intense, Fancy Deep, and Fancy Vivid). It was interesting to note that this group encompassed 73% of the 1,166 type I diamonds but only 38% of the 324 type II diamonds. Based on the samples in our study (and our experience in general), type I pink diamonds are almost twice as likely as their type II counterparts to be stronger and darker in color. Type II pink diamonds are generally lighter in tone, although they vary in saturation from very weak to moderately strong.

Microscopic Examination. *Clarity.* Pink diamonds tend to be included, as is reflected in their clarity grades (figure 11). Of the 691 diamonds examined for clarity, only 7% were in the Flawless or Internally Flawless (FL/IF) grades, whereas almost half (49%) were in the Slightly Included (SI) or Included (I) grades. Overall, the most common clarity grade range was SI (35%). However, 56% of the 488 type I diamonds in this group had the lower clarity grades (SI and I), compared to only 32% of the 203 type II diamonds. Thus, on average, type II pink diamonds receive higher clarity grades (FL/IF, VVS, and VS) than type I pink diamonds.

Inclusions. Pink diamonds may exhibit fractures or cleavages as well as mineral inclusions. The internal features observed in our study samples were typical of those generally seen in other included diamonds. Dark, opaque graphite spots (figure 12, left) or pin-point inclusions were more common in the type II

Figure 11. These pie charts illustrate the breakdown by clarity grade for the 691 pink diamonds examined for this characteristic, overall and by type. Note that the (203) type II samples were generally higher in clarity than the (488) type I samples.

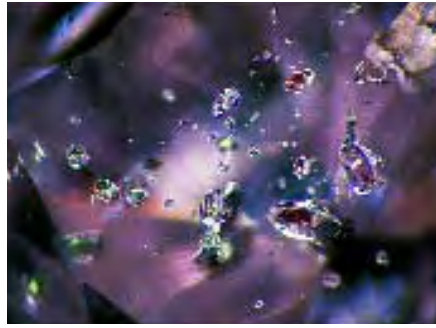
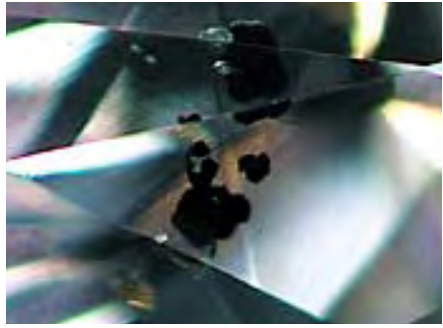


Figure 12. The mineral inclusions in the pink diamonds studied were typical of those generally seen in other diamonds. Left: Type II pinks were more likely to have dark, opaque graphite spots. Right: This type I diamond contains inclusions of garnet and pyroxene. Photomicrographs by Thomas H. Gelb and John I. Koivula; magnified 50 x and 15 x, respectively).

pink diamonds than in the type I pinks (similar-appearing inclusions have been observed in blue diamonds; see King et al., 1998). In our study sample, the type I pink diamonds more often contained mineral inclusions such as garnet and pyroxene (figure 12, right), or anhedral crystals of diamond.

Graining. Both internal and surface graining are frequently seen in pink diamonds. The photomicrographs in figure 13 illustrate some common forms of this graining. Surface graining typically appears as linear patterns that cross facet junctions (figure 13A). If the linear pattern is extensive and reflects



Figure 13. Surface and internal graining were common features in the pink diamonds studied for clarity. Surface graining (A) appears as a line or lines crossing facet junctions; when there are numerous lines, as seen here at 23x magnification, the clarity grade may be affected. Internal graining can appear in a number of different forms: as internal reflective planes (B, magnified 10x), as parallel whitish bands (C, magnified 20x), and as an overall whitish haze (D, magnified 10x). Photomicrographs by Vincent J. Cracco.



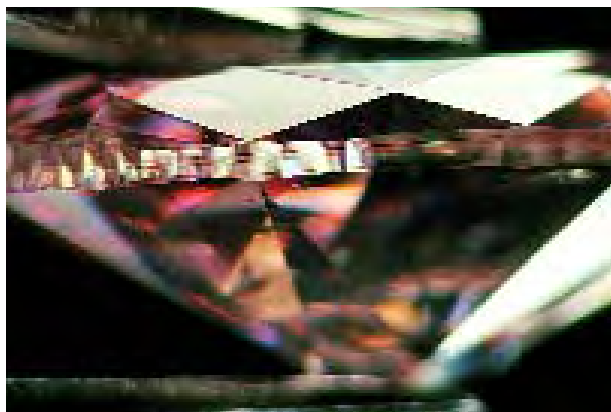
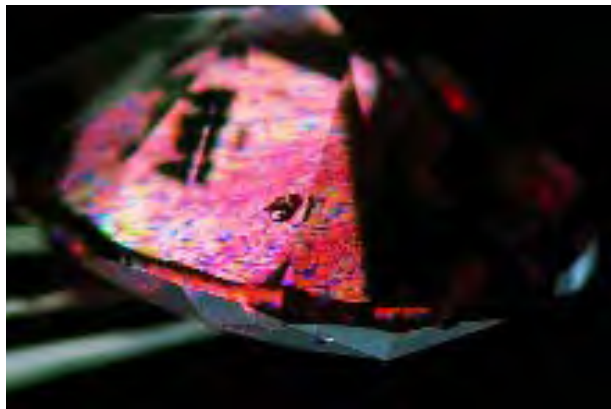


Figure 14. Color zoning may appear as thin, discrete, parallel bands. In this 2.12 ct oval brilliant, very narrow color zones are visible in the girdle, paralleling the table facet. The orientation of such bands may affect the face-up color appearance. Photomicrograph by Vincent J. Cracco, magnified 20x.

around the diamond when it is viewed in the face-up position, it can lower the clarity grade. Even if there are only a few surface lines, they are noted in the “Comments” section of the grading report for identification purposes.

Internal planar graining that reaches the surface is sometimes seen as reflective sheets that may appear colorless, pink, or brown (figure 13B); such graining may impact both the clarity grade and the color description. The presence of both pink and brown

Figure 15. This pink diamond displays bright interference colors in a mosaic pattern when it is observed with magnification between crossed polarizing filters. This anomalous birefringence is evidence that the diamond was subjected to plastic deformation while it was in the earth. Photomicrograph by Vincent J. Cracco, magnified 23x.



colors of graining in the same diamond is uncommon, but we have observed it on several occasions. This graining can occur in one or more planes oriented along octahedral {111} directions.

In addition to surface lines and reflective planes, internal graining also can appear as whitish bands (figure 13C), or as an overall hazy appearance (figure 13D). When observed with magnification, this haziness may appear cottony, wispy, or silky, and can impart a shimmer- or rain-like quality that may affect the transparency and clarity grade of the diamond.

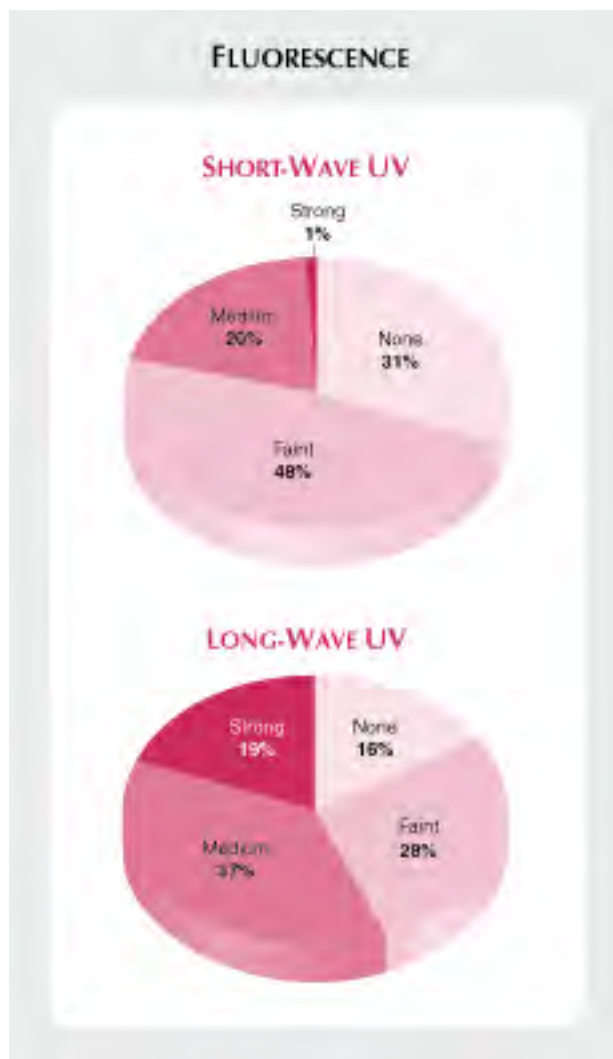
Among our study samples, the type I pink diamonds were more likely to have surface grain lines and reflective internal planes. In contrast, graining in the type II samples was more likely to appear as an overall haze with varying degrees of transparency rather than as distinct bands.

Color Zoning. Color zoning was noted in 46% of the diamonds examined. This zoning most often appeared as discrete, parallel bands of darker pink color or alternating pink and colorless areas (again, see figure 4). Less commonly, color zoning was seen as an indistinct distribution of color. Zoning was noted more often in those pink diamonds that displayed a greater depth of color; it is likely the darker color contributed to making the distinction between colored and colorless, or differently colored, areas more visible. As mentioned previously, the type I pink diamonds in our study were more likely to display stronger, darker colors. Therefore, it was not surprising to find color zoning observed in 65% of our type I samples, but in only 12% of the type II diamonds examined. In the more intensely colored type I diamonds, we observed the pink coloration as broad bands oriented parallel to the internal graining. In some samples, the color zoning occurred as thin, discrete bands (figure 14) that appeared either pink or brown depending on the direction of the illumination. In type II diamonds, banding may be present but is much less obvious.

Anomalous Birefringence (Strain). As noted above, pink diamonds may be subject to plastic deformation in the earth. The resulting strain pattern can be seen when crossed polarizing filters are used (figure 15). These patterns may parallel the orientation of the pink color zoning, but more typically they are seen as a mosaic arrangement of bright interference colors that change as the diamond is tilted during observation.

Ultraviolet Fluorescence. In our sample, 1,363 pink diamonds of both types were examined for fluorescence to short- and long-wave UV radiation. We found that 79% showed either no reaction or a faint reaction to short-wave UV (SWUV), whereas approximately 20% exhibited medium fluorescence, and only 1% exhibited strong fluorescence (figure 16). When exposed to long-wave UV (LWUV), 44%

Figure 16. In general, the pink diamonds examined for fluorescence (1,363 samples) showed a stronger reaction to long-wave UV radiation than to short-wave UV. This same pattern was consistent for both the type I and type II diamonds, although type I pink diamonds tended to have a stronger reaction (medium to strong) to long-wave UV than their type II counterparts (faint to medium).



exhibited no or a faint reaction and 56% displayed medium to strong fluorescence.

More than half of the type I pink diamonds exhibited a medium to strong reaction to LWUV, most commonly blue in color. The same samples exhibited no or only a faint reaction to SWUV, usually blue or yellow.

Most of the type II pink diamonds exhibited faint to medium fluorescence to LWUV, usually blue; 84% showed only a faint (usually blue) or no reaction to SWUV. It has been our experience that increasing the duration of SWUV exposure by a number of seconds tends to strengthen the intensity of the fluorescence reaction (to a level similar to the LWUV reaction). On occasion, type II pink diamonds display medium-to-strong orange fluorescence to both kinds of UV radiation (Anderson, 1960; Scarratt, 1987; and our own observations). These diamonds commonly exhibited a 575 nm absorption line at room temperature (seen with a desk-model spectroscope) and an adjacent emission line on the low energy side.

In some diamonds, the fluorescence reaction appeared "transparent," whereas in others it appeared cloudy, turbid, or chalky. The type I pink diamonds more frequently appeared chalky to both LWUV and SWUV, whereas their type II counterparts usually did not exhibit a chalky appearance.

Infrared/Visible Spectra. Figures 17A and 17B depict typical infrared spectra of a type I and type II pink diamond, respectively. These are consistent with the spectra observed for diamonds in this study. Absorption features in the one-phonon region (between 1000 and 1400 cm^{-1}) indicate the presence of nitrogen in a diamond (Fritsch and Scarratt, 1992). As mentioned above, as the nitrogen concentration decreases, the one-phonon absorption decreases. When this absorption is not detectable, the diamond is by definition type II.

The dominant feature in the visible spectra of pink diamonds is a broad absorption band centered around 550 nm (figures 17C and 17D) that, as mentioned above, is responsible for the color in most pink diamonds (Collins, 1982). Typically, the 550 nm absorption band occurs together with a band at 390 nm (Collins, 1982). This applies to both type II and type I diamonds, although in the case of type I diamonds (figure 17C), the 390 nm band is superimposed on the N3 center. Further evidence that the 550 and 390 nm bands are linked is that they increase or decrease together in response to thermochromic or photochromic (heat- or light-related)

effects (C. Welbourn, pers. comm., 2002).

In addition to absorptions at 550 and 390 nm, the visible spectra of many pink diamonds contain an absorption line at 415 nm. This feature is due to the N3 center (Collins, 1982). In type I pink diamonds, the N3 center overlaps the 390 nm absorption band, and is typically accompanied by an increase in absorption toward the ultraviolet. The N3 center in type II diamonds is generally very weak to nonexistent due to the low nitrogen content; consequently, the 390 nm absorption may be clearly observed in the spectrum (figure 17D).

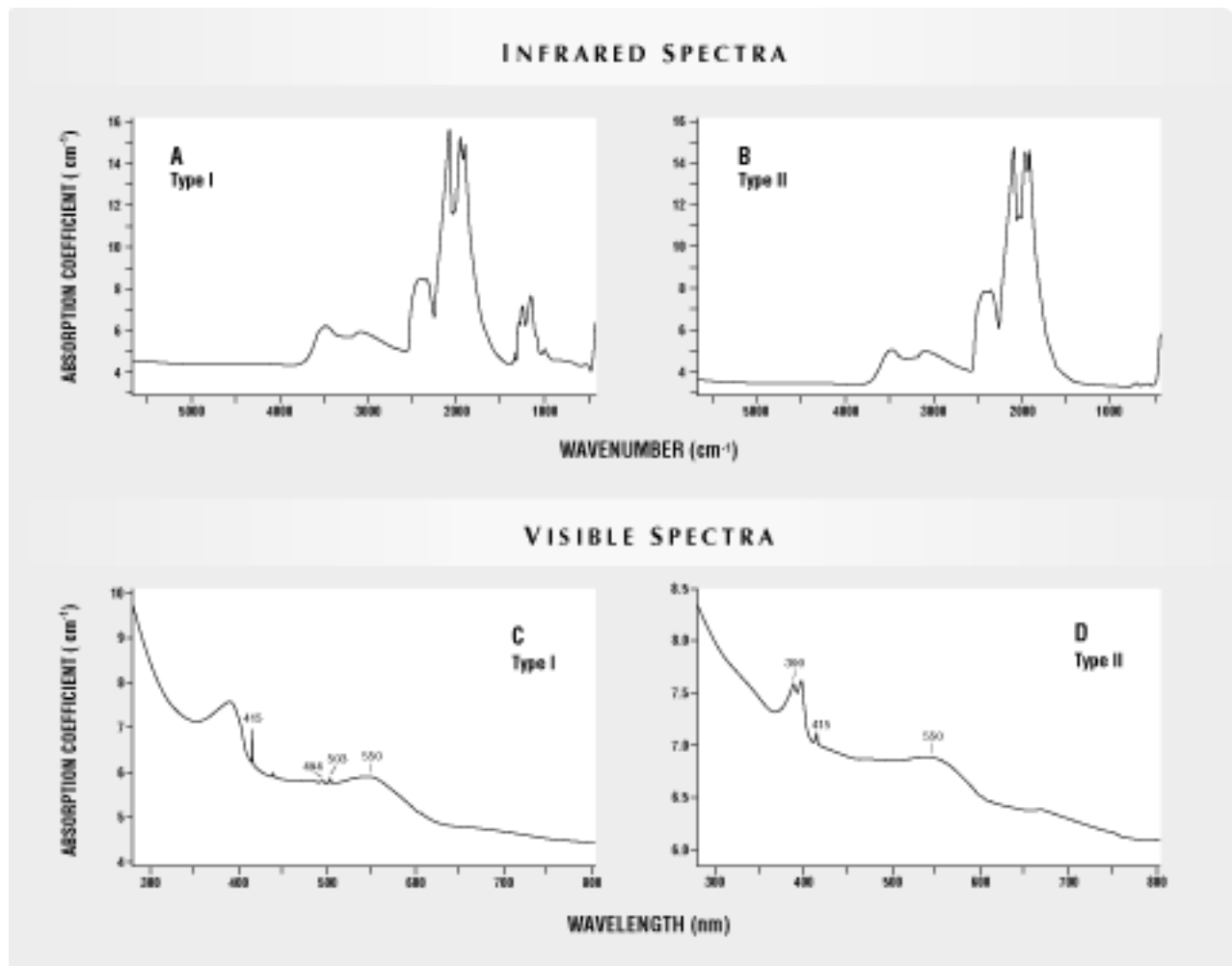
In type I diamonds, in addition to the 415 nm

line, we occasionally noted absorption bands at 494 and 503 nm [associated with the H3 color center (Collins, 1982)].

DISCUSSION

Color Relationships. GIA GTL color descriptions for pink diamonds depend on variations in hue, tone, and/or saturation. The subtle differences that can occur in these three color attributes, independently or in combination, add to the complexity of consistently determining the fancy color grade or description of pink diamonds. For example:

Figure 17. Spectra A and B depict typical infrared spectra of type I and type II pink diamonds. Absorption between 1000 cm^{-1} and 1400 cm^{-1} approximates the concentration of nitrogen in a diamond, and in turn determines the diamond type. Spectra C and D represent typical visible spectra of type I and type II pink diamonds. Both these spectra exhibit broad absorption at 550 nm; however, type I diamonds show strong absorption at 415 nm, whereas in type II diamonds the 415 nm absorption is absent or very weak.



- “Warmer” (i.e., orangy) pink diamonds may be confused with brownish pink if color is not compared to color references using consistent observation methodology (figure 18). It is not uncommon for observers who see a “warmer” color appearance to associate it with low saturation (i.e., with the terms *brownish* or *brown*) instead of with a certain hue. Relatively strong warmer color appearances, such as orangy pink, can be incorrectly valued if their color is not analyzed properly.
- “Cooler” (i.e., purplish) pink diamonds often appear weaker than warmer pinks of similar tone and saturation (figure 19), as has been

Figure 18. When evaluating the appearance of a colored diamond, it is necessary to compare the stone in question to known color references. If this is not done, it is difficult to judge correctly what attribute(s) are affecting appearance. “Warm”-color pink diamonds are often considered weaker (i.e., browner) unless they are compared to graded-brownish/brown diamonds. On the top, a pink diamond (left) is shown next to an orangy pink diamond. In this comparison, it is easy to misinterpret the orangy pink color appearance as brownish. On the bottom, the same orangy pink diamond (now on the left) is placed next to a brownish pink marquise—and the difference in color appearance is apparent. Photos by Elizabeth Schrader and Don Mengason.

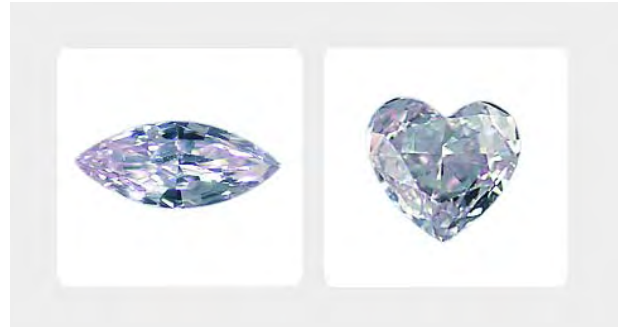
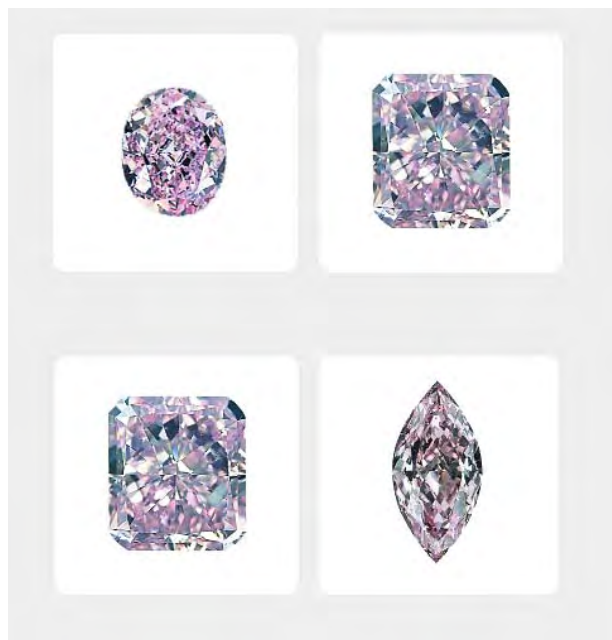


Figure 19. Pink diamonds with a noticeable purple component to their color may appear less saturated if compared to a pink diamond of warmer color. For example, the two diamonds seen here are considered to be of similar saturation in the GIA grading system. To the inexperienced observer, however, the cooler pink of the marquise on the left might appear weaker than the warmer pink of the heart shape on the right. Photos by Elizabeth Schrader.

noted in color studies for other materials (Albers, 1975). Again, if such diamonds are not analyzed using consistent methodology and comparison to known references, such colors may be graded lower for strength.

It is important to remember that all of these factors (hue, tone, and saturation) are a continuum in color space. The GIA grading system has established boundaries for groups of diamonds representing a range of tones and saturations of color within this continuum. For different hues, the tone and saturation boundaries will differ because of the natural range in which that color occurs (e.g., just as blue occurs in a narrower range of saturation than yellow [see again, King et al., 1998], pink occurs in a slightly narrower range than orangy pink). The fancy grade and color description boundaries graduate subtly around the hue circle (King et al., 1994). As a result, for each hue (e.g., red [pink] or orangy red [orangy pink]), the range of tones and saturation may differ from one fancy grade to another. That is, as illustrated in figure 20, a pink diamond that falls within the Fancy Intense grade range may be similar in tone and saturation to an orangy pink diamond in the Fancy range.

Clarity. The primary importance of color in the valuation of colored diamonds is clearly supported with pink diamonds. As shown in figure 11, over half (56%) of the sample diamonds were of SI or I clarity grades, yet dealers indicate that this grading

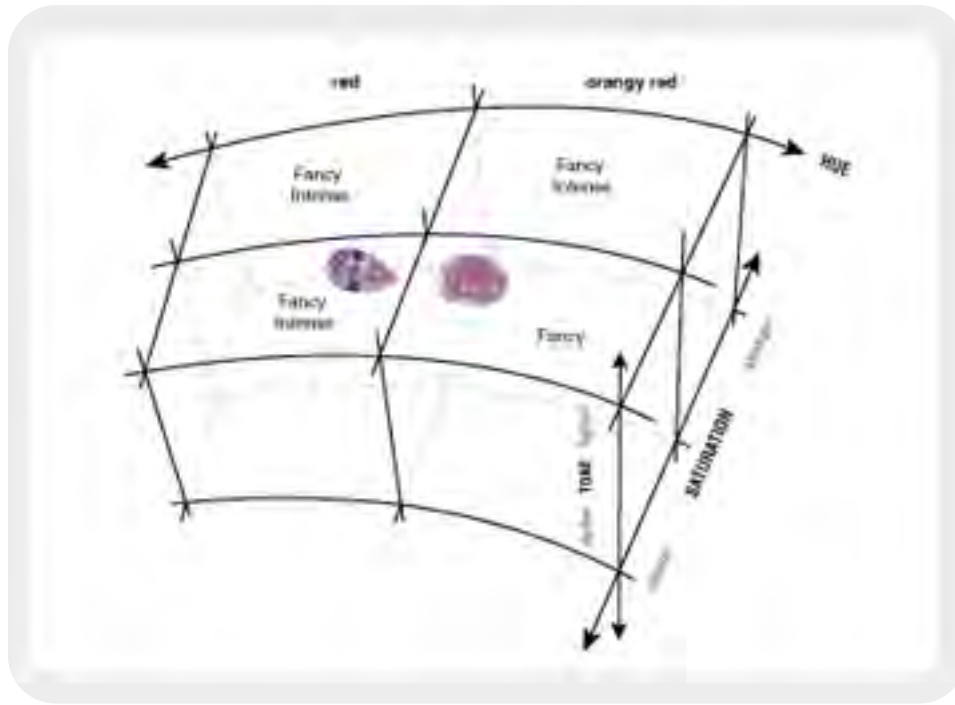


Figure 20. Because different hues encompass different ranges of tone and saturation, it is not uncommon to encounter two diamonds of similar tone and saturation but different fancy grades, as seen here for these two—Fancy Intense pink and Fancy orangy pink—diamonds. The chart shows a section in color space, with different fancy grades for the red (pink) and orangy red (orangy pink) hues denoted by three-dimensional “boxes.” Photos by Elizabeth Schrader.

aspect is of secondary importance to that of color in determining the value of a pink diamond (M. Kirschenbaum, pers. comm., 2002).

Type II diamonds have been noted to be of higher clarity than type I diamonds (Scarratt, 1987). This observation was supported by our study, as 68% of the type II pink diamonds in our sample group were FL/IF, VVS, or VS.

Graining and Color Zoning. As mentioned previously, the graining and color zoning in type I pink diamonds often occurs in discrete bands. The number of planes and their intensity of color affect the overall depth (i.e., the combination of tone and satu-

ration) of color in a pink diamond (which is the basis for judging face-up color appearance; see King et al., 1994). In our sample, we found a direct correlation between more intense or more numerous banded colored graining (that is appropriately oriented) and a stronger face-up color appearance.

Manufacturing. Many of the concerns manufacturers have when working with pink diamonds are similar to those discussed previously for blue diamonds (King et al., 1998). To achieve the best face-up color appearance, diamond cutters often use French culets and half-moon facets on the pavilion around the girdle (Watermeyer, 1991). These tech-

Figure 21. When pink diamonds are manufactured, the potential difference in color appearance between the rough and the faceted gem can be dramatic. This series show the original cleaved rough (left), the gem being cut from this rough at an interim stage in the faceting process (17.39 ct; middle), and the final 12.74 ct Fancy Vivid orangy pink diamond (right). Courtesy of Jacques Mouw; photos by Elizabeth Schrader.



niques help cutters achieve the strongest face-up color with an even distribution.

As mentioned above, color zoning in pink diamonds can affect the intensity of color. When such zones are present, their orientation relative to the table during cutting is critical to obtaining the best face-up appearance for a given facet arrangement.

One important distinction in the manufacture of pink diamonds is the change in color appearance that can occur during the cutting process. Manufacturers have reported observing a range of changes during the polishing process. When hot from the polishing wheel, some pink diamonds may appear weaker (closer to colorless) than their stable color. Immediately on cooling, the same diamonds may appear stronger than their stable color. This color change is temporary, and the diamonds do not retain the stronger pink color. Input energy (from heat due to the friction created by the rotating polishing wheel) produces these changes (M. Witriol, pers. comm., 2002).

As is often the case with colored diamond rough, the change in color appearance from the original rough to the faceted diamond can be significant. Figure 21 shows the transition in appearance of a diamond that when finished was graded Fancy Vivid orangy pink.

Spectroscopy. The broad region of absorption centered at about 550 nm is due to a color center of unknown structure along slip planes in a pink diamond (Raal, 1958; Collins, 1982; Fritsch, 1998). The broad band at 550 nm is always accompanied by a band at about 390 nm (again, see figure 17C and D). Shigley and Fritsch (1993) presented a comparison of the visible spectra of three diamonds (red-brown, purplish red, and purplish pink) to illustrate the presence of the same 550 nm absorption band in differing intensity in each spectrum. In our sample, we also noted the increasing strength of the 550 nm absorption band with greater depth of the pink-to-red color.

SUMMARY AND CONCLUSIONS

The beauty and relative rarity of pink diamonds have made them highly valued and desired through the centuries. Although they have been recovered from a number of localities around the world, historically their production has been quite sporadic. Only in the past 20 years has one source, the Argyle mine in Australia, produced a consistent supply of pink diamonds, which has given these special gem-



Figure 22. With the discovery of the Argyle mine in Western Australia, pink diamonds have become more available and gained broader commercial importance. As illustrated here, pink diamond melee and even larger single stones have established a special niche in the gem and jewelry industry. The Fancy orangy pink diamond in the ring weighs 1.15 ct; whereas the cross, dangle earrings, and brooch are set with a total weight in pink diamonds of 0.33 ct, 1.14 ct, and 1.43 ct, respectively. Courtesy of Alan Friedman Co., Beverly Hills, California; photo © Harold & Erica Van Pelt.

stones broader commercial importance in the jewelry marketplace (figure 22).

This report is based on the largest sample of pink diamonds published to date. With regard to the two types in which pink diamonds occur, I and II, this study confirmed that while the gemological characteristics associated with pink diamonds in these two categories may overlap, in the majority of cases there are some general differences in color appearance, clarity, and graining.

A key goal of this study was to illustrate aspects of the color grading of pink diamonds, which span a wide range of color hues, tones, and saturations. Again, this large sample confirmed the broader

range of tones and saturations in some hue categories, and the importance of using consistent observation methodology and established color references in the color grading of colored diamonds.

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Mr. King is laboratory projects officer, Mr. Gelb is staff gemologist, and Mr. Hall is analytical equipment supervisor at the GIA Gem Trade Laboratory (GTL) in New York. Dr. Shigley is director of GIA Research, and Mr. Guhin is grading lab manager at GIA GTL, in Carlsbad, California.

ACKNOWLEDGMENTS: The authors thank Thomas M. Moses, vice-president of Identification Services at GIA GTL in New York, for his comments and suggestions. Akira Hyatt, staff gemologist at GIA GTL in New York, assisted in the selection of images and determining their color relationship. Kim Cino, administrative director of GIA

GTL in Carlsbad, assisted with the Horizon computer management system retrieval of data on pink diamonds. Kim Rockwell, staff gemologist in GIA GTL Identification in Carlsbad, and David Kondo, staff gemologist in GIA GTL Identification in New York, collected visible spectra on a selection of pink diamonds. Wuyi Wang, research scientist in GIA GTL Identification in New York, offered comments on the spectra. Elizabeth Schrader, digital imaging operator at GIA GTL in New York, photographed and created composite illustrations of many of the diamonds in this article. Martin Kirschenbaum of M. Kirschenbaum Trading, Lewis Wolf of Lewis Wolf Trading, Mates Witriol, and Christopher M. Welbourn of De Beers DTC Research Centre provided insights and helpful information.

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NEW CHROMIUM- AND VANADIUM-BEARING GARNETS FROM TRANOROA, MADAGASCAR

By Karl Schmetzer, Thomas Hainschwang, Heinz-Jürgen Bernhardt, and Lore Kiefert

Pyrope-spessartine garnets from Tranoroa, in southern Madagascar, contain appreciable Cr and somewhat lower V contents. Although these elements are responsible for the color-change behavior of similar garnets from the nearby Bekily area, the Tranoroa samples show only a slight change in color appearance from day or fluorescent light (brownish purple-red) to incandescent light (purplish red). Characteristic internal features in the Tranoroa garnets include networks of rutile needles and strain patterns caused by anomalous double refraction. Additional inclusions are graphite, quartz, negative crystals, apatite, zircon, and monazite. One Cr-bearing spessartine from the same area is also described.

Gem-quality pyrope-spessartine garnets have been known from Tanzania and Sri Lanka since the late 1970s. Recently, two important varieties of these intermediate garnets have come from the Bekily area in southern Madagascar. Pink to pinkish orange Bekily material with variable iron contents but almost no vanadium or chromium has been called "malaya" garnet in the trade (Schmetzer et al., 2001). Bekily garnets with variable amounts of vanadium and lesser chromium generally show a distinct color change between day (or fluorescent) light and incandescent light. These color-change pyrope-spessartine garnets have been subdivided into several groups or types according to the different colors observed under variable illumination (see Schmetzer and Bernhardt, 1999; Krzemnicki et al., 2001).

In June 2001, we obtained a parcel of about 30 faceted garnets from southern Madagascar with unusual coloration (see, e.g., figure 1). According to our supplier, these garnets had been mined recently from a new area near Tranoroa, about 60 km southwest of Bekily (figure 2). We do not know the amount of this material that has been mined to date. Both the Tranoroa and Bekily localities belong to a region formed by several metamorphic belts consisting of high-grade metamorphic rocks of Precambrian age (Windley et al., 1994). More information on the geology, mining, and production of garnets from the Bekily area can be found in Schmetzer et al. (2001).

The present study was undertaken to characterize these new garnets, which differ from those previously described from Madagascar with regard to their color and color behavior.

MATERIALS AND METHODS

For this study we selected seven samples, which ranged from 1.52 to 4.77 ct (see, e.g., figure 1), from the parcel of about 30 faceted garnets. Six were brownish purple-red in daylight and represented the majority of the samples. We also studied one brownish orange garnet from the same parcel (see box A). From several other parcels totaling more

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GEMS & GEMOLOGY, Vol. 38, No. 2, pp. 148–155
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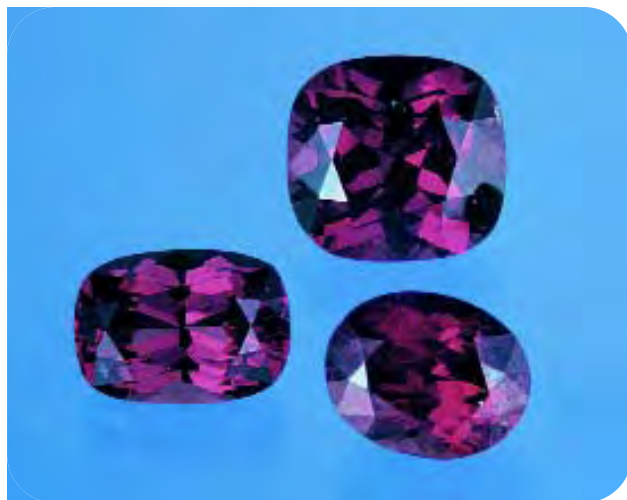
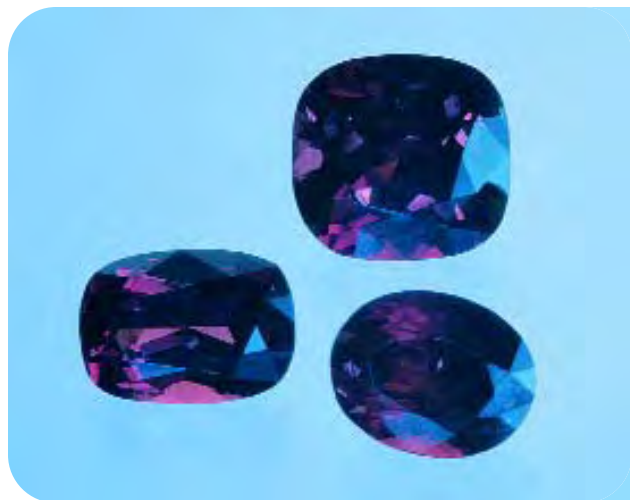


Figure 1. Chemical analysis of these pyrope-spessartine garnets from Tranoroa, Madagascar—shown here in fluorescent light (left) and incandescent light (right)—revealed appreciable amounts of Cr and V. However, they do not show the distinct color change in daylight and incandescent light that is observed in pyrope-spessartines from the nearby deposit at Bekily. The samples weigh 4.77, 3.26, and 2.81 ct. Photos by Maha Tannous.

than 400 garnets from Bekily, we chose about 50 Cr- and V-bearing samples for chemical analysis. From these samples, we selected three representative stones for comparison of their color appearance and composition with the Tranoroa garnets.

The seven Tranoroa samples were tested by standard gemological methods for refractive index, fluorescence to long- and short-wave ultraviolet radiation, and specific gravity. We examined the samples for inclusions and internal structural properties using various microscopes and lighting conditions, both with and without immersion in methylene iodide. In addition, we identified solid inclusions by laser Raman microspectrometry using a Renishaw 1000 system.

For all these Tranoroa samples, we recorded spectra in the UV-visible range with a Leitz-Unicam SP 800 spectrophotometer as well as with an Adamas Advantage SAS 2000 spectrophotometer. To determine quantitative chemical composition, we used a Cameca Camebax SX 50 electron microprobe, with traverses of 10 point analyses each, measured across the tables of the faceted stones. The same instrument was used to analyze the three garnets from Bekily.

RESULTS

The results for the six brownish purple-red Tranoroa samples are listed in table 1 and discussed below. The results for the three Bekily samples are included in table 1 for comparison.

Visual Appearance and Gemological Properties. All samples revealed a homogeneous brownish purple-red color in day or fluorescent light and were pur-

Figure 2. The garnets described here were mined recently near Tranoroa, which is located about 60 km southwest of the Bekily garnet deposits in southern Madagascar.



BOX A: A CHROMIUM-BEARING SPESSARTINE

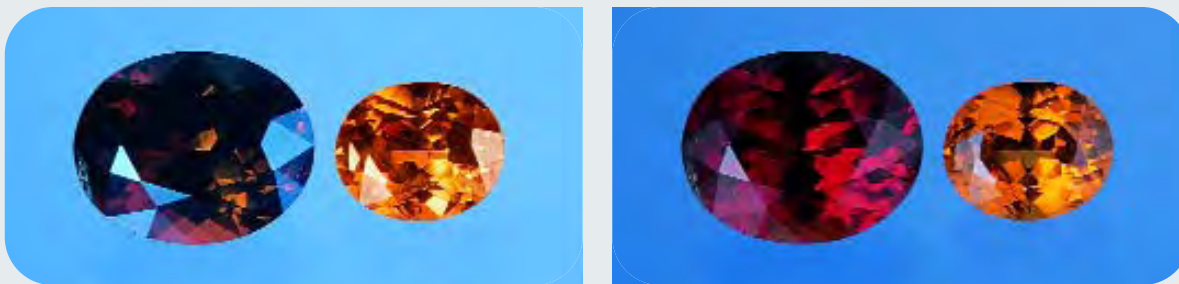


Figure A-1. As seen in day or fluorescent light (left) and incandescent light (right), the color appearance of this 2.84 ct Cr-bearing Tranoroa spessartine (sample G, see table 1) is distinctly different from the 1.03 ct V- and Cr-free Madagascar spessartine (0.02 wt. % V_2O_3 , 0.02 wt. % Cr_2O_3 , 39.34 wt. % MnO, and 2.29 wt. % FeO). Photos by Maha Tannous.

Within the parcel of brownish purple-red garnets from Tranoroa, we observed one sample that appeared brownish orange in day or fluorescent light and reddish orange in incandescent light (figure A-1). Physical and chemical properties of this garnet (sample G) are given in table 1.

This garnet showed distinctly higher R.I. and S.G. values than the other six samples. Microprobe analysis revealed that it was different in composition from the other six garnets, with only about 5 mol. % pyrope and a relatively high spessartine value of just over 88 mol. % (again, see table 1). The almandine content was rather small, and chromium (1.01 wt. % Cr_2O_3) was again more abundant than vanadium (0.32 wt. % V_2O_3). The sample was inert to long- and short-wave UV radiation.

The color behavior of this sample, as compared to that of typical spessartine (again, see figure A-1), was

undoubtedly associated with its high Cr content. The absorption spectrum (figure A-2) was similar to that of the Cr-bearing intermediate pyrope-spessartines from the same area. The spectrum revealed a dominant chromium absorption in the yellow region and weak iron absorption bands. Consistent with the distinctly higher Mn content of the sample, the absorption bands of manganese were stronger, and thus the absorption minimum in the blue-green to violet range was less pronounced than in the intermediate pyrope-spessartine samples from Tranoroa. This difference in transparency in the blue-green to violet region is responsible for the differences in color in daylight and incandescent light observed in the two types of Tranoroa garnets.

Microscopically, the spessartine sample was free of rutile needles or other mineral inclusions. With crossed polarizers, we observed a mosaic-like pattern that showed high-order interference colors (figure A-3).

The garnet from Tranoroa is, to the best of our knowledge, the first chromium-bearing spessartine described as a faceted gemstone.

Figure A-2. The absorption bands observed in the spectrum of the Tranoroa spessartine (sample G) are consistent with those of Cr-bearing pyrope-spessartines. The bands are due to chromium, manganese, and iron (see figure 3 in the main text).

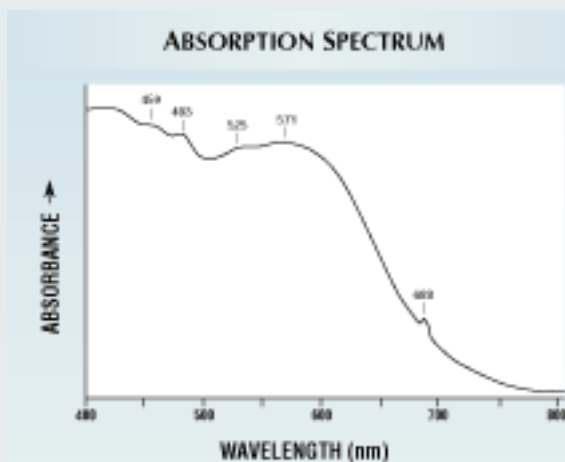
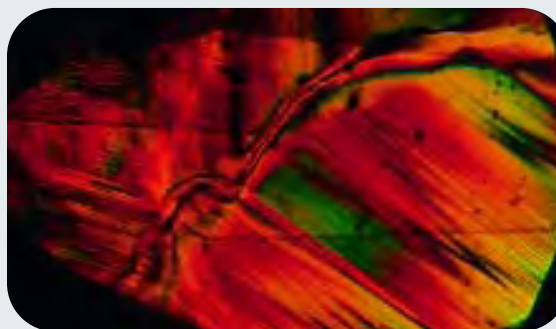


Figure A-3. Microscopic examination of the Tranoroa spessartine revealed high-order interference colors in an irregular mosaic-like structure and strain pattern. Photomicrograph by K. Schmetzer; immersion, crossed polarizers, magnified 40 \times .



plish red in incandescent light (again, see figure 1). Refractive indices for the six samples were found to vary within a small range, from 1.768 to 1.773 (table 1). Likewise, the specific gravity values fell between 3.95 and 3.97, which indicates a narrow range of chemical composition within the pyrope-almandine-

spessartine solid-solution series. These R.I. and S.G. values are within the ranges found for malaya garnets from the same region, although they are higher than the average values recorded for the samples described in Schmetzer et al. (2001). All garnets were inert to both long- and short-wave UV radiation.

TABLE 1. Physical and chemical properties of pyrope-spessartine garnets from Tranoroa and Bekily, Madagascar.

Property	Tranoroa							Bekily			
	A	B	C	D	E	F	G	X	Y	Z	
Weight (ct)	4.77	1.86	3.26	2.81	2.02	1.52	2.84	0.67	0.90	0.78	
Color											
Day or fluorescent light			Brownish purple-red					Brownish orange	Grayish green	Slightly reddish purple	Bluish green-gray
Incandescent light			Purplish red					Reddish orange	Grayish purple	Strongly reddish purple	Pinkish purple
Refractive index	1.768	1.768	1.769	1.770	1.770	1.773	1.808	1.750	1.752	1.755	
Specific gravity	3.95	3.96	3.95	3.96	3.97	3.97	4.15	3.82	3.83	3.86	
Microprobe analyses (wt.%) ^a											
SiO ₂	38.70	37.67	38.82	38.41	37.91	37.88	35.81	40.62	40.83	39.66	
TiO ₂	0.05	0.08	0.04	0.07	0.12	0.16	0.33	0.05	0.07	0.05	
Al ₂ O ₃	21.98	21.75	22.00	21.69	21.46	21.33	20.24	22.92	22.91	22.50	
Cr ₂ O ₃	0.67	0.69	0.68	0.71	0.75	0.75	1.01	0.11	0.53	0.15	
V ₂ O ₃	0.38	0.41	0.35	0.43	0.51	0.58	0.32	0.58	0.56	0.67	
FeO ^b	2.57	2.60	2.55	2.54	2.67	2.32	1.13	1.50	3.69	1.71	
MnO	23.60	23.41	23.44	23.68	24.02	25.00	37.80	15.52	14.27	16.98	
MgO	10.25	10.26	10.24	9.90	9.68	8.40	1.59	14.18	16.10	14.07	
CaO	1.42	1.42	1.42	1.60	1.62	2.50	0.80	5.09	2.02	3.40	
Total	99.62	98.29	99.55	99.03	98.72	98.94	99.04	100.56	100.98	99.19	
Cations ^c											
Si	2.967	2.934	2.975	2.968	2.951	2.959	2.950	2.979	2.972	2.965	
Ti	0.003	0.004	0.002	0.004	0.007	0.009	0.020	0.003	0.004	0.003	
Al	1.986	1.997	1.987	1.976	1.969	1.964	1.965	1.981	1.965	1.982	
Cr	0.041	0.043	0.041	0.043	0.046	0.046	0.066	0.006	0.031	0.009	
V	0.023	0.026	0.022	0.027	0.032	0.037	0.021	0.034	0.033	0.040	
Fe	0.165	0.170	0.163	0.190	0.174	0.152	0.078	0.092	0.224	0.107	
Mn	1.532	1.544	1.522	1.550	1.583	1.654	2.637	0.964	0.879	1.075	
Mg	1.172	1.195	1.170	1.140	1.123	0.978	0.195	1.551	1.746	1.568	
Ca	0.117	0.119	0.177	0.133	0.135	0.209	0.017	0.400	0.157	0.272	
Mol.% end-members											
Pyrope	39.35	39.46	39.37	37.84	37.35	32.68	4.68	51.58	58.08	51.89	
Spessartine	51.31	50.99	51.04	51.44	52.50	55.26	88.46	32.06	29.24	35.57	
Almandine	5.53	5.61	5.48	6.31	5.77	5.08	2.62	3.06	7.45	3.54	
Grossular	0.80	0.59	0.87	0.99	0.67	2.92	—	11.32	2.06	6.59	
Goldmanite	1.12	1.26	1.07	1.32	1.56	1.81	1.02	1.68	1.63	1.99	
Uvarovite	2.00	2.08	2.00	2.10	2.25	2.25	1.36	0.30	1.53	0.42	
Knorringite	—	—	—	—	—	—	1.86 ^d	—	—	—	

^a Average composition of 10 analyses each; all samples were relatively homogeneous in composition.

^b Total iron as FeO.

^c Calculated on the basis of 12 oxygens.

^d Because CaO was smaller than necessary to account for all the chromium and vanadium as uvarovite and goldmanite, the residual chromium in this sample was assigned to the Mg-Cr end member, knorringite [Mg₃Cr₂(SiO₄)₃].

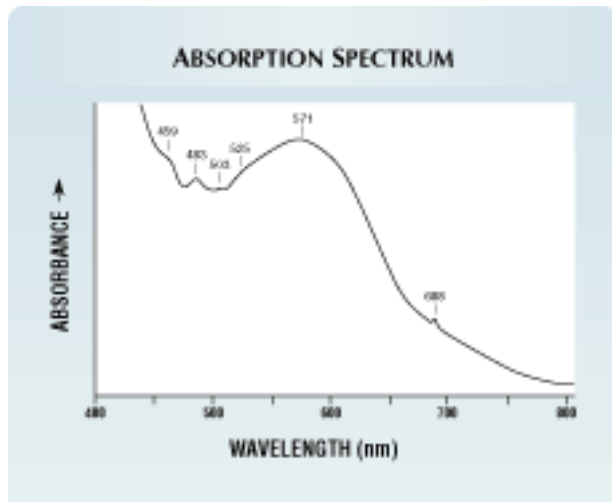


Figure 3. This absorption spectrum of a representative brownish purple-red garnet from Tranoroa (sample E) shows features that are consistent with a chromium-bearing intermediate pyrope-spessartine. The bands labeled are due to Cr^{3+} (571, 688 nm), V^{3+} (571 nm), Mn^{2+} (459, 483, 525 nm), and Fe^{2+} (459, 503, 525 nm).

Chemical Properties. The garnets were members of the pyrope-almandine-spessartine solid-solution series, with 33–39 mol.% pyrope and 51–55 mol.% spessartine (table 1). Almandine percentages varied only between 5 and 7 mol.% for these six samples, with smaller percentages of grossular (0.6–3 mol.%). All samples contained more chromium than vanadium: 0.67–0.75 wt.% Cr_2O_3 (~2 mol.% uvarovite) and 0.35–0.58 wt.% V_2O_3 (1–2 mol.% goldmanite).

Calculations of Fe^{2+} and Fe^{3+} for a garnet com-

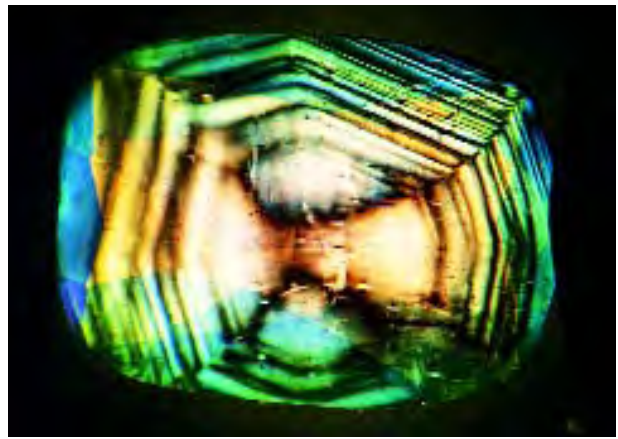


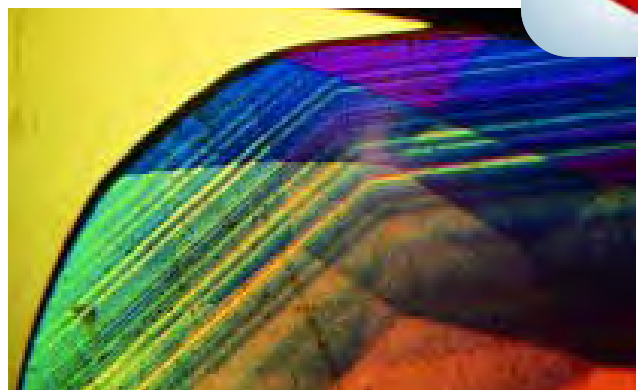
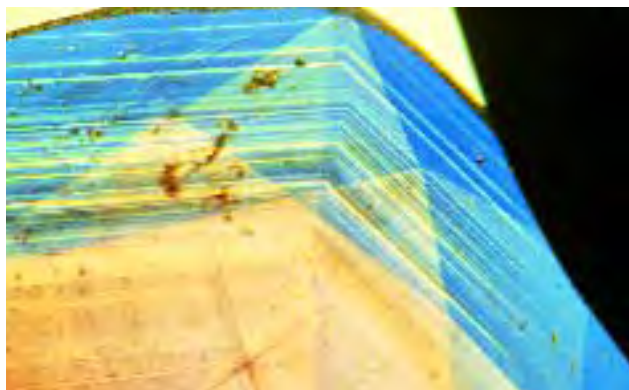
Figure 4. This pyrope-spessartine shows anomalous double refraction and strain parallel to growth planes that were determined as the trapezohedron $\{211\}$. Photomicrograph by K. Schmetzer; immersion, crossed polarizers, magnified 20 \times .

position with 12 oxygens suggested that Fe^{3+} is either not present or present in only a very small amount (<0.01 Fe^{3+} atoms per formula unit). This indicates little or no andradite component in the samples.

In summary, all samples contained more chromium than vanadium. They were intermediate pyrope-spessartine garnets with greater amounts of spessartine than pyrope.

Spectroscopic Properties. The absorption spectra of all six samples consisted of a strong broad absorption band centered at 571 nm; weak bands at 459, 483, 503, 525, and 688 nm; and an absorption edge

Figure 5. In two of the Tranoroa pyrope-spessartine garnets, growth planes were seen to form angles of 132° (left) or 147° (right), which are typical for the trapezohedron $\{211\}$ in the cubic system. Both photomicrographs taken with immersion, magnified 50 \times . The inset shows an idealized drawing (clinographic projection) of a crystal composed of $\{211\}$ faces.



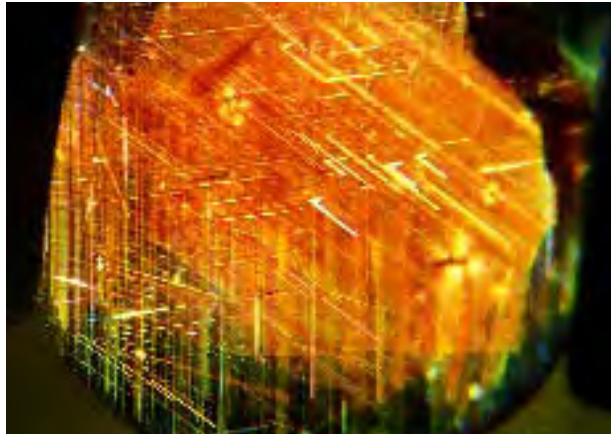


Figure 6. All of the pyrope-spessartine study samples revealed dense, three-dimensional networks of oriented rutile needles. Photomicrograph by K. Schmetzer; immersion, crossed polarizers, magnified 40 \times .



Figure 7. As with the Bekily garnets examined earlier, some of the Tranoroa pyrope-spessartines also contained tabular graphite crystals. Photomicrograph by L. Kiefert; magnified 100 \times .

near 440 nm with an almost continuous strong absorption below 440 nm (figure 3).

Features Observed with the Microscope. As illustrated and described for the non-color-change pyrope-spessartines from Bekily (Schmetzer et al., 2001), all of the Tranoroa samples revealed strong anomalous double refraction (ADR) when examined with crossed polarizers (figure 4). In two samples, this ADR was also seen parallel to growth planes of the trapezohedron {211}, which forms pairs of faces with two characteristic angles of 132° and 147° (figure 5). The trapezohedron (figure 5, inset) is one of the two most common forms observed in garnet crystals (the other is the dodeca-

hedron {110}). Two of these garnets also showed a swirl-like pattern of growth inhomogeneities.

Also as described and illustrated in Schmetzer et al. (2001) for Bekily garnets, all six Tranoroa samples revealed a three-dimensional network of oriented rutile needles (figure 6), and some contained numerous other inclusions, which were identified by laser Raman microspectrometry: irregularly shaped graphite platelets (figure 7) and fragments of quartz crystals; negative crystals reflecting the external garnet morphology (figure 8); prismatic apatite crystals, sometimes with slightly rounded edges; and small zircon crystals with tension cracks. In one of the garnets, we found an irregularly shaped monazite crystal (figure 9).

Figure 8. This negative crystal in a pyrope-spessartine represents the garnet morphology. The faces are probably also the trapezohedron {211}. Photomicrograph by L. Kiefert; magnified 200 \times .

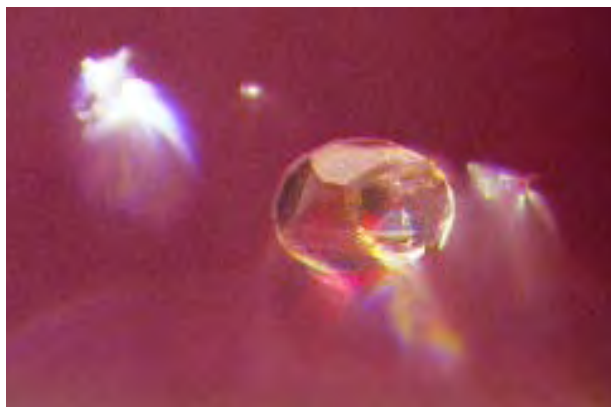
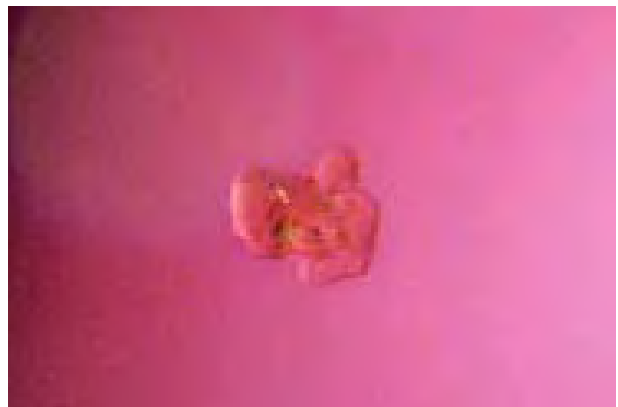


Figure 9. One of the garnet samples contained this irregularly shaped monazite crystal. Photomicrograph by L. Kiefert; magnified 100 \times .



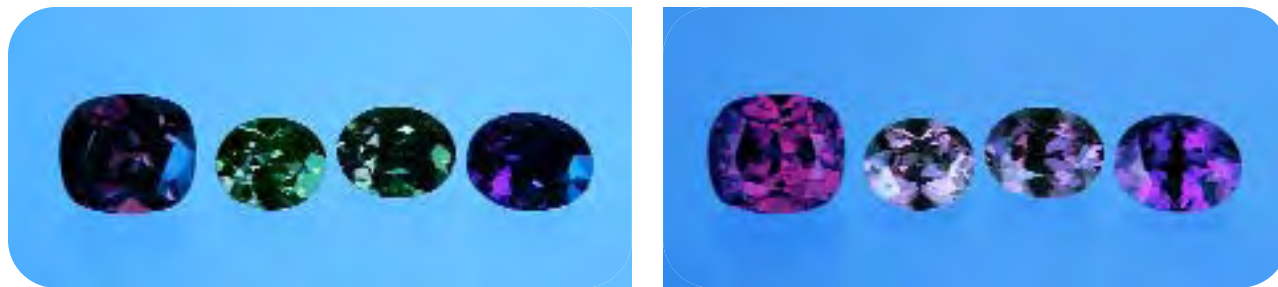


Figure 10. Chemical differences (table 1) are responsible for the different colors shown by the pyrope-spessartines from Tranoroa as compared to pyrope-spessartines from Bekily in day or fluorescent light (left) and incandescent light (right). From left to right: sample E, 2.02 ct from Tranoroa, with Cr>V; sample X, 0.67 ct from Bekily, with V>Cr; sample Y, 0.90 ct from Bekily, with V~Cr; and sample Z, 0.78 ct from Bekily, with V>Cr. Photos by Maha Tannous.

DISCUSSION

Absorption Spectra. The strong band at 571 nm in the absorption spectra of the Tranoroa samples is assigned to Cr³⁺, because a Cr³⁺ absorption band in an almost identical position has been reported in pyropes with high chromium contents (Amthauer, 1976). A chromium absorption maximum at this wavelength also has been found in alexandrite-like intermediate pyrope-spessartine garnets with higher Cr than V contents (Schmetzer and Ottemann, 1979; Schmetzer et al., 1980). In the latter type of garnet, however, the V³⁺ absorption band is located in the same spectral range (Schmetzer and Ottemann, 1979; Manson and Stockton, 1984; Schmetzer and Bernhardt, 1999; Krzemnicki et al., 2001). As a result of this overlap, the absorption bands of chromium and vanadium cannot be separated in intermediate pyrope-spessartine garnets. Rather, they have a combined effect that strengthens the absorption in this region of the spectrum. The weak absorption band at 688 nm is also caused by Cr³⁺ and is commonly observed in various Cr-bearing garnets (Amthauer, 1976).

The four remaining absorption bands are assigned to Fe²⁺ and/or Mn²⁺ as follows: 459 nm = Fe + Mn, 483 nm = Mn, 503 nm = Fe, and 525 nm = Fe + Mn. A detailed discussion of this assignment appears in Schmetzer et al. (2001). The almost continuous absorption below 440 nm is caused by several manganese absorption bands.

Chemical Composition and Color Appearance. The brownish purple-red garnets from Tranoroa are intermediate members of the pyrope-spessartine series. All samples contained greater amounts of chromium than vanadium. Although the Tranoroa garnets did show a perceptible difference in appearance between daylight and incandescent light, these samples did not show the distinct change in hue seen in the Bekily color-change garnets. (Note that “color

change” terminology is not well defined and will be interpreted differently by different viewers and organizations. Because the Tranoroa samples showed a distinct change in color appearance but not from one hue to another, we are not referring to them as “color change” in this article. Some laboratories and other members of the trade might describe these samples as showing a “color shift.”) Color-change garnets with more Cr than V have been known from Tanzania and Sri Lanka for decades (Schmetzer and Ottemann, 1979; Schmetzer et al., 1980; Stockton, 1982; Manson and Stockton, 1984). However, the color-change pyrope-spessartines examined to date from Bekily, Madagascar, typically contain more vanadium than chromium (Schmetzer and Bernhardt, 1999; Krzemnicki et al., 2001; see also figure 10 and table 1). Only six of the 50 color-change Bekily samples analyzed had almost the same amount of vanadium as chromium (again see, figure 10 and table 1).

Color change in pyrope-spessartine garnets is a complex function of the relative amounts of color-causing transition metals (i.e., V, Cr, Mn, and Fe). Colorimetric data have been applied to explain the various changes in color appearance in different lighting environments for garnets and other gem materials (Schmetzer et al., 1980; Liu et al., 1999; Krzemnicki et al., 2001). The Tranoroa samples have absorption characteristics that are similar to the V>Cr-bearing color-change garnets from Bekily, which have an absorption maximum in the yellow region at 571 nm and two areas of transparency in the red and in the blue-green to violet regions (see Schmetzer and Bernhardt, 1999). However, in the Cr>V-bearing samples from Tranoroa, the transparency in the blue-green to violet region is distinctly smaller. This gives rise to the difference in color behavior of the Cr- and V-bearing garnets from Bekily and Tranoroa. It is evident that an

increase in manganese in intermediate pyrope-spessartine garnets causes an increase in the intensity of the manganese absorption bands and a reduction in transparency in the blue-green to violet spectral range (again, see figure 3), thus decreasing the blue color component and increasing the orange.

CONCLUSION

The new pyrope-spessartine garnets from Tranoroa have a brownish purple-red color not seen thus far in the nearby Bekily material. Despite their appreciable Cr and V contents, they do not show the distinct color change from daylight to incandescent light observed in the Bekily material. This is mainly due to their relatively high Mn contents, which reduce their transparency in the blue-green to violet range.

Garnets from both Tranoroa and Bekily formed in high-grade metamorphic Precambrian rocks. Differences in the composition of the host rocks are the most likely source of variations in the chemical properties and color appearance of these garnets.

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UPDATE ON THE IDENTIFICATION OF TREATED “GOLDEN” SOUTH SEA CULTURED PEARLS

By Shane Elen

Most of the “golden” South Sea cultured pearls in a single strand were found to exhibit unusual brownish orange fluorescence to long-wave UV radiation and atypical absorption features at 405 nm and 558 nm. On the basis of these features and visual examination, 33 of the 35 cultured pearls were identified as color treated. This study demonstrates how atypical absorption features, particularly in the blue region of the spectrum, can be used to positively identify color treatment, even in the presence of the 330–385 nm UV absorption feature characteristic of natural-color “golden” pearls from the *Pinctada maxima* mollusk.

The identification of treated “golden” South Sea cultured pearls has relied primarily on observations made with the gemological microscope. Unusual fluorescence to long-wave ultraviolet radiation often has been used as supporting evidence. When present, color concentrations in nacre defects or around drill holes can be used to positively identify treated color. Ongoing investigation at GIA Research has shown that some types of color treatment might be identified by the presence of atypical absorption features in the visible region of the reflectance spectrum.

The present study centers on the examination of a strand of 35 “golden” South Sea cultured pearls (11–14 mm in diameter) that were submitted to the GIA Gem Trade Laboratory for an identification report earlier this year. The pearls exhibited quite uniform yellow coloration (figure 1), but standard gemological testing revealed evidence of treatment. In keeping with our pearl research program, these cultured pearls were examined further in an attempt

to determine the identifying characteristics of this treatment method. Particular attention was paid to spectra in the UV-visible range.

BACKGROUND

Recently, UV-Vis reflectance spectroscopy was used to help distinguish natural-color “golden” cultured pearls from those reportedly treated using heat (Elen, 2001). The application of this “heat” treatment method to undrilled pearls was unlike the more common dyeing method encountered by gemologists, which typically is applied after drilling, often resulting in a characteristic concentration of color in the drill hole. Evidence of the “heat” treatment method in undrilled pearls occasionally could be detected by observing an unusual color concentration in surface defects, or was indicated by the atypical fluorescence.

However, testing of known natural-color samples has revealed that both yellow shell nacre and natural-color “golden” cultured pearls from the *Pinctada maxima* mollusk exhibit broad absorption from 330 to 460 nm (Elen, 2001). This absorption was found to consist of two features, one in the UV region from 330 to 385 nm and a weaker one in the blue region of the visible spectrum from 385 to 460 nm. Closer examination of these features showed absorption maxima between 350 and 365 nm and from 420 to 435 nm. The strength of both these absorption features increased with increasing saturation of the yellow.

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Shane Elen is a research gemologist at GIA Research in Carlsbad, California. See end of article for Acknowledgments.

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Figure 1. This strand of loosely strung, predominantly treated-color “golden” South Sea cultured pearls (11 to 14 mm in diameter) was characterized in this study. Photo by Maha Tannous.



low color (figure 2). It was concluded that the absence of the UV absorption feature in “golden” cultured pearls indicated treated color, regardless of the treatment method used. However, given that numerous chemicals and dyes are available to produce yellow coloration (see Green, 1990), it also was noted that the presence of the absorption features in the UV and blue regions of the spectrum could not be used with certainty to indicate natural color. This article demonstrates how atypical absorption features in these regions extend the application of UV-Vis spectroscopy for the identification of treated “golden” South Sea cultured pearls.

MATERIALS AND METHODS

All 35 cultured pearls in the strand were examined with a standard gemological microscope equipped with fiber-optic lighting. Although it is difficult to inspect the drill holes of a knotted strand of cultured pearls for evidence of color concentrations, this particular strand was strung temporarily, so relatively few (four) of the cultured pearls were knotted tightly in place. Therefore, the others could be separated easily for inspection of the drill holes.

The fluorescence reaction was tested in a darkened room using a UVP model B100 AP long-wave UV lamp. UV-Vis reflectance spectra were obtained for all 35 samples with a Hitachi 4001 UV-Vis spectrophotometer. Energy-dispersive X-ray fluorescence (EDXRF) analysis was performed with a Thermo Noran Spectrace 5000 EDXRF spectrometer for four samples chosen on the basis of their reaction to long-wave UV: two that exhibited strong brownish orange fluorescence and two that displayed greenish yellow fluorescence.

RESULTS

Visual Appearance. All 35 cultured pearls in the strand were yellow with uniform color distribution and exhibited a good color match to one another (again, see figure 1).

For those cultured pearls that were loose on the strand, microscopic examination with fiber-optic lighting revealed an unusual color distribution within the drill holes of the vast majority of the samples (figure 3). The color appeared to be more saturated at the surface of the nacre and to decrease in intensity with depth into the drill hole.

In reflected light, faint color concentrations were noted in small surface defects on several of the cultured pearls, and these were accompanied by a “blotchy” appearance of the color when observed in transmitted light. Two of the cultured pearls revealed an orange residue around their drill holes, and another revealed an orange residue concentrated in a large pit adjacent to the drill hole.

Fluorescence and UV-Vis Reflectance Spectra.

Twenty-seven of the 35 cultured pearls revealed brownish orange fluorescence to long-wave UV radiation. All of these samples also showed a distinct absorption feature at 405 nm and a weaker one at 558 nm (figure 4). The strength of the absorption at 558 nm appeared proportional to the absorption at 405 nm. Six other samples showed greenish orangy yellow fluorescence and revealed only a weak 405 nm absorption feature. The remaining two samples exhibited greenish yellow fluorescence and absorption in the blue region centered at 430 nm (figure 4), which are both characteristic of “golden” cultured pearls from *P. maxima*. No color concentrations were evident in the drill holes of these two samples.

All 35 samples exhibited absorption between 355 and 365 nm in the UV region of the spectrum; in all but 10 of the samples, the UV absorption was stronger than the absorption in the blue region. Of the exceptions, six exhibited strong brownish orange fluorescence and the remaining four fluoresced brownish orange with moderate intensity. In addition, six other samples showed noticeably patchy fluorescence in which different areas exhibited distinct regions of greenish orangy yellow and brownish orange fluorescence.

EDXRF Chemical Analysis. EDXRF analysis revealed the presence of calcium, strontium, and sulfur in all four samples tested.

DISCUSSION

In our experience, the relatively saturated color at the surface of the nacre, which gradually became lighter as one looked deeper into the drill hole, suggests that the cultured pearls exhibiting this feature were color treated prior to drilling. Had color treatment been applied after drilling, it most likely would appear to color the nacre uniformly within the drill hole, or to be concentrated at the conchiolin layer between the nucleus and the nacre (Gauthier and Lasnier, 1990).

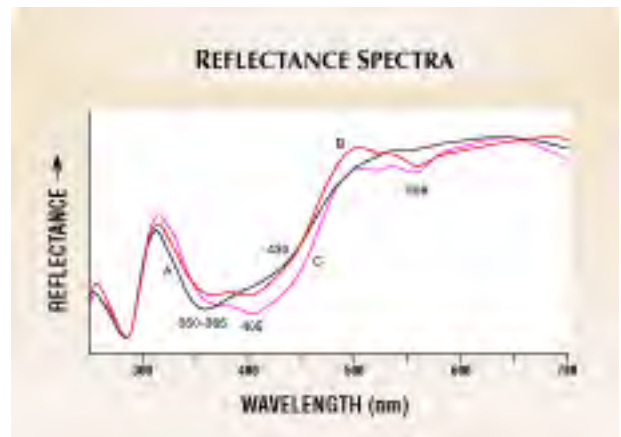
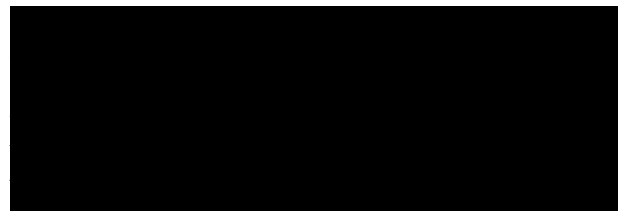
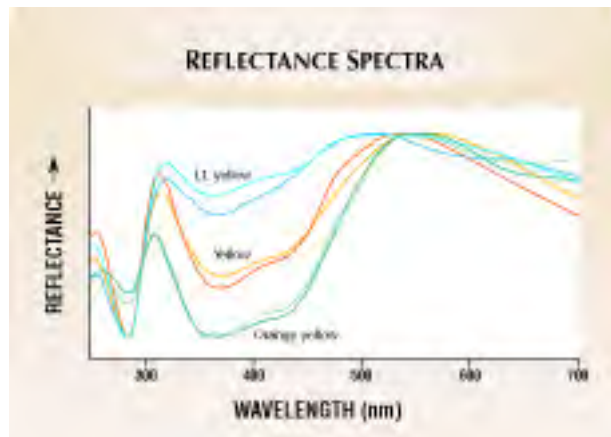
Although the observation of both a color concentration inside the drill hole and unusual fluorescence often can indicate color treatment, detection



Figure 3. In many of the cultured pearls, the color appeared to be concentrated near the surface when viewed down the drill hole. Such concentrations of color in pearls are good indicators of treatment. Photomicrograph by John Koivula; magnified 5 \times .

requires both experience and the appropriate lighting environment (such as the proper orientation of the fiber-optic light for examination of the drill hole, and a dark room for fluorescence testing). In some cases, these observations can be quite difficult to interpret and are thus subjective criteria. In other cases, such as cultured pearls that are undrilled, post mounted, or tightly strung, it may not be possible to inspect inside the drill hole. In all these situations, UV-Vis reflectance spectroscopy is especially important because it provides objective data in the form of a spectrum. Often, color treatment can be identified conclusively only by com-

Figure 2. These reflectance spectra of six light yellow to orangy yellow cultured pearls from the *P. maxima* oyster show absorption features that are characteristic of natural color. These features are located in the UV region between 350 and 365 nm, and in the blue region from 420 to 435 nm. Adapted from Elen (2001).



paring the data from a variety of these tests.

For all the cultured pearls in the strand examined for this study, the absorption from 355 to 365 nm was similar to that observed in the UV region of natural-color "golden" cultured pearls (Elen, 2001). However, 10 of the samples exhibited stronger absorption in the blue than in the UV region, which is not characteristic of natural yellow color in *P. maxima* (again, see figure 3). In these 10 samples, the brownish orange fluorescence was generally quite strong. However, there was not a consistent correlation between the strength of the 405 nm absorption and the intensity of the brownish orange fluorescence. Nevertheless, all 33 samples that showed either the unusual brownish orange or greenish orangy yellow fluorescence also had an absorption feature at 405 nm. This, in conjunction with the color concentration, indicates that this particular color treatment uses a chemical or dye in which absorption in the blue region at 405 nm is responsible for the yellow coloration. Absorption at 405 nm and 558 nm, and the brownish orange fluorescence, are not characteristic of natural-color "golden" cultured pearls from the gold-lipped oyster *P. maxima* (Elen, 2001).

Different yellow dyes and chemicals may have distinctly different absorption features in the blue region of the visible spectrum (e.g., Thiazol Yellow G and Mordant Yellow 12 [Green, 1990]). They also may exhibit additional absorption features in the UV as well as other regions of the spectrum (Green, 1990). When present, these absorption features can be used to identify color treatment.

No difference was observed in the EDXRF analyses for the treated samples compared to those of natural-color cultured pearls tested previously (see Elen, 2001). Organic compounds cannot be detected

by this technique, and sodium (a relatively light element) can only be detected when present in high concentration; no sodium was detected in the four samples analyzed. This suggests that the treatment involved the use of organic chemicals or dyes, or inorganic chemicals composed of light elements such as sodium salts.

CONCLUSION

All but two of the cultured pearls tested in this study were found to have been color treated prior to drilling. However, the treatment process used for these pearls appears to be different from the "heat" treatment method reported in an earlier study (see Elen, 2001). Evidence of treatment consisted of a surface color concentration noted in the drill hole, color concentrations in nacre defects, unusual brownish orange fluorescence to long-wave UV radiation, and the presence of atypical (for natural-color "golden" cultured pearls) absorption features at 405 and 558 nm in the UV-Vis reflectance spectrum.

In the absence of conclusive visual indicators, a variety of treatment methods for producing "golden" color in South Sea cultured pearls may be detected by atypical absorption features in the visible region of their reflectance spectrum. When several cultured pearls on a strand exhibit matching absorption features, particularly in the blue region of the spectrum, and these are not typical of natural-color "golden" cultured pearls, then treatment is indicated for those samples. However, as more data are obtained on natural-color "golden" cultured pearls, it is likely that we will see an occasional anomalous absorption feature. Therefore, the detection of unusual absorption features in a single cultured pearl should be evaluated with caution.

ACKNOWLEDGMENTS: The author thanks the following persons for providing samples of natural-color "golden" South Sea cultured pearls and shells used as reference material for this study: Alex Vock of ProVocative Gems, New York; Jacques Branellec of Jeweler International, the Philippines; Salvador Assael of Assael International, New York; Terry D'Elia

of D'Elia & Tasaki Co., New York; Nicholas Paspaley of Paspaley Pearling Co., Darwin, Australia; and David Norman of Broome Pearls Pty, Broome, Western Australia. Thanks also to Cheryl Wentzell of the GIA Gem Trade Laboratory for demonstrating an effective method for detecting color treatment using the microscope and fiber-optic light.

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AURICHALCITE

Occasionally we receive items for identification that none of our staff members can recall ever seeing in the lab. Such was the case with a combination pendant and brooch that had a banded white and greenish blue oval cabochon mounted as the center stone. The 29.50 × 18.10 mm cabochon was set in yellow metal and surrounded by square and round cabochon-cut blue moonstones (figure 1).

The central cabochon had a very distinctive appearance: semi-translucent to opaque with a fibrous botryoidal structure that was somewhat reminiscent of malachite. The bright greenish blue color was typical of minerals that are colored by traces of copper. We obtained spot R.I. readings of 1.63–1.75, which exhibited what is known as a “carbonate blink” on the refractometer. The stone effervesced to a small drop of dilute HCl acid applied to the back, which proved

that the material was a carbonate. Gemological testing was limited because the stone was mounted and mostly opaque. Aggregate carbonates can be difficult to identify in any case, so more-advanced testing was necessary.

Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy revealed mostly zinc and copper, with a trace amount of lead (carbon and oxygen are below the detection limits of this instrument). X-ray diffraction analysis produced a pattern that closely matched both aurichalcite $[(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6]$ and hydrozincite $[\text{Zn}_5(\text{CO}_3)_2(\text{OH})_6]$. The relatively high copper content of this cabochon proved that the material was aurichalcite.

This is indeed the first example of aurichalcite set in jewelry that we can recall seeing in the laboratory. Aurichalcite is quite soft (1–2 on the Mohs scale) and somewhat fragile. This was illustrated by the fact that the cabochon had been repaired; that is, a small piece on the top had been reattached with glue. *SFM*

Figure 1. Advanced testing proved that the unusual center stone (29.50 × 18.10 mm) in this combination brooch and pendant was aurichalcite.



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Gems & Gemology, Vol. 38, No. 2, pp. 161–168
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Figure 2. After HPHT treatment, this type Ia diamond (1.07 ct) changed from brown to green-yellow.

DIAMOND

Another Commercial U.S. Facility Offers HPHT Annealing

It recently came to our attention that another U.S. facility is offering high-pressure, high-temperature (HPHT) annealing of diamonds to improve their color. Phoenix Crystal Corp. of Ann Arbor, Michigan, an industrial supplier of diamond abrasives and cutting tools, is commercially treating gem diamonds using a standard belt-type press.

Dr. Robert Frushour, president of Phoenix Crystal Corp., has informed us that his facility has both decol-

orized brown type IIa diamonds and produced a range of colors in type I diamonds. Figure 2 shows a 1.07 ct type Ia diamond before and after HPHT annealing at this facility. Similar to other samples with comparable properties, this one illustrates the predictable color enhancement from brown to green-yellow (see, e.g., I. M. Reinitz et al., "Identification of HPHT-treated yellow to green diamonds," Summer 2000 *Gems & Gemology*, pp. 128–137). Figure 3 shows the mid- and near-infrared absorption spectra of the 1.07 ct diamond before and after treatment. The presence of the H2 absorption feature

at $10,126\text{ cm}^{-1}$ (approximately 987 nm) in the near-infrared spectrum is indicative of similarly annealed type I diamonds, as are the graphitized "feathers" seen with a gemological microscope. Some variations were also observed in the mid-infrared range.

According to Dr. Frushour, the normal annealing temperature used at their facility is generally above 1800°C , with pressure in the range of 5 to 6 GPa. The diamonds annealed range from under 1 ct to over 10 ct. Phoenix Crystal Corp. is not marketing diamonds processed at its facility, but is offering the HPHT service to the trade. We do not know the exact number of commercial HPHT annealing facilities in the U.S., but we suspect that it is very small.

Wuyi Wang

Challenges in Recognizing a Color Attribute's Effect on Color Grading Fancy Colors

GIA fancy grades for colored diamonds represent a range of appearances based on the combination of a color's attributes (hue, tone, and saturation). If a diamond is located near the boundary of its grade range, subtle differences between it and another

Figure 3. Absorption spectra in the near- and mid-infrared range of the diamond shown in figure 2, before and after treatment, provide evidence of HPHT annealing.

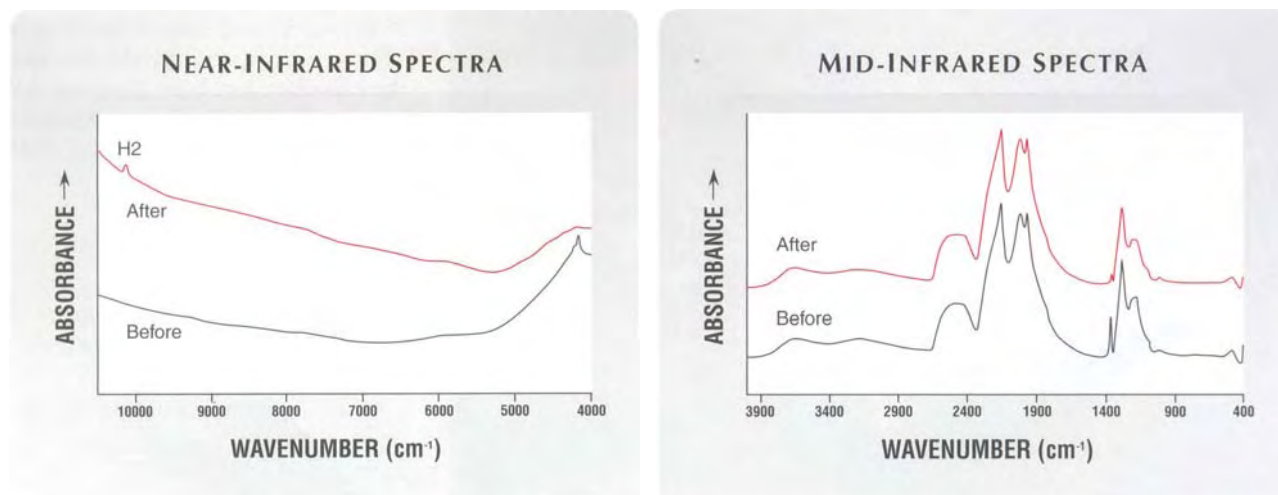




Figure 4. These three diamonds (1.03–2.80 ct) are in the same hue range and of approximately the same saturation. The differences in appearance are due to variations in tone (i.e., relative lightness or darkness), all of which are within the range that would be described in GIA's colored diamond color grading system as Fancy Vivid yellow-orange.

diamond in one or more of these attributes can result in different grades. For example, in this section of the last issue (Spring 2002 GTLN, p. 80), we reported on two blue diamonds that had such a result based on their difference in tone (lightness to darkness). However, there are also situations in which recognizable differences in an attribute may *not* affect the grade because the different appearances occur *within* the established range (i.e., if the range of differences does not cross a boundary, the grade will be the same).

Even in situations where a grade is not affected, understanding which attribute is causing an appearance difference is important because it is not uncommon for a difference in one attribute to be confused with that in another. As a result, some observers interpret differences in an attribute, such as tone, as a difference in saturation or hue. If, for example, two diamonds of different tone were both Fancy yellow and the difference was confused with saturation, they might be thought of as Fancy and Fancy Intense; if hue, the perception might be yellow and orangy yellow. Consistent evaluations are very difficult without a sys-

tematic approach, using references of known location in color space (such as diamonds with established locations in grade ranges), and they require a familiarity with the way colors change with different attributes that can only be attained by observing considerable numbers and varieties of colored diamonds.

A group of colored diamonds recently submitted to the East Coast laboratory highlights the challenges of identifying the cause of appearance differences without a consistent approach and awareness of how colors change. The three diamonds in figure 4 appear slightly different in hue and saturation, which could lead one to believe they are of different fancy grades and hues. When observed under controlled conditions with known references, however, all were found to be in the same hue range and of the same approximate saturation. The perceived differences are due to differences in tone within an area of the GIA color space that does not cross a grade or hue boundary. In this case, all three diamonds received the same color grade and description: Fancy Vivid yellow-orange.

John M. King

Diamond "Pearl" Necklace

The 1990s saw increasing interest in antique-cut diamonds such as briolettes, rondelles, and rose, old European and old mine cuts. Due to their old-fashioned look, diamond beads have also enjoyed a dramatic rise in popularity, even though they are "without historic precedent" (E. Misiorowski, "Jewelry of the 1990s," Winter 2000 *Gems & Gemology*, pp. 398–417).

It was, therefore, not surprising last spring when the East Coast lab received a double-strand necklace of diamond "pearls" for determination of color origin (see figure 5). These spherical diamond beads, first seen by one of our staff members as a commercial product at the 1997 Tucson gem shows, owe their shape to a combination of physical and chemical processes. Ground to rough rounds, they acquire their shiny polish by selective dissolution as they "cook" in sodium carbonate in an inert atmosphere at approximately 800°C ("Diamond 'pearls'," Spring 1997 *Gem News*, pp. 60–61).

The two strands consisted of numerous variously colored round diamond beads graduated in size from approximately 1.75 to 10.00 mm. The client had requested that we test the origin for each color represented in the necklace. As a result, we randomly selected and tested a total of five beads: yellow, dark gray, reddish brown, black, and near colorless. These sample beads ranged in diaphaneity from transparent to opaque. All had refractive indices that were over-the-limit (OTL) of the standard refractometer and had a hardness greater than 9 on the Mohs scale. Only the transparent, near-colorless bead showed a spectrum with the desk-model spectroscope—a 415 nm line.

The dark gray and black beads were inert to both long- and short-wave UV. The yellow bead fluoresced weak orange to long-wave and very weak orange to short-wave UV. The reddish brown bead fluoresced patchy medium-to-strong blue to long-wave



Figure 5. This double-strand necklace of graduated diamond “pearls” was sent to the East Coast lab for determination of color origin. The beads ranged from approximately 1.75 to 10.00 mm.

and patchy medium orangy yellow to short-wave UV. Blue fluorescence was seen in the near-colorless bead in medium and weak strengths with long- and short-wave UV, respectively. Magnification, with the help of fiberoptic lighting, revealed numerous feathers and fractures in each bead. The dark gray bead also contained many whitish clouds of pinpoint inclusions. The reddish brown bead owed its color to orangy red iron staining in many of its surface-reaching fractures. The black bead contained numerous dark crystals and pinpoints.

In summary, standard gemological testing revealed a combination of properties and features that both proved the identity of the beads as diamond and confirmed that the colors in all five beads were of natural origin.

Wendi Mayerson

Internal Laser Drilling Update

In the Summer 2000 issue of *Gems & Gemology*, S. McClure et al. documented a new laser treatment (“A new lasering technique for diamond,” pp. 138–146). The purpose of this treatment, as with typical laser drill holes, is to provide a path for acid solutions to bleach dark, totally internal inclusions. By focusing a laser beam on or near such an inclusion, the technician creates feathers (cleavages) or enlarges existing ones so that they extend to the surface of the faceted diamond. Within the feathers one can see irregular lines or channels that have been left behind by the laser. These channels are typically black or white (figure 6), with a sugary or frosted appearance. Occasionally, we see larger areas that contain numerous small feathers in a step-like progression to the surface. These also may have a white, sugary look (figure 7). In all three of these examples, the treatment is fairly obvious when the diamond is examined with magnification.

Since the 2000 article, we have seen many variations in the appearance of this internal laser drilling.

Figure 6. Laser drilling channels typically are black or white. Left—a nest of black channels in the center of the image is surrounded by a barely visible transparent feather, also created by the laser. Right—the white channels may appear sugary or frosted. Magnified 63× and 45×, respectively.

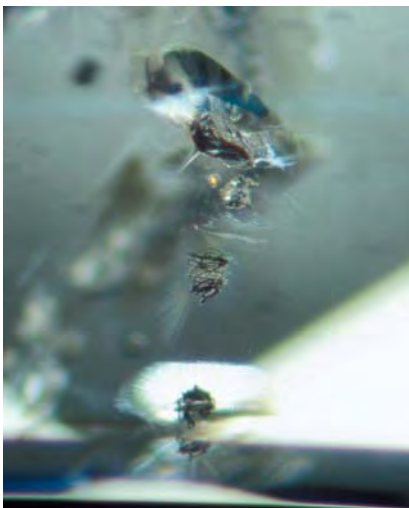




Figure 7. Internal laser drilling can create a series of small step-like feathers that connect an inclusion to the surface of the diamond, often leaving behind a white area with a sugary texture in the center of the feathers. Magnified 37 \times .

Recently, in our laboratories on both coasts, we have encountered a number of feathers that have small, white, disk-like areas with irregular outlines and a sugary texture, rather than the channels described above (figure 8). These disk-like features are located in the same areas of the fractures where we would expect to see the more obvious irregular channels. The “disks” are visible when one looks perpendicular to the plane of the feather, but they are practically invisible when the viewing direction is more parallel to the feather.

The fact that we have seen these unusual features in a large number of diamonds clearly indicates that they are being created by design. These disk-like characteristics are more difficult to recognize than the irregular channels noted earlier in these laser-induced feathers, which makes this treatment more challenging to detect. It is, therefore, very important to use high magnification and various light sources to check all surface-reaching fractures that extend from totally internal inclusions.

Vincent Cracco and
Halina Kaban

Figure 8. These two images show examples of the disk-like characteristics created by internal laser drilling that have recently become very common. These disks may be small and nondescript (left, at 63 \times magnification) or larger and still show some evidence of irregular channels within them (right, at 40 \times magnification).

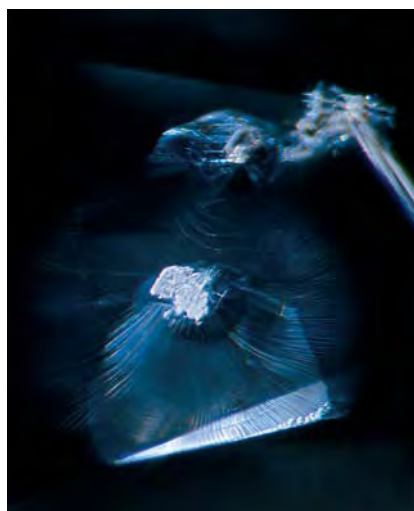
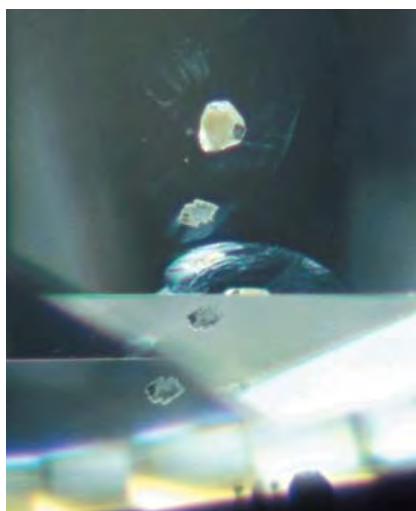


Figure 9. This 3.58 ct heart-shaped diamond was graded Very Light pink in a standard laboratory viewing environment. When exposed to short-wave UV radiation, however, it became F color. Its appearance with standard lighting provided no clue to its unusual luminescence behavior.

Unusual “Pink”

Some diamonds display a change of color when exposed to light or heat. The most frequently encountered diamonds exhibiting this phenomenon are chameleon diamonds, which change from yellow to yellowish green or green when exposed to light after storage in the dark. Gentle heating of this type of diamond produces a temporary bright yellow color. In addition, some Argyle pink diamonds have been observed to change from pink to brownish pink or brown when exposed to ultraviolet radiation. In both cases, the color change is temporary, with the diamond quickly returning to a stable color state once it is removed from the environment that produces the temporary color.

Recently a 3.58 ct Internally Flawless type IIa diamond was submitted to the West Coast lab for investigation of its color-change phenomenon. When examined in the lab’s standard viewing environment, this particular diamond was given a color grade of Very Light pink (figure 9). When it was exposed to short-wave UV radiation, however, the gem

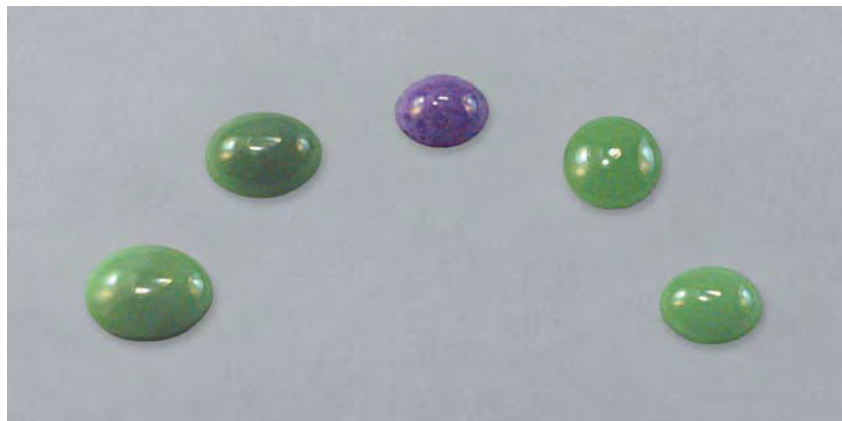


Figure 10. GE has started commercial production of synthetic jadeite in a range of colors and qualities. The samples shown here weigh 1.54–4.06 ct.

changed to an F color. The pink could be restored by exposure to either long-wave UV or daylight.

In contrast to the above-mentioned more common “chameleon” change in color, this diamond showed no change during or immediately after storage in the dark. Thus, the diamond remained pink if it was stored as a pink diamond or colorless if it was stored as a colorless diamond. The pink color “returned” slowly after exposure to long-wave UV radiation or daylight.

Note that, in addition to producing a strong orange fluorescence when exposed to long- or short-wave UV radiation (which is typical for some type IIa pink diamonds), the 3.58 ct diamond also exhibited orangy red fluorescence to the wavelengths of blue light. Depending on the initial diamond color, the excitation wavelength, exposure duration, and number of exposures, up to four different phosphorescence states were observed in this diamond:

1. Diamond color “pink”: medium orange phosphorescence lasting 3 to 15 seconds
2. Diamond color changing from “pink” to “near colorless”: no phosphorescence
3. Diamond color “near colorless”: strong greenish blue phosphores-

cence lasting 2 to 60 minutes or more

4. Diamond color changing from “near colorless” to “pink”: weak orange phosphorescence lasting 1 to 2 seconds, changing to moderate greenish blue phosphorescence lasting 5 to 30 seconds

Although the observation of phosphorescence typically requires a dark-room environment, the strong greenish blue phosphorescence was visible for quite some time even in dim light under certain exposure conditions.

This is one of the very rare color-change “pink” diamonds in which

Figure 11. The finest green GE synthetic jadeite, such as this 6.11 ct cabochon, has an appearance very similar to “Imperial” jade.



the illumination history of the diamond can produce different fluorescence and phosphorescence phenomena and result in different color states. For these types of diamond, a careful neutralization of the temporary phenomenon is necessary before a final color grade can be determined. A more detailed report on the unusual properties of this particular diamond is currently underway.

Shane Elen and Ronnie Geurts

High-Quality SYNTHETIC JADEITE from General Electric

General Electric (GE) Gem Technology has developed a proprietary process for manufacturing synthetic jadeite. GE shared a small number of early production samples with the GIA Gem Trade Laboratory. The samples ranged in color and quality (figure 10), but the finest green material rivaled “Imperial” jade in appearance (see figure 11). Although GE has not yet released details about the new technology, a GE spokesperson did tell us that it is achieved in a high-pressure environment.

The gemological properties of the small number of samples we have tested to date overlap those of natural jadeite. For example, the 6.11 ct cabochon (13.60 × 12.00 × 4.00 mm) shown in figure 11 had a refractive index of 1.66, measured on the flat base, and a specific gravity of 3.34, determined hydrostatically. Using a desk-model spectroscope, we observed a 437 nm line along with three strong chrome lines at approximately 630, 655, and 690 nm. We are currently analyzing the results of additional spectroscopic testing, as we work with GE to determine identification criteria for this new product.

GE research on jadeite synthesis extends back 20 years (see, e.g., R. C. Devries and J. F. Fleischer, “Synthesis of jadeite for jewelry,” *Symposium Proceedings of the Materials Research Society*, Vol. 22, 1984, pp. 203–207; and K. Nassau and J. E. Shigley, “A



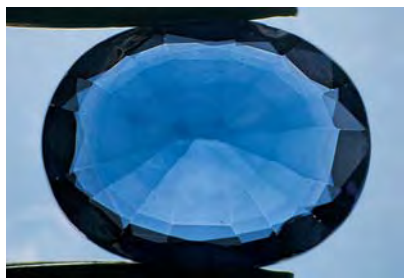
Figure 12. These two sapphires (2.74 and 2.23 ct) were submitted to the laboratory together. The lighter one (left) showed evidence of standard diffusion treatment with titanium. The darker stone was colored by a very shallow surface layer that contained cobalt.

study of the General Electric synthetic jadeite," Spring 1987 *Gems & Gemology*, pp. 27–35). GE plans to publish a detailed article on the characteristics of this new material in the next several months. TM

Cobalt-“Diffused” SAPPHIRE

Since the introduction of diffusion-treated blue sapphire in the early

Figure 13. When the cobalt-colored sapphire was immersed in methylene iodide and examined with magnification in diffused light, irregularities in the color were evident. Note the light-colored spots and paler facet junctions.



1980s, many articles have been written about such stones and their identification (see, e.g., R.E. Kane et al., “The identification of blue diffusion-treated sapphires,” Summer 1990 *Gems & Gemology*, pp. 115–133). The blue color was produced by diffusing titanium into the surface of the sapphire.

About the time the aforementioned article was published, we were also shown some experimental sapphires in which cobalt was used instead of titanium as the diffusing agent. This produced a vibrant blue color, but the color layer was so thin that no real penetration of the corundum could be seen at 60× magnification. In the years that followed, we never saw this product sold on the market.

A short time ago, two blue sapphires (2.23 and 2.74 ct) were submitted to the West Coast laboratory for identification (figure 12). The 2.74 ct sapphire was easily proved to be diffusion treated, as it possessed the characteristics typical of this process: high relief in methylene iodide, concentrations of color at facet junctions, and patchy coloration.

The 2.23 ct sapphire, however, was much different. The color of this stone was darker and more saturated

than the first. The refractive index was over the limits of the refractometer, and the desk-model spectroscope showed three broad bands that are typically associated with cobalt. Microscopic examination did not reveal any inclusions. However, there were numerous spots of lighter color on the surface, and some facet junctions appeared paler than the surrounding facets (figure 13).

Because the refractive index of this stone was so high, we used the laser Raman microspectrometer to determine its identity. The Raman spectrum matched that of sapphire. With EDXRF, we then determined that there was a very high concentration of cobalt at the surface of the stone.

It was clear that the high cobalt concentration at the surface was the cause of the extremely high R.I. readings. We have encountered this before, particularly with red diffusion-treated corundum that has very high concentrations of chromium at the surface and, more recently, with blue-to-green topaz that derives its color from a cobalt-rich surface layer (see, e.g., S. F. McClure and C. P. Smith, “Gemstone enhancement and detection in the 1990s,” Winter 2000 *Gems & Gemology*, pp. 336–359). The blue-to-green treated topaz is often referred to in the trade as “diffusion-treated,” even though it has not been proved that diffusion is actually taking place.

As with the topaz, the depth of the blue surface coloration on the 2.23 ct sapphire could not be seen. The layer was obviously very shallow, with even small chips and scratches penetrating through to the colorless core. Thus, we could not be certain whether the color of the sapphire was due to diffusion treatment, or the product of some other type of surface reaction with the cobalt.

The submission of this cobalt-colored sapphire to the laboratory raises some questions about whether this material has now entered the marketplace. Since we saw only the one stone, we do not know the answer at this time. SFM



Figure 14. Advanced testing revealed that these three beads (each approximately $14.00 \times 10.00 \times 5.00$ mm) were fashioned from the rare gem material schlossmacherite.

SCHLOSSMACHERITE, Yellow-Green Beads

In early 2002, staff members in the West Coast laboratory were challenged to identify several opaque yellow-green beads that had been submitted for analysis. The material had been represented as variscite, an essentially colorless aluminum phosphate that appears green-blue when iron and chromium are present. Green-blue variscite is often used as an ornamental stone, or dyed and sold as a substitute for turquoise.

Because these beads were an unusual yellow-green (see, e.g., figure 14), our client had questioned their identity as variscite. The lenticular beads, which measured approximately $14.00 \times 10.00 \times 5.00$ mm, were evenly colored and appeared to have been fashioned from the same piece of material. A few beads also showed some prominent darker green “veins.” When we examined the beads with a microscope at standard $10\times$ magnification, we noticed that the material had a fine-grained, almost colloidal-appearing structure. We also observed that the darker-appearing “veins” were actually a finer-grained phase of this material. Despite the poor polish, we were able to determine a vague spot refractive index reading of 1.57. The specific gravity was measured at 2.35. The beads did not show an absorption spectrum or any reaction to long- or short-wave ultraviolet radiation. Since these properties are not within the reported range for variscite, we turned to advanced testing methods to identify the beads.

With the client’s permission, Dino DeGhionno performed an X-ray powder diffraction analysis and determined that the beads had been fash-

ioned from schlossmacherite, a sulfate-arsenate member of the beudantite group. To confirm the identity of this rare material, Sam Muhlmeister performed EDXRF qualitative chemical analysis. The analyses revealed that the material primarily contained aluminum, sulfur, and arsenic, as well as calcium, copper, and other minor trace elements, which substantiated the identification as schlossmacherite.

This rare mineral was named after the dean of German gemology, Prof. Dr. Karl Schlossmacher. Originally found in Guanaco (Chile), it was first introduced by K. Schmetzer and H. Bank in 1979 (*Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 28, No. 3, pp. 131–133) and described as a new mineral in 1980 by K. Schmetzer et al. (*Neues Jahrbuch für Mineralogie Monatshefte*, Vol. 1980, No. 5, pp. 215–222). KNH

PHOTO CREDITS

Maha Tannous—figures 1, 9, and 12;
Elizabeth Schrader—figures 2, 4, 5, 10,
and 11; Vincent Cracco—figures 6, 7, and
8 (left); Shane McClure—figures 8 (right)
and 13; Don Mengason—figure 14.

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CONFERENCE REPORTS

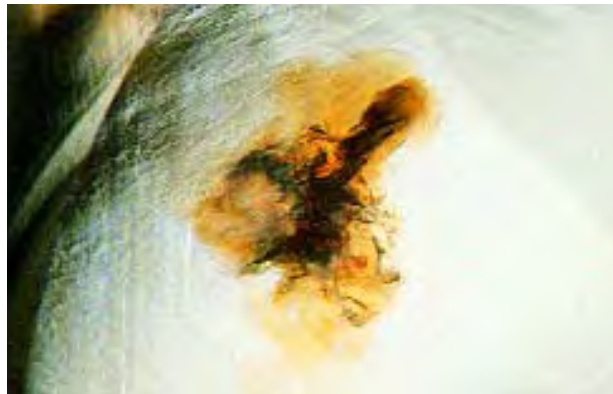
AGU meeting examines diamond provenance. A session on "Determining Diamond Provenance" was held at the American Geophysical Union's Spring 2002 semiannual meeting, which took place May 28–31 in Washington, D.C. The session was prompted by concerns over identifying "conflict" diamonds after they have been removed from their source area. **Dr. Stephen Haggerty** of the University of Massachusetts, Amherst, began with an overview of the problems associated with determining the geographic origin of gem diamonds. The contributor of this entry, director of research for GIA, discussed technical challenges for determining "country of origin" by analytical methods—for example, the lack of a representative collection of diamonds from known primary and secondary deposits to establish if there are characteristics unique to each deposit. Since determining country of origin by analytical means appears to be impossible at this time, the jewelry industry has recommended procedures to track diamonds from legitimate sources so as to exclude illegitimate diamonds from conflict countries. **Dr. Larry Taylor** of the University of Tennessee, Knoxville, also described the need for a more thorough scientific study of larger collections of diamonds from major deposits to establish if certain features (such as inclusions and isotopic data) provide evidence of geographic source.

Dr. Peter Deines of Pennsylvania State University, University Park, presented carbon isotope and inclusion chemical data on diamonds from kimberlite pipes in Botswana and South Africa, and demonstrated that while diamonds from different kimberlites can be geochemically distinct, they may show complex variability within single samples or among different ones. He concluded that there was no simple diagnostic pattern of geochemical features that could link his diamond samples unambiguously to a particular kimberlite. **Dr. Pierre Cartigny** of the Labora-

toire de Geochimie des Isotopes Stables, Paris, studied diamonds from the Panda kimberlite in Canada, and concluded that nitrogen and carbon isotopic data could not be used to distinguish them from other sources. **Dr. Erik Hauri** of the Carnegie Institution of Washington (D.C.) demonstrated how variations in nitrogen and carbon isotopes—as well as a complex cathodoluminescence zoning pattern—in a diamond crystal from the Mir kimberlite in Russia provided evidence of a complicated growth history. Such variations within a single crystal illustrate the difficulties of using geochemical data to establish diamond provenance.

Dr. Nikolai Sobolev of the Institute of Mineralogy and Petrography, Russian Academy of Sciences, Novosibirsk, illustrated how the prevalence of chromite as mineral

Figure 1. The sulfur isotope compositions of sulfide inclusions—such as the one shown here in a rough diamond—may help determine the geographic source of diamonds, when combined with other information. Photomicrograph by John I. Koivula; magnified 10 \times .



inclusions in Yakutian diamonds can provide evidence of their geographic origin. **Dr. Jeffrey Harris** of the University of Glasgow, U.K., showed how variations in shape, color, and surface features also offer a potential means of establishing geographic source. However, the absence of similar data on conflict diamonds is a major drawback to validating this approach. **Dr. Steven Shirey**, also of the Carnegie Institution of Washington, described how establishing the ages of diamonds using radiometric methods does not appear to hold potential for establishing provenance due to overlap in diamond ages from various deposits. **Dr. James Farquhar** of the University of Maryland, College Park, studied sulfur isotope compositions of sulfide inclusions (see figure 1) in diamonds from Orapa, Botswana, as an alternate means of elucidating their geologic history. When combined with other information, this might help determine the source of diamonds. **Dr. Eva Anckar** of the University of Cape Town, South Africa, presented results of a multivariate analysis of diamonds—incorporating nitrogen content and aggregation, hydrogen content, infrared spectra, color, shape, size, surface features, and cathodoluminescence patterns—to show that this statistical approach has the potential to differentiate among diamond sources.

Overall, these presentations demonstrated that some analytical techniques hold promise for distinguishing diamonds from particular deposits, but further work is needed on a more complete collection of diamonds from all major sources to fully establish the validity of these techniques.

JES

GSA meeting reports on Western U.S. gem occurrences.

The 54th Annual Meeting of the Rocky Mountain Section of the Geological Society of America took place May 7–9 at Southern Utah University in Cedar City, Utah. The meeting included a session on “Gemstone and Semiprecious Minerals and Host Rocks in the Western United States.” **Peter Modreski** of the U.S. Geological Survey, Denver, Colorado, outlined the gem occurrences in Colorado, which include deposits of pegmatite minerals [aquamarine [figure 2], smoky quartz, topaz, and amazonite feldspar], as well as diamond, peridot, turquoise, lapis lazuli, and rhodochrosite. **W. Dan Hausel** of the Wyoming State Geological Survey, Laramie, summarized gem and mineral localities in that state. Historically, nephrite jade and various agates and jaspers have been the most important gem materials, but sapphires and iolite were found recently. In a separate presentation, he described new kimberlite discoveries in the Iron Mountain district in southeastern Wyoming.

Richard Berg of the Montana Bureau of Mines and Geology, Butte, discussed probable sources of Montana’s large alluvial sapphire deposits. Preservation of delicate surface features that formed during magmatic transport, and the absence of internal conchoidal fracturing, indicate that the sapphires were transported only a short distance from



Figure 2. Colorado is the source of several gem materials, including this aquamarine from Mt. Antero in the Sawatch Range. The faceted stones range from 3.50 to 18.95 ct. Courtesy of the Denver Museum of Nature and Science; photo by Jack Thompson.

their original host rock. The lack of rock fragments on the sapphires, and the fact that more than 100 years of sapphire mining has failed to reveal the primary host rock, suggest that the original bedrock was friable and easily eroded, so it would not leave surface outcrops. **Dr. Jeffrey Keith** of Brigham Young University (BYU), Provo, Utah, described a rare occurrence of emeralds (not of gem quality) in a black, organic-rich shale in the Uinta Mountains in northern Utah, and pointed out the geologic similarities to the famous emerald deposits in Colombia. In the same area is an extensive occurrence of massive, fibrous, translucent brownish yellow calcite that is carved for ornamental purposes. Presentations on the deposits and genesis of red beryl in the Wah Wah and Thomas Mountains in Utah were

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GEMS & GEMOLOGY, Vol. 38, No. 2, pp. 170–186
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given by **Timothy Thompson** and **Jean Baker**, also from BYU. At both localities, red beryl is a post-magmatic mineral that occurs in fractures within rhyolite host rock. Crystallization of red beryl probably resulted from the reaction of beryllium- and fluoride-rich vapors with groundwater in the fractures. *JES*

Report from the 3rd World Diamond Conference, Vancouver. On June 17 and 18, 2002, this conference attracted approximately 450 diamond exploration company executives, as well as investors, government officials, mining geologists and engineers, and diamond dealers. As was the case with the previous conferences (see, e.g., Fall 2001 GNI section, pp. 222–225), Chaim Even-Zohar was the moderator. The conference program was well rounded, but was dominated by two topics: (1) Canada as a major player in the world diamond scene, and (2) “conflict” diamonds.

Figure 3. More than 50 companies are currently exploring for diamonds in Quebec, which is the most recent exploration region in Canada (i.e., since 1996). Six diamond-bearing kimberlites have been found in the Otish Mountains area since late 2001. A diamondiferous kimberlite dike was found in the Wemindji area in early 2002, and a system of diamond-bearing ultramafic dikes was discovered in 1996 in the Torngat Mountains. Diamond indicator minerals are being investigated in glacial deposits in several other regions of the province.



Canada. In 2001, Canada produced about 3.5 million carats of diamonds, all from the Ekati mine in the Northwest Territories (NWT). The diamonds were mined from both the Panda pipe and the newly opened Misery pipe, and represent about 3% of the world’s supply by weight and 6% by value. Within one year, these figures are expected to increase to perhaps 10% in both categories when the Diavik mine (which has diamonds of overall lower quality than Ekati) starts production. The status of several Canadian diamond projects at various stages of evaluation and development (mainly in the NWT, Nunavut, and Saskatchewan) was also discussed, as were exploration programs in new regions. Currently, the most exciting activities in Canada, in which more than 50 companies are involved, are taking place in Quebec. Diamonds are now known from three new areas in this province (figure 3), and geologists have found encouraging diamond-indicator-mineral “trains” in others. Elsewhere in Canada, exploration continues at a feverish pace (e.g., in the North Slave geological province, also known as the Coronation Gulf area), and has resulted in the discovery of several new diamond-bearing kimberlites.

Inevitably, additional mines will be developed in Canada, which is a preferred country for diamond exploration and mining because of its good infrastructure and political, social, and economic stability, as well as favorable geologic factors. In fact, it is estimated that currently 50% of the diamond exploration monies budgeted worldwide are spent in Canada. The main requirements for diamond mining companies, as stipulated by all levels of Canadian government, are: (1) respect for the environment and local (indigenous) cultures; and (2) creation of meaningful opportunities for Canadian workers—for example, in diamond cutting as well as mining.

Conflict Diamonds. The future of the Kimberley Process (to certify locality of origin for diamonds as they move through the trade from the source to the retailer, so that conflict diamonds will be excluded from the marketplace) is not yet assured, because it has not been ratified by several of the approximately 30 countries necessary for its success; at press time, for example, it had not yet passed the U.S. Senate. However, the unrest that initially generated the issue—that is, civil wars in certain African countries—appears to be improving naturally. With political stability on the horizon for both Angola and Sierra Leone, and with signs of improvement in the Democratic Republic of Congo, the proportion of conflict diamonds may be as low as 1.5% of the total world rough diamond production (compared to as much as 4% two years ago).

Several conference participants expressed concerns about the practicality of the Kimberley Process. Some maintained that two factors are critical to the success of the initiative: (1) Control of the diamonds by authorized persons must be achieved at the point of extraction from the ground, and (2) uncertified stones must not be allowed



Figure 4. These round modified brilliants (0.50–0.76 ct) have unusual faceting arrangements. The two on the left have 100 facets, and those on the right, 73 facets. Courtesy of Rosy Blue International; photo by Maha Tannous.

to enter the legitimate stream. Nevertheless, the industry overwhelmingly supports the Kimberley Process, both for its humanitarian aspects and to safeguard the integrity of the market. Further, enforcement measures of the Kimberley Process may forestall any future attempts to use diamonds for inappropriate purposes.

Special Award. The conference ended with a fitting tribute to Charles E. Fipke, who was presented with the first “Diamond Pioneer of Canada” award for being instrumental in finding the Lac de Gras kimberlite field in 1990.

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DIAMONDS

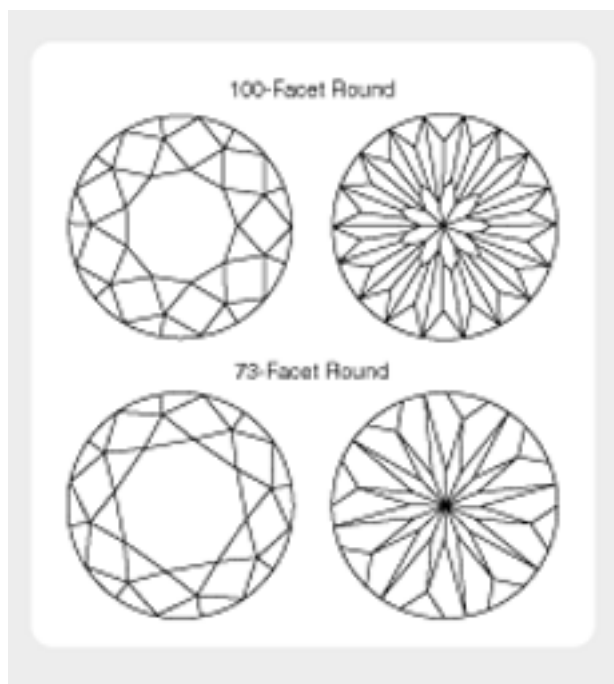
New round diamond cuts. Rosy Blue International (Antwerp, Belgium) recently showed GIA researchers several examples of two unusual round modified brilliant cuts that provide additional perspective on the relationship between cut and the face-up appearance of a faceted diamond (figure 4). The faceting arrangements of these diamonds create an interesting pattern of contrasting light and dark areas in the face-up diamond. Over the preceding several months, we had begun to focus some of our diamond cut research efforts on the patterns displayed by round brilliants of various proportions, and how the properties of these patterns can affect human perception of a diamond’s brilliance. Therefore, we were pleased to have the opportunity to examine these diamonds, to see how changes in the number and arrangements of facets could affect face-up appearance.

A standard round brilliant has 58 facets: 33 on the crown and 25 on the pavilion (including a culet but excluding girdle facets), with eight-fold symmetry around a central axis. As illustrated in figure 5, one of these new cuts has the usual facet types on the crown but with nine-fold symmetry, which produces 37 crown facets. The pavilion has 63 facets, also with nine-fold symmetry, for a total of 100 facets (excluding a culet or any girdle facets). The nine pavilion

main facets are each split into three facets, two trapezoids, and an elongated hexagon. Two more trapezoids plus two small triangular facets substitute for each of the nine pairs of lower-girdle facets. Both the nine-fold symmetry and the division of the pavilion into many facets with small angular differences among them contribute to the distinctive appearance of this cut.

The other round modified brilliant cut, named the “Aster” cut, has 73 facets (again, see figure 5). The crown

Figure 5. These faceting diagrams for the 100-facet and Aster (73-facet) cuts display the complexity of these designs. The many small facets demand precision cutting to achieve the desired optical effects. Courtesy of Rosy Blue International.



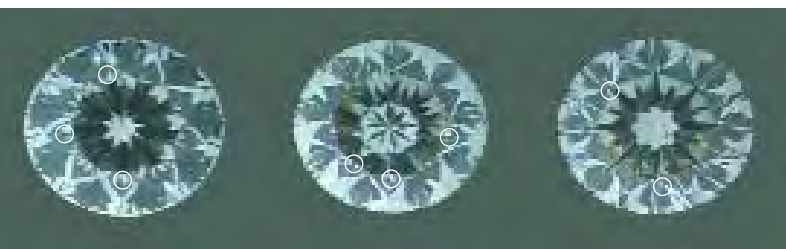


Figure 6. In an environment that emphasizes contrast, these diamonds show patterns with many small bright spots (some are circled), contributing to their scintillation. The images on the left and center are of the 100-facet round modified brilliants, whereas the one on the right is of a 73-facet round. Courtesy of Rosy Blue International; composite photo by Al Gilbertson.

is standard, but 16 facets have been added to the pavilion as eight additional pavilion mains (extending about three-fourths of the way to the girdle) and eight triangular facets above them (which break into the lower-girdle facets).

Figure 6 shows two of the 100-facet round modified brilliants and one of the 73-facet rounds photographed in an environment that emphasizes the contrast pattern of a faceted diamond in the face-up position. In the two 100-facet diamonds, the nine short, hexagonal facets that radiate from the culet create nine bright reflections under the center of the table, like a nine-petalled flower. At the same time, the pairs of trapezoidal facets beyond them are seen as nine dark reflections of these pavilion “mains” distributed under the bezel facets of the crown. The 73-facet design shows 16 distinct reflections of both the full and partial pavilion mains, while the eight triangular facets above the partial mains create an effect similar to that of a French tip on a fancy shape at eight spots around the girdle.

The size and distribution of spots of bright white and black in these patterns is significant. The movement of such spots when the diamond, light source, or observer moves is an important factor in scintillation (i.e., flashes of light seen through the crown as the diamond moves relative to the light source and observer), and the contrast they produce can affect human perception of overall brightness. For the 100-facet design, the specific distribution of these spots depends strongly on the precision of the pavilion faceting. We noted marked variations in this appearance aspect among the eight examples of this faceting style we examined, and we mentioned these differences to the client. By repolishing two of the samples (one of them more than once), cutters at Rosy Blue succeeded in making the pattern appear more uniform. These observations showed again the importance of precise cutting to achieve the desired result from a complicated faceting design.

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COLORED STONES AND ORGANIC MATERIALS

Benitoite recovery and cutting: Significant progress. Since March 2001, the Benitoite Gem mine in San Benito County, California, has been worked on a seasonal basis (generally from March to May, when water is available) by Benitoite Mining Inc., Golden, Colorado (see Spring 2001 GNI section, p. 68). During the 2001 season, the company focused on mining gem and specimen material from the lode and evaluating the best way to recover gem rough (including small fragments discarded by previous activities) from the eluvial deposit, mine dumps, and other unconsolidated material. In 2002, mining focused mainly on gem rough. By the time the 2002 season ended in early June, some important strides had been made in both recovery and cutting.

According to company president Bryan Lees, a new processing plant—with a capacity of 150 tons of material per day—began operation in April 2002 (figure 7). The plant uses a system of vibrating screens combined with high-pressure washing. First, the ore is dumped in a hopper and the boulders are removed; next, any fragments over $3\frac{1}{4}$ inch (1.9 cm) are sprayed by water jets and directed to a conveyer belt for hand-picking of potential mineral specimens. The remaining washed and screened material is sent through a jig system. Two large jigs catch pieces over $5\frac{1}{4}$ inch (4 mm), while smaller fractions pass down into their hutch compartments. This hutch material is dewatered and sent to a smaller jig, which catches pieces down to 2 mm. By comparison, fragments smaller than 3 mm were rejected during previous mining activities. The benitoite concentrate—including gem, near-gem, and nongem material—is removed from the jigs each day.

Experiments were done to test whether X-rays could be used to automate the concentration process (as is done in diamond mines), but benitoite’s strong fluorescence to X-rays resulted in an unacceptably large amount of contaminants being allowed into the concentrate because the system was over-activated. Also, the technique could not discern between gem- and nongem material.

However, Mr. Lees indicated that another technique has revolutionized the processing of the concentrate: magnetic separation. Since benitoite is the only material in the concentrate that contains iron, 100% of the gems can be separated by this technique. In addition, this method has proved useful in separating much of the near-gem and nongem benitoite from the facetable fraction. Experiments to date have shown that 400 pounds (181 kg) of concentrate can be processed in just two hours. Mr. Lees feels that magnetic separation could be applied successfully to other gem minerals as well.

Cutting and marketing are being handled by Iteco Inc. of Powell, Ohio. Iteco president Paul Cory stated that approximately 1,000 carats of melee have been faceted during the last year, in full round brilliants ranging from

Figure 7. This new processing plant was installed at the Benitoite Gem mine in spring 2002. Material is dumped into the hopper (far left) and proceeds up the conveyor belt to a washing/screening apparatus (top right). Mineral specimens larger than $\frac{3}{4}$ inch (1.9 cm) are hand picked from the conveyor belt on the far right. Smaller material is sent through a jig system, which is partially visible (tan-colored box) below the screening apparatus. Benitoite concentrate, down to 2 mm, is removed from the jigs each day.
Photo by Bryan Lees.



1.5 to 4 mm in diameter. Based on the critical angle of benitoite (34.7°), all of the stones are faceted in a consistent set of proportions to yield the best face-up appearance. A range of color, from colorless to deep violetish blue, is available (figure 8). Most of the material is a medium violetish blue, with near-colorless and deep violetish blue each accounting for about 10% of the volume. Since all the melee was faceted from rough found during the 2001 season—derived mostly from the mine dumps—future production may show a different color distribution as various parts of the deposit are mined. Dichroism is taken into account when orienting larger rough to yield the best color, but the melee stones are not cut in any particular orientation. So far, the largest stone cut from the 2001 production weighed 3.55 ct, and several other stones exceeding 3 ct also were produced. Although Benitoite Mining sells many of the stones loose, it is presently seeking partnerships with jewelry manufacturers and developing its own line.

Depending on demand and mining activity, Mr. Lees expects the mine to produce commercial quantities of benitoite for approximately 5–10 years. Specimen material will remain an important part of the production, as there appears to be more *in-situ* lode material than originally anticipated. Mining of both loose material and the lode deposit will occur concurrently during the next several field seasons.

Cassiterite from Viloco, Bolivia. Faceted cassiterite is rare. Although Nigeria, Russia, and China produce limited quantities, the only locality producing significant amounts of gem rough is the Viloco mine, near Araca in La Paz Department, Bolivia.

Cassiterite is tin oxide, SnO_2 , that is typically brown to black due to iron impurities. Cassiterite from Viloco forms as druses of highly lustrous crystals that are considered by collectors to be among the finest examples of the

mineral species (figure 9). They too are usually brown to black, but very rarely the crystals are color zoned brown and light yellowish brown; the latter color is concentrated near the surface. The cut gems are most commonly light yellowish brown, but some bicolored brown and yellowish brown stones have also been faceted (figure 10). As part of a German foreign aid project, the Viloco miners have been instructed to separate out top-quality gem- and specimen-grade cassiterite rather than process it as ore. The gemstones are cut in Bolivia and marketed overseas. During a 2001 trip to Bolivia, this contributor saw hundreds of carats of faceted Viloco cassiterite.

According to R. Webster's *Gems* (5th ed., rev. by P. G.

Figure 8. Benitoite melee is now being faceted in full round brilliants with a consistent set of proportions. A range of colors is available, as shown here (0.07 ct each). Courtesy of Benitoite Mining Inc. and Iteco Inc.; photo by Robert Weldon.





Figure 9. This 9 ↔ 7 cm specimen with numerous partially transparent cassiterite crystals is from the Viloco mine in Bolivia. Photo by Jaroslav Hyrsl.

Read, Butterworth-Heinemann, London, 1994), cassiterite is uniaxial with very high refractive indices— $n_o=2.003$, $n_e=2.101$ —which are well over the limit of a standard refractometer. It also has very high dispersion (0.071, nearly twice that of diamond) and a hardness of 6.5 on the Mohs scale. Cassiterite has an extremely high specific gravity of about 7, so loose stones are easy to recognize by their heft. It shows no features with a hand spectroscope and is inert to UV radiation.

Due to its high birefringence (0.098), cassiterite is often faceted with the table perpendicular to the optic axis (similar to synthetic moissanite), so the facet edges do not appear blurred. Although near-colorless cassiterite is rare, it could be easily confused with synthetic moissanite. Like synthetic moissanite, it has high thermal conductivity, so

Figure 11. Tourmaline needles occur as inclusions in some cassiterites from Viloco. Photomicrograph by John I. Koivula; magnified 20↔.

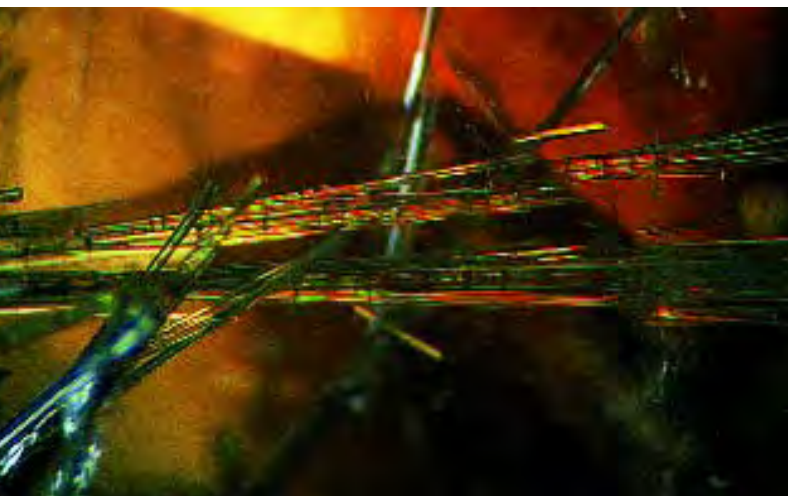


Figure 10. Faceted cassiterite from Viloco is typically light brownish yellow, although bicolored stones—similar to the oval on the far right—also are cut. The center stone weighs 11.77 ct; photo by Jaroslav Hyrsl.

it tests positive for “diamond” on conventional diamond testers. Cassiterite is electrically conductive, so it also will test positive for “moissanite” on some of the new synthetic moissanite testers. The best way to distinguish the two materials when set in jewelry is by microscopic examination of their inclusions. Parallel white or silvery needles are typical for synthetic moissanite, whereas virtually all cassiterites contain veils of two-phase inclusions. Cassiterite from Viloco also occasionally contains tourmaline needles (figure 11; probably dravite), as confirmed by X-ray diffraction analysis.

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Emerald with feldspar matrix from Brazil. While in Minas Gerais in summer 2001, this contributor encountered significant quantities of a new type of fashioned emerald from the Nova Era area. These cabochons consisted of irregular intergrowths of semitransparent emerald in a white matrix (figure 12). Only rarely were euhedral emerald crystals (i.e., with hexagonal cross sections) seen in the cabochons. Most of the white material showed well-developed cleavage, and X-ray diffraction analysis of one sample proved it was plagioclase (most probably andesine). Quartz was present only sporadically in the matrix, as small colorless grains without cleavage. Rough pieces of the emerald rock were surrounded by dark mica, probably phlogopite. Some of the polished stones also contained dark greenish brown flakes of mica. The specific gravity of five representative cabochons ranged from 2.67 to 2.74; it increased only slightly with emerald content. The emerald in the cabochons was inert to long- and short-wave UV radiation, and showed no reaction to the Chelsea filter.

A similar emerald matrix material is known from the Big Crabtree mine in North Carolina (see Summer 1993 Gem News, p. 132). In contrast to the new Brazilian

material, however, the North Carolina cabochons contained well-formed emerald crystals in a granular quartz-feldspar matrix.

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Sunstone feldspar from Tanzania. At the 2002 Tucson gems shows, Abe Suleman of Tuckman Mines and Minerals Ltd., Arusha, Tanzania, showed *G&G* editors a 7.88 ct sunstone from a new deposit in Tanzania (figure 13). He reported that the mining area covers several square kilometers in the vicinity of the village of Engare Naibor, northwest of Arusha, near the border with Kenya. The area, which is occupied predominantly by members of the Masaai tribe, is semi-arid and hilly. The feldspar reportedly is found in dolomitic layers, with mica schist and traces of calcite. The miners have dug several pits up to 4–5 m deep.

Production is inconsistent and hampered by the remoteness of the locality. Both faceted stones and cabochons (figure 14) are produced. The polished stones commonly attain weights up to 10 ct, although Mr. Suleman has cut cabochons as large as 125 ct.

The 7.88 ct sunstone, which was donated to GIA by Abe and Anisa Suleman, was examined by Elizabeth Quinn of the GIA Gem Trade Laboratory in Carlsbad. The modified round brilliant was light grayish green with numerous eye-visible iridescent orange platelets (figures 15 and 16). Refractive indices of the stone were 1.537 and 1.547, and the specific gravity was 2.64; these properties are consistent with oligoclase feldspar. The orange inclusions

Figure 12. These cabochons (here, up to 16 mm long) have been fashioned from irregular intergrowths of emerald and plagioclase found in Minas Gerais, Brazil. Photo by J. Hyrsl.

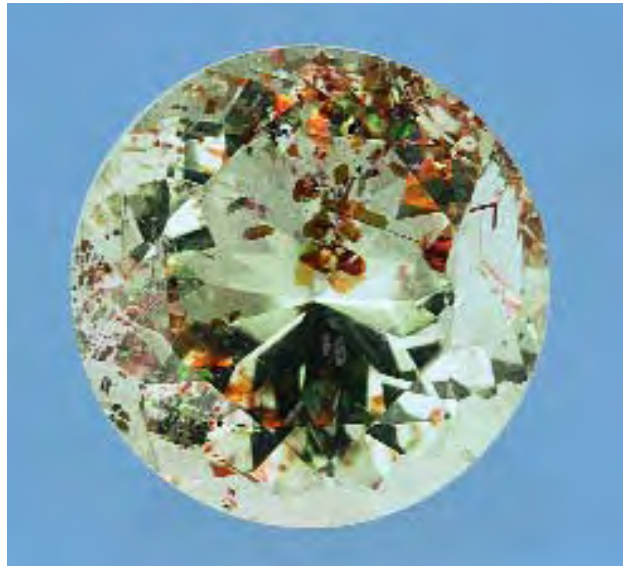


Figure 13. This 7.88 ct sunstone, from a new locality in Tanzania, contains conspicuous iridescent orange inclusions that were identified as hematite. Courtesy of Abe and Anisa Suleman; photo by Maha Tannous.

were identified as hematite on the basis of laser Raman microspectrometry by GNI editor Brendan Laurs. Several near-colorless needles were identified as an amphibole, probably anthophyllite (again, see figure 15), also by Raman analysis. In addition, microscopic examination revealed lamellar twin planes and a fracture.

Figure 14. Abundant hematite platelets—some showing iridescence—are visible in this 20.81 ct cabochon of sunstone from Tanzania. Courtesy of Michael Randall, Gem Reflections, San Anselmo, California; photo by Robert Weldon.





Figure 15. The inclusion scene in the 7.88 ct sunstone consists of orange platelets of hematite and near-colorless needles of anthophyllite. Photomicrograph by John I. Koivula; magnified 10 \leftrightarrow .

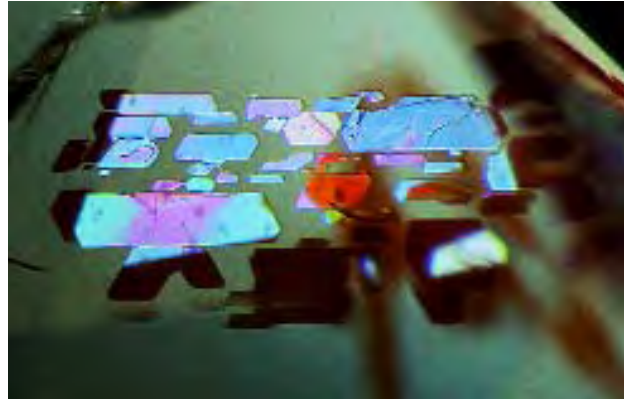
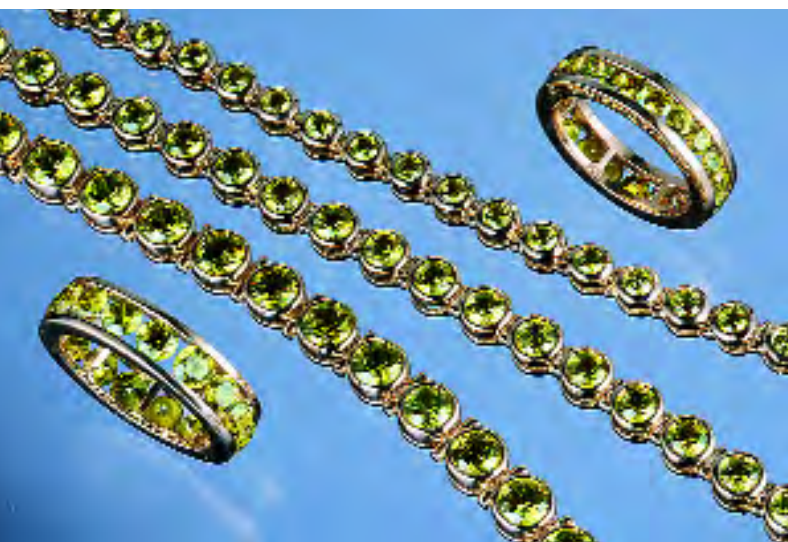


Figure 16. The iridescence displayed by the hematite inclusions in the 7.88 ct sunstone was particularly pronounced when a fiber-optic light was used in conjunction with the shadowing technique. Photomicrograph by John I. Koivula; magnified 15 \leftrightarrow .

Update on Namibian demantoid garnet. At the 2002 Tucson shows, Chris Johnston, owner of Johnston-Namibia C.C. of Omaruru, Namibia, showed the *G&G* editors some attractive jewelry set with well-cut demantoid garnet in calibrated sizes (figure 17). To supplement the Fall 1997 (pp. 222–223) *Gem News* item on this material, Mr. Johnston provided the following information.

Demantoid from Namibia has been known since at least the 1930s, but the deposit lay idle until rediscovered by the gem trade in 1997. The mines are located in the Erongo Mountains area of west-central Namibia, between Omaruru

Figure 17. The Namibian demantoid in this 18K yellow/white gold jewelry was mined recently and cut to calibrated sizes ranging from 3 to 5 mm in diameter. Courtesy of Chris Johnston; photo by Maha Tannous.



and the small desert town of Usakos. The garnet is hosted by skarns (metamorphosed carbonate rocks) that are near the contacts with granitic rocks. Only near-surface, small-scale mining of these primary deposits has been done to date, with limited mechanized equipment. Most of the mining has taken place on Farm Tubussis off the Okombahe-Usakos road, near the small Damara village of Tubussis. Besides informal mining activities, currently there is one active mechanized operation, which markets the stones through Gem Demantoid Inc. of Bangkok, Thailand.

Mr. Johnston estimates the total current production of demantoid at about 8 kg per month, of which 2 kg is gem quality, mostly in the 0.3–1 gram range. About 15% of the gem rough is top green color (i.e., without too much yellow/brown). Most of the cut goods he has sold range from 3 to 5 mm in diameter, in round, trillion, and oval shapes. He believes the market strength of this niche material is in melee and as accents in Art Deco and Art Nouveau-style jewelry.

Unusual kyanite from Brazil. Brazil is one of the main sources of gem-quality kyanite. During the last few years, large quantities of kyanite crystals (some with facetable portions) were mined from the vicinity of Vitoria de Conquista in Bahia. The crystals can approach 10 cm long, and very rarely they exhibit unusual shapes that result from natural deformation (figure 18). The faceted stones typically range up to about 5 ct, although attractive gems over 50 ct have been cut. The crystals can show both blue and green areas; generally a strip of blue is seen along their length. A few bicolored stones have been faceted.

One of us (JH) observed some interesting inclusions in recently acquired green and bluish green kyanite from Brazil (probably also from the Vitoria de Conquista area). In two stones, light brown to orange-brown inclusions up to approximately 1 mm in diameter were identified as garnet by Raman analysis at GIA in Carlsbad (figure 19); it was

not possible to establish the particular species. Associated with garnet in one sample were green tourmaline and irregular masses of colorless quartz, also identified by Raman analysis (figure 20). Flat, black crystals with a metallic luster were probably ilmenite.

The two samples with garnet inclusions were light yellow-green, with greenish yellow and bluish green pleochroism. Both stones had refractive indices of $n_{\alpha} = 1.718$, $n_{\beta} = 1.727$, and $n_{\gamma} = 1.734$, yielding a birefringence of 0.016; both were biaxial negative. (Note that n_{β} was found by rotating the stones on the refractometer to find the direction of maximum birefringence [n_{γ}], and then rotating the polarizing filter.) Specific gravity values were 3.67 and 3.69; both stones were inert to UV radiation.

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South Sea cultured pearls with broken beads. The Gübelin Gem Lab recently examined a single-strand necklace composed of 25 South Sea cultured pearls (figure 21). When X-rayed, several of the pearls seen on the x-radiograph were revealed to contain beads with a series of dark lines. The owners later mentioned that those particular cultured pearls were very difficult to drill, with several drill bits broken in the process.

At the CIBJO conference held in Munich, Germany, last March, Shigeru Akamatsu of K. Mikimoto & Co. Ltd. (Tokyo, Japan) announced that a new type of bead was being used to nucleate larger South Sea cultured pearls. These beads were fashioned from the shell of the giant clam (*Tridacna gigas*). He indicated that massive amounts of this abundant shell material were being used to produce large-diameter beads (i.e., 8+ mm), which are reportedly manufactured at Chinese factories on Hainan Island

Figure 18. These kyanite crystals from Brazil were deformed by natural forces. Portions of the crystals are transparent enough to be faceted. The largest crystal here is 5 cm long; photo by Jaroslav Hyrsl.



Figure 19. Garnet forms conspicuous inclusions in these Brazilian kyanites (largest, 9.62 ct). Photo by Jaroslav Hyrsl.

(S. Akamatsu, pers. comm., July 2002). It is difficult to obtain large-diameter beads from the Mississippi freshwater mollusks that are typically used for South Sea cultured pearls because of their size. Mr. Akamatsu noted, however, that the beads derived from giant clam shells have an inherent problem: They tend to break during the drilling process.

This necklace contains the first examples seen by the Gübelin lab of large South Sea cultured pearls with broken beads. It is not known what effect these broken beads may have on the long-term durability of the cultured pearls. With the large quantities of these beads that are reportedly being used, it can be expected that more such cultured pearls will be encountered in the future.

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Figure 20. An unusual inclusion assemblage of orange-brown garnet, colorless quartz, and green tourmaline is present in this kyanite from Brazil. Photomicrograph by John I. Koivula; magnified 15x.



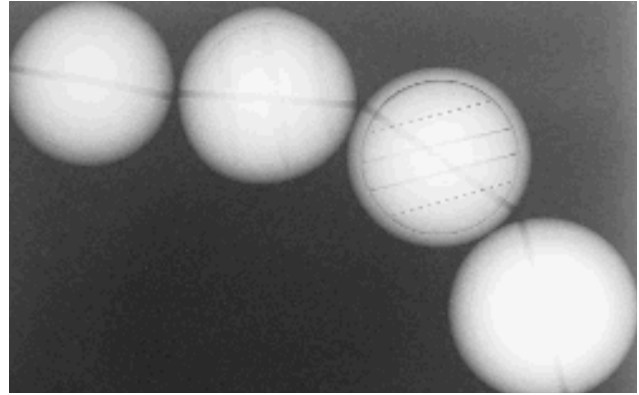


Figure 21. This necklace of South Sea cultured pearls (16.25–19.40 mm) contained several broken shell beads. The X-radiograph clearly shows a series of parallel breaks in two of the beads. In one of these, the breaks are visible as a series of sharp lines because they are parallel to the viewing direction; in the other, the breaks appear as elliptical areas because they are inclined to the viewing direction. These cultured pearls apparently contain a new type of bead, made with the shell of the giant clam. Photo by Franzisca Imfeld.

Some developments in freshwater cultured and “keshi” pearls. At the AGTA show in Tucson last February, this contributor noticed some eye-catching freshwater cultured pearls. Betty Sue King of King’s Ransom (Sausalito, California) had some of the popular cross-shaped tissue-nucleated cultured pearls in dramatic strands that were

Figure 22. Strung together, these cross-shaped tissue-nucleated cultured pearls resemble a crown of thorns, and are marketed as “spikes.” Their dimensions average approximately 45 ↔ 25 mm. Courtesy of King’s Ransom; photo by Maha Tannous.



aptly marketed as “spikes” (figure 22). The individual crosses averaged approximately 45 ↔ 25 mm, and were available in white, pink to orangy pink, grayish pink to purple, and multicolored, as well as dyed “silver”-gray to black. Ms. King indicated that naturally colored cultured pearls are used to produce the dyed colors, since they accept the dye better than the white ones. Although large amounts of low- to medium-quality material are on the market, the higher-quality cultured pearls—with smooth surfaces, even luster, and perpendicular cross members—are available only in limited quantities.

Ms. King also had pink Chinese freshwater cultured pearls that were nucleated with square-to-rectangular shell preforms. They measured approximately 25–20 mm on a side, with rounded corners. Their surfaces varied from smooth to wavy or welted, with high luster and very high orient.

Distinctive shapes of freshwater “keshi” pearls were seen at Adachi America Corp., Los Angeles (figure 23). The pink to light purple “butterfly keshi” resembled two thick flakes or “wings” attached at the edges. A similar-appearing white product was named “snowflake keshi.” Other names include “keshi twins” and “flowering keshi.” Another freshwater keshi product, which Sayoko Adachi called “puka pearls,” took the form of wavy, wafer-thin disks, which were available in natural cream to brown, brownish green to greenish brown, and pink. In strands, they resembled a puka shell necklace. Both the butterfly and “puka” products, which measured about 11 mm in longest dimension, are non-nucleated by-products of the freshwater pearl culturing industry in Shanghai, China; they result from spontaneous growth after a harvest of tis-

sue-nucleated cultured pearls. An Adachi representative reported that due to the popularity of the “puka” material, pearl farmers are now attempting to nucleate this shape.

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New sapphire locality in Afghanistan. At the 2002 Tucson shows, Dudley Blauwet of Dudley Blauwet Gems, Louisville, Colorado, showed GNI editor Brendan Laurs two sapphires (0.40 and 0.72 ct; figure 24) that were reportedly mined from Medan Khar, in Vardak Province west of Kabul. Small-scale mining of the deposit started in late October 2001. During a trip to Pakistan in June 2002, Mr. Blauwet learned that at least 2 kg of rough had been produced. Approximately 1,000 carats have been cut so far, with the largest stones reaching approximately 2 ct. Almost all of the faceted stones were being sold into the local market in Peshawar.

Examination of the two sapphires by Elizabeth Quinn at the GIA Gem Trade Laboratory in Carlsbad yielded the following properties: Color—dark blue to very dark blue; pleochroism—blue and bluish green; R.I.— $n_o=1.772$, $n_e=1.764$; birefringence—0.008; S.G.—3.98, 4.03; inert to long- and short-wave UV radiation; and iron absorption bands at approximately 450, 460, and 470 nm seen with the desk-model spectroscope. These properties are consistent with those typically found in blue sapphires. Microscopic examination revealed lamellar twin planes, needles, clouds, feathers, “fingerprints,” and straight (planar) color zoning. No evidence of heat treatment was seen.

Elbaite-liddicoatite tourmaline from Vietnam. In the process of researching potential liddicoatite localities for the Spring 2002 *G&G* article on this tourmaline (see D. M. Dirlam et al., “Liddicoatite tourmaline from Anjanabonoina, Madagascar,” pp. 28–53), one of these contributors (BL) borrowed an attractive slice of Vietnamese tourmaline from the collection of William Larson of Fallbrook, California. The slice showed the red trigonal star that is so commonly seen in liddicoatite-elbaite from Madagascar (figure 25), and electron-microprobe analysis of the red area by one of these contributors (WS) confirmed the presence of liddicoatite (see table A-1 of the Dirlam et al. article). Since descriptions of gem-quality tourmaline from Vietnam are scarce in the literature, this GNI report will describe the sample in more detail.

As seen in figure 25, the slice was complexly zoned with an overall yellowish green rim and pink-to-red core, which is typical of “watermelon” tourmaline. Portions of the sample showed “aggregate”-type color zoning (see F. Benesch, *Der Turmalin*, Verlag Urachhaus, Stuttgart, Germany, 1990), but the most conspicuous feature was the red trigonal star mentioned above. Refractive indices of a representative portion of the red area were $n_o=1.647$

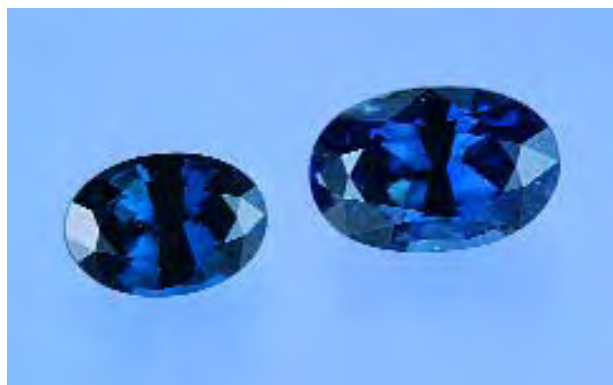


Figure 23. These freshwater “keshi” pearls have distinctive butterfly and puka shell shapes. The “butterfly” cultured pearls are approximately 11 mm in longest dimension. Courtesy of Adachi America Corp.; photo by Maha Tannous.

and $n_e=1.625$ (birefringence 0.022); by comparison, R.I. readings of the pink area yielded $n_o=1.641$ and $n_e=1.623$ (birefringence 0.018), and the yellowish green rim had $n_o=1.640$ and $n_e=1.620$ (birefringence 0.020). As mentioned in the Dirlam et al. article, the measurement of birefringence on tourmaline slices cut perpendicular to the c-axis may be related to biaxial domains within the crystal. When the slice was viewed parallel to the c-axis with a polariscope, anomalous double refraction was prevalent.

The pink-to-red tourmaline was inert to long- and short-wave UV radiation, whereas the yellowish green rim showed weak yellow-green fluorescence to short-wave UV. Microscopic examination revealed a network of

Figure 24. These two sapphires (0.40 and 0.72 ct) were reportedly mined from a new locality in Afghanistan, west of Kabul in Vardak Province. Courtesy of Dudley Blauwet Gems; photo by Maha Tannous.



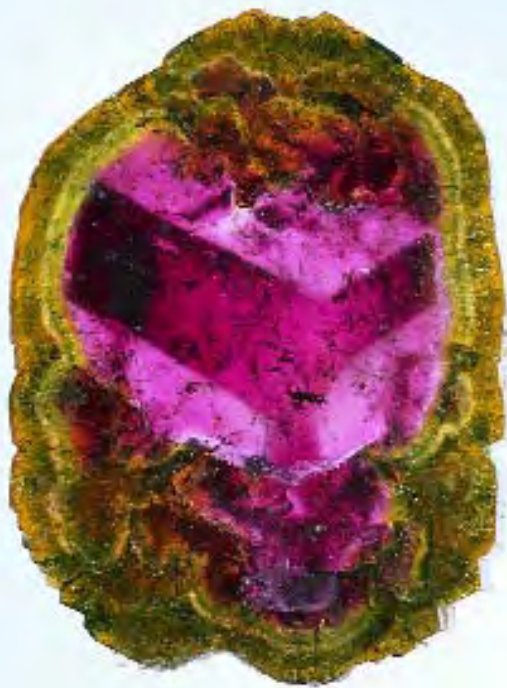


Figure 25. This tourmaline slice from Vietnam (5.5 ↔ 4.1 cm) resembles liddicoatite from Madagascar, but was found to consist mainly of Ca-rich elbaite. Courtesy of William Larson; photo by Maha Tannous.

abundant partially healed fractures, as well as growth structures (or “graining”) in directions parallel to the color zoning. Solid inclusions consisted of two white equant crystals that resembled albite, and a minute spherical brown particle.

The slice was analyzed by electron microprobe along two traverses: one starting in the core and following the dominant red zone to the yellowish green rim, and the other perpendicular to this (from rim to rim). Of 29 points that yielded quantitative data, one analysis—in the red zone, approximately halfway between the core and rim—corresponded to liddicoatite, with $Ca/(Ca+Na) = 0.51$. The other analyses revealed Ca-rich elbaite, with $Ca/(Ca+Na) = 0.34-0.48$. There were no systematic correlations between Ca content and color. However, the chromophoric elements Mn, Fe, and Ti did vary with color, as expected. Average values (in wt.%) were: Red = 0.12 FeO, 1.91 MnO, and 0.04 TiO₂; pink = 0.23 FeO, 0.91 MnO, 0.03 TiO₂; and yellowish green = 0.53 FeO, 0.44 MnO, 0.07 TiO₂. No other chromophoric elements (i.e., Cr, V, or Cu) were detected.

BL and

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Green zoisite reappears. Gem-quality green zoisite from the Merelani area in Tanzania reappeared at the 2002 Tucson gem shows this year after a 10-year hiatus (figure 26). This unusual color variety of zoisite was first discovered in Tanzania in 1991. Like some emeralds, it derives

its color from trace amounts of chromium and vanadium (see N. R. Barot and E. W. Boehm, “Gem-quality green zoisite,” Spring 1992 *Gems & Gemology*, pp. 4–15). As described by Barot and Boehm, “pure” green zoisite does not respond to heat treatment, whereas bluish green and yellowish or brownish green material typically will become a more saturated “steel” blue or greenish blue when subjected to temperatures above 600°C.

According to Tom Schneider (of Thomas M. Schneider, San Diego, California), several kilograms of green to bluish green rough became available just before the 2002 Tucson show. Most of the rough weighed approximately 1 gram and yielded cut stones of 2 ct or less. No new production has entered the market since then, although miners are again quite active in the Merelani region.

Aside from the original 1991 find and this most recent production from Merelani, this contributor knows of only one other discovery of green zoisite—in Pakistan in the early 1990s—which produced less than half a kilogram of rough and some attractive crystals (see Winter 1992 *Gem News*, pp. 275–276).

Also at this year’s Tucson shows, zoisite rough exhibiting combinations of colors that may be seen in this gem material—green, blue, purple, and even pink—appeared more prevalent than in previous years (see, e.g., Spring

Figure 26. This 12.33 ct bluish green zoisite from the recent production at Merelani, Tanzania, was fashioned from a 32 ct piece of rough by Meg Berry. The characteristic distinct pleochroism of zoisite is quite evident. Courtesy of JOEB Enterprises and Pala International (Fallbrook, California); photo by Maha Tannous.

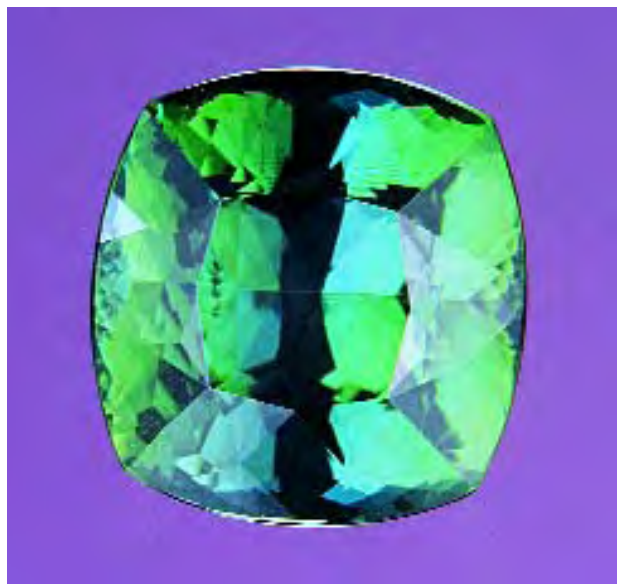




Figure 27. These three cabochons (up to 1.5 ct) were identified as massive fuchsite. This material has been sold as emerald in India. Courtesy of Shyamala Fernandes; photo by H. A. Hänni.

1993 Gem News, pp. 61 and 63). This material was sold as “Mardi Gras tanzanite” by some dealers.

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SYNTHETICS AND SIMULANTS

Massive fuchsite imitations of emerald. Recently Shyamala Fernandes of the Gem Testing Laboratory in Jaipur, India, asked this contributor for assistance with identifying three translucent green cabochons (figure 27) that are representative of material that is sometimes sold as emerald in that country. Certain aspects of their appearance were quite unlike emerald, however: A granular to flaky structure was visible with magnification, and the

Figure 28. Microscopic examination of the massive fuchsite revealed an aggregate of crystals in different orientations, resulting in various tones of green. Photomicrograph by H. A. Hänni; magnified 50 \times .

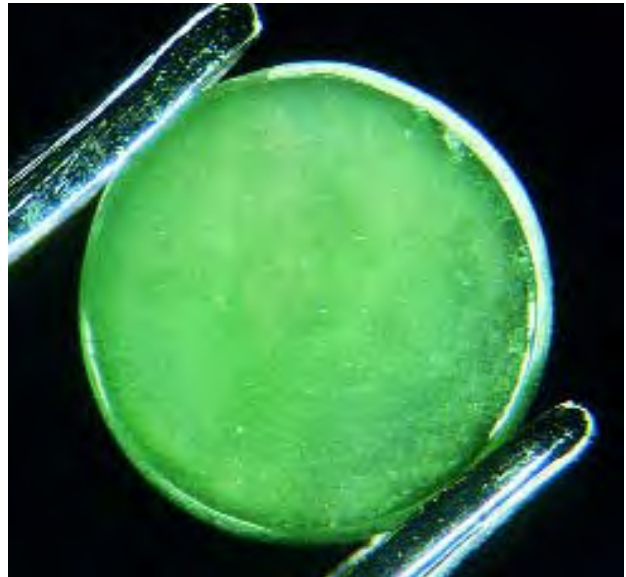


Figure 29. A green rim of higher saturation is visible through the polished base of this massive fuchsite cabochon (5.5 mm in diameter). The stone was probably treated with green oil. Photo by H. A. Hänni.

material appeared to be composed of more than one mineral that showed different tones of green (figure 28).

The specific gravity of the cabochons (measured together, due to their rather small size) was 2.89, and their refractive index was 1.58 (approximate value only, due to the shape of the cabochons and their polycrystalline structure). Since these results were not satisfactory for identification, the samples were studied by advanced techniques.

Raman analysis of five spots that showed various tones of green identified only muscovite. To investigate the cause of the green color, the samples were analyzed by EDXRF spectrometry, which revealed major amounts of Si, Al, and K, and minor amounts of Ca, Rb, Sr, Fe, and Cr. The presence of Cr was consistent with the green color of this mica, which we identified as the fuchsite variety. The texture of the mineral aggregate, with the strongly pleochroic crystals in various orientations, caused the appearance of different tones of green (again, see figure 28). The cabochons also contained rare orange and white grains, which were identified by Raman analysis as rutile and dolomite, respectively.

Examination of the flat polished base of one of the cabochons revealed a rim of higher green saturation (figure 29), which suggests that green Joban oil was present. FTIR spectroscopy confirmed the presence of an oil.

Fuchsite is typically found included in quartz (aventurine), but less commonly it forms in nearly monomineralic aggregates. A similar material—verdite—is a metamorphic rock that is composed of fuchsite and traces of rutile; it was originally found in South Africa (J. A. Jackson, Ed., *Glossary of Geology*, 4th ed., American Geological Institute, Alexandria, Virginia, 1997, p. 699). Similar fuch-

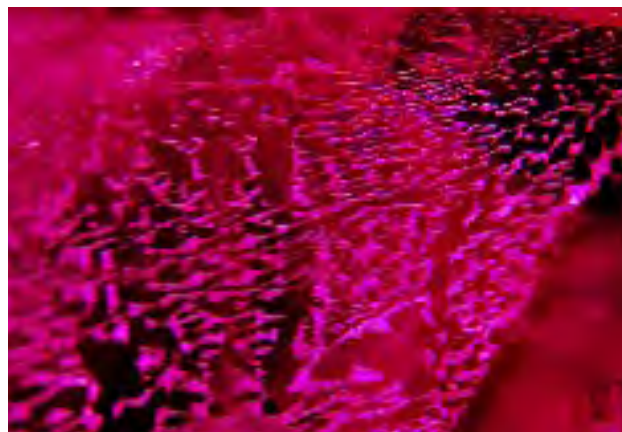


Figure 30. These two flux-grown synthetic rubies (7.61 and 4.49 ct) had an unusual combination of properties, including trace-element contents that have not been recorded previously. Photo by H. Hänni.

site-rich ornamental rocks have since been found in several world localities (see R. Webster, *Gems*, 5th ed., rev. by P. G. Read, Butterworth-Heinemann, Oxford, England, 1994, p. 383). The origin of the material used to fashion these particular cabochons is unknown. HAH

Unusual synthetic rubies. Recently, the SSEF and Gübelin laboratories examined three unusual synthetic rubies weighing 3.21, 4.49, and 7.61 ct (see, e.g., figure 30). With magnification, all showed flux remnants along healed fissures (figure 31) as well as linear trails of pinpoint inclusions (figure 32). An analysis of the internal growth structures revealed dominant bipyramidal and rhombohedral

Figure 31. This partially healed fracture contains a network of flux inclusions that is typical of those seen in most flux-grown synthetic rubies. Fracturing of the flux remnants gives them an appearance similar to crazing. Photomicrograph by Christopher P. Smith; magnified 30 \times .



growth planes $n-r-n$. In addition, one of the stones also had incomplete twin planes along the positive rhombohedron r {1011}. Semi-quantitative chemical analysis by EDXRF revealed 0.54–0.92 wt.% Cr_2O_3 , 0.06–0.11 wt.% Fe_2O_3 , and 0.01–0.03 wt.% Ga_2O_3 . Titanium and vanadium were at or below detection limits. In addition to these elements, traces of zirconium (0.02–0.03 wt.% ZrO_2) also were measured, which did not relate to inclusions visible with a standard gemological microscope. No other heavy elements were detected.

The presence of the flux remnants, together with the internal growth structures and trace-element concentrations, confirmed that these three stones were flux-grown synthetic rubies. However, the combination of these characteristics is not wholly consistent with the features seen in the more familiar flux-grown synthetic rubies. Similar forms of pinpoint stringers, commonly referred to as “rain,” are generally associated with the Kashan product, and may be encountered in some flux-grown synthetic rubies from other producers such as Douros. The dominant $n-r-n$ growth structures are typical of flux-grown synthetic rubies from a variety of producers, such as Ramaura, Douros, and Kashan. Nevertheless, zirconium has not been recorded in any commercial flux-grown synthetic rubies (i.e., by Chatham, Douros, Kashan, Knischka, or Ramaura, or in the experimental flux-grown synthetic rubies by Gilson). Zirconium has been recorded on occasion in natural rubies, but it always coincided with zircon crystals located at or just below the surface of the area being analyzed. In addition, the presence of iron and gallium, combined with the lack of titanium and vanadium, is uncommon in various flux-grown synthetic rubies. Heavy elements such as lead or tungsten, which would be expected in the synthetic rubies

Figure 32. Very fine, parallel to subparallel stringers of pinpoints also were visible in the unusual flux-grown synthetic rubies. Photomicrograph by Christopher P. Smith; magnified 18 \times .





Figure 33. This 45.45 ct rutile with man-made asterism shows an 11-rayed asymmetric star with incomplete arms. Some of the arms also are split at the outer region of the cabochon. The star is sharp, but the stone appears fuzzy because the camera is focused below the cabochon's curved upper surface. Photo by M. Glas.



Figure 34. This yellowish brown, slightly translucent tourmaline (13.14 ct) with man-made asterism displays a 12-rayed, asymmetric star with additional "satellite" lines in the center of the sample. As in figure 33, the stone appears fuzzy (and the star sharp) because the camera is focused below the upper surface of the cabochon. Photo by M. Glas.

from Chatham, Douros, or Ramaura, were not detected.

Only once before, in October 2001, has the Gübelin Gem Lab encountered a synthetic flux-grown ruby that contained Zr. The other properties and characteristics of that stone were also similar to the three samples described here. Since it is difficult to explain how Zr would be incorporated into the corundum structure, we presume that it was related to the presence of submicroscopic particles in those four synthetic ruby samples.

It is unclear at this time whether these synthetic rubies represent a new product. Regardless, the identification of these unusual synthetics is easily accomplished through careful observation of the flux inclusions with a loupe or microscope. Chemical analysis will also reveal traces of zirconium, as well as distinctive trace-element patterns.

CPS

Lore Kiefert, SSEF

Dietmar Schwarz, Gübelin Gem Lab

TREATMENTS

Another identification criterion for imitation asterism produced by surface scratching. Oriented, man-made scratches on the upper surface of cabochons have recently been described as the cause of fake asterism in several gem varieties (see articles by S. F. McClure and J. I. Koivula, Summer 2001 *Gems & Gemology*, pp. 124–128; and K. Schmetzer and M. P. Steinbach, *Journal of Gemmology*, Vol. 28, No. 1, 2002, pp. 41–42). This man-made asterism can be easily recognized by several factors: the absence of oriented, needle-like inclusions; the presence of oriented

scratches on the surface; incomplete arms on the stars; irregular splitting or misoriented "satellite" arms; somewhat curved or asymmetric rays; and/or extra rays or a number that is inconsistent with the symmetry of the mineral. These observations suggest the cabochons are scratched using a non-automatic (manual) production process without complex equipment. Most probably, the technique is similar to that described in 1950 by R. S. Mukai in U.S. Patent 2,511,510 (see K. Schmetzer, "Production of fake asterism," *Journal of Gemmology*, Vol. 28, No. 2, 2002, pp. 109–110).

While photographing some of these cabochons, we noticed another factor that also might be helpful for identifying the man-made asterism: The stars appeared sharpest when the camera was focused *below* the curved upper surface of the cabochons (figures 33 and 34). We noted this characteristic in all seven of the cabochons that were available to us (i.e., three rutiles, two pyrope-almandine garnets, and two tourmalines). In contrast, cabochons with natural asterism—such as ruby, sapphire, garnet, quartz, or spinel that contain oriented needle- or rod-like inclusions—have stars that appear sharpest when the camera is focused *above* the curved upper surface. These differences in asterism also can be readily seen with the gemological microscope. This technique is particularly helpful in examining very dark or opaque samples in which the asterism-causing inclusions may be difficult to see, as well as for gems (such as quartz) that commonly contain needles too small to observe with the gemological microscope.

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Figure 35. This 9.84 ct irradiated fluorite appears deep blue in daylight-equivalent fluorescent light (as shown here) and purple in incandescent light. Photo by Maha Tannous.

Irradiated color-change fluorite. At the Tucson 2002 AGTA show, this contributor noticed a small group of attractive irradiated blue fluorites at the booth of MCM Gems, Middletown, Ohio. The rough was reportedly obtained from the Tres Barras mine in Minas Gerais, Brazil, and was light yellow before gamma irradiation. This material was observed to show a color-change: deep blue in daylight-equivalent fluorescent light and purple in incandescent light.

Standard gemological testing of a 9.84 ct oval modified brilliant (figure 35) yielded the following properties, which are consistent with fluorite: R.I.—1.431, S.G.—3.19, inert to long- and short-wave UV radiation, moderate anomalous double refraction, 570 nm band observed with a desk-model spectroscope, and a red appearance with a Chelsea filter. Microscopic examination revealed numerous two-phase inclusions, a few cleavage fractures, and patchy blue color concentrations. No fade testing was conducted. However, the color appeared stable in several pieces that were on display for the duration of the show.

The irradiation of fluorite has been performed for many years, but it is interesting to find irradiated fluorite with an attractive blue color and a color change.

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ANNOUNCEMENTS

Now available: *extraLapis English*. Selected issues of the popular German periodical *extraLapis* are being translated

into English and published by Lapis International LLC, East Hampton, Connecticut. Issue 1, "Madagascar," was published in 2001, and Issue 2, "Emeralds of the World," has just been released. Call 860-257-1512, fax 860-267-7225, or visit www.lapisint.com.

Conferences

Natural Glasses. Scheduled to be held in Lyon, France, on August 29–31, this fourth international congress will include presentations on materials such as obsidian, fulgurite, Libyan desert glass, meteorite glasses, and others. Call 33-04-7243-1037, fax 33-04-7243-1261, or e-mail natglasses.info@adm.univ-lyon1.fr, or visit <http://natglasses.univ-lyon1.fr>.

Diamond 2002. The 13th European Conference on Diamond, Diamond-like Materials, Carbon Nanotubes, Nitrides & Silicon Carbide will take place September 8–13 at the Granada Conference and Exhibition Centre, Granada, Spain. Sessions will cover diamond growth, optical properties, and mechanical applications and properties of diamond and other superhard materials. Visit <http://www.diamond-conference.com>, or contact Gill Heaton at diamond@heaton-connexion.co.uk, 44-0-1865-373625 (phone), 44-0-1865-375855 (fax).

Hong Kong Jewellery and Watch Fair. To be held September 25–29 at the Hong Kong Convention and Exhibition Centre in Wanchai, this show will feature educational seminars from leading gemological laboratories, as well as auctions of fine South Sea and Tahitian cultured pearls September 22–27. For more information, visit <http://www.jewellery-net-asia.com>.

Exhibits

Pearls exhibit at the Field Museum. The comprehensive *Pearls* exhibition that debuted at the American Museum of Natural History in New York (see Winter 2001 GNI section, pp. 341–342) is now at Chicago's Field Museum until January 5, 2003. A weekly lecture series will complement the exhibit. Visit <http://www.fnmh.org/pearls>.

Diamond exhibition in Antwerp. The Antwerp Diamond Council (HRD) will present the exhibition "Living Diamonds—Fauna and Flora in Diamond Jewellery Until 1960" October 10–November 10 at the new Diamond Museum of Antwerp. The exhibition will illustrate animal and plant motifs in diamond jewelry from leading auction houses, jewelers, museums, and private collectors. Visit www.diamonds.be/hotnews, e-mail info@diamant.provant.be, or call 32-03-202-4890.

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EDITORS

Susan B. Johnson
Jana E. Miyahira-Smith

Diamond Ring Buying Guide, 6th Ed.

By Renée Newman, 160 pp., illus., publ. by International Jewelry Publications, Los Angeles, CA, 2002. US\$17.95*

This is another fine update in a series of books that are useful to both the jewelry industry and consumers. This sixth edition is current on recent changes in the diamond industry, particularly in its discussion of diamond treatments. It provides explanations of HPHT, fracture filling, laser drilling, coatings, and irradiation, with information on how to detect them.

Chapter 6, "Judging Cut Quality," deals with the thorniest issue in the diamond world in a nontechnical fashion. With generous photo examples, one can easily view the differences between a good cut and an inexact cut. A comparison of the AGS, GIA, and HRD proportion-grading standards illustrates the dilemma created by the lack of a unified standard. However, the chapter ends with a very practical section on "Judging Cut with the Eye Instead of with Numbers."

Newman makes the gemological data easy to understand for novice and veteran alike. The terminology is not confusing, but rather clear and concise, with a writing style that is spare and factual. This book could be used as a training manual for your sales staff, or as a gift for those favored and inquisitive customers.

For the consumer, everything is there, so that the book serves as a checklist for the purchase, mounting, and care of a diamond. The photos are excellent, and there are plenty of

uncomplicated illustrations to drive home the verbal points. *The Diamond Ring Buying Guide* is an entire course on judging diamonds in 156 pages of well-organized information.

GAIL BRETT LEVINE
Publisher, Auction Market Resource
Rego Park, New York

Tiaras: Past and Present

By Geoffrey Munn, 128 pp., illus., publ. by V&A Publications, London, 2002. US\$22.50*

Today when you think jewelry, you rarely think "tiara." But as Geoffrey Munn points out in this excellent book, for much of history tiaras have been essential parts of jewelry ensembles for women of wealth. Since the development of the art of goldsmithing in ancient times, writes Munn, tiaras have been associated with "privilege and ostentation."

In this exceptionally well-illustrated work, Munn follows the history of tiaras, starting with early Greek and Roman use of flower and leaf head wreaths, through the incorporation of tiaras into the traditional costume of Russian women and their use as the traditional adornment of brides. Tiaras were embraced by European nobility in the 18th and 19th centuries, and were the mark of married women at society functions. Although the use of tiaras fell by the wayside in the more casual and democratic 20th century, modern designers are reintroducing the tiara with a contemporary flair and unusual materials.

Keith Davey's superb photos clearly show the workmanship, design, and

gemstones of these remarkable pieces. The tiara photos are complemented by remarkable portraits, ancient and modern, of the owners wearing their pieces, as well as by original renderings of tiaras produced by well-known jewelry houses such as Boucheron, E. Wolff & Company, and Fabergé.

One has to go to great lengths to find anything even mildly critical to say about *Tiaras: Past and Present*. The only passage I found slow in this immensely readable and fascinating book was the complex and somewhat confusing (to an American) enumeration of which tiaras were owned by which members of the British and European royalty in the 20th century (in the chapter "At Court"). However, such a listing is invaluable to jewelry historians researching specific pieces. And the stories about these individual women, often found in the picture captions, are delightful.

As Munn shows, tiaras are a window into cultural history, and they act as a lens through which we see the development of jewelry art itself. *Tiaras: Past and Present* is a worthwhile addition to the libraries of art and jewelry historians for its personal sketches and documentation of many pieces. It is also sure to fascinate jewelers and gemologists with breathtaking designs and gemstones. Taken all

**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.*

together, the book creates in the reader a true appreciation of what Munn calls the "noblest and most flattering of jewels."

SHARON ELAINE THOMPSON
Salem, Oregon

Diamond Stories: Enduring Change on 47th Street

By Renee Rose Shield, 234 pp., illus., publ. by Cornell University Press, Ithaca, NY, 2002. US\$29.95

The author, an accomplished cultural anthropologist, is a niece and cousin of several New York diamantaires. In researching this book, she spent more than 14 years talking with diamond people in their offices and in the New York Diamond Dealers Club. The result is an intimate and very personal look at the closed world of the Jewish diamond brokers, from the philosophical humor that peppers much of their conversation to the ways in which the strict religious practices of the ultra-orthodox and Hasidim are integrated into their business dealings.

The book is divided into seven chapters. The first four describe in detail the business world of the brokers, who generally act as go-betweens for large manufacturers and dealers. There is a highly competitive arena—many subsist on small commissions for each transaction—filled with rituals, customs, and rules.

In this first part, the author attempts to establish the perspective of New York Jewish life and the city's thriving diamond community within the diamond industry as a whole. The author offers a brief history of the diamond industry, a now somewhat out-of-date discussion of De Beers's role, and a look at key issues that affect the diamond market, including a brief review of the conflict diamond issues, balanced with a discussion of the prosperity that diamonds bring to some countries.

The author then discusses the atmosphere in the DDC and the dealers' offices, often through her personal experiences with family members in the business. She uses a number of

anecdotes and vignettes to demonstrate how traders look at diamonds and deal with one another as well as with a female "stranger" in their midst. She uses fictitious names to preserve her subjects' privacy.

The middle of the book offers a detailed look at diamond trading rules and customs, from the haggling over price to the sealing of the diamond in a cachet (small envelope) until the buyer says "Mahzal" and offers his handshake. Within this simple procedure are time-honored rules. One cannot, for example, show the diamond to another buyer after it has been "cached." One broker was roundly criticized for his practice of making high counteroffers to one dealer, then turning around and selling to someone else for a much lower premium before the first buyer actually refused the deal.

The author discusses in detail how GIA diamond grading reports and the *Rapaport Report* price lists have revolutionized the industry. As might be expected, the "old guard" brokers complained that price lists and "certs" have removed the human factor from the diamond business, but the author makes the counter-argument that they have helped level the playing field and broaden consumer confidence, such that sales are probably higher as a result.

The final part of the book discusses the changes taking place in the New York industry: Women are making slow inroads into the diamond trade, and the network of orthodox and Hasidic brokers is declining as a majority of the business now goes to big players who rarely use the DDC or brokers. Change comes slowly inside the club, partly because so many elderly members do not want to retire. One dealer in his nineties, who still visited the club every day, told the author that he did not want "to become bored or lazy" and still loved his work after all the years.

The author does tend to bound abruptly from subject to subject, making the book difficult to follow at times. Moreover, it is in a netherworld between an academic anthropological

study and a book written for a popular audience. The author does expressly state the boundaries of her study (the ultraorthodox Jews and Hasidim for whom the DDC is a center of their business life), but it seems that a book on New York's diamond community that is intended for a general audience should at least acknowledge the large number of Indian dealers and the growing number of Asians who have become integral to the industry.

Nevertheless, *Diamond Stories* is the best view of the cloistered world of New York's Jewish diamond community that anyone has ever set down in print. The author captures the trading environment, the negotiation rituals, and the sardonic wit and "folklore" with a sympathetic insider's view and without the stereotypes and clichés to which others have fallen prey. Throughout the book, she relates how diamond dealers admonished her to "get the tone right." That she has done very well.

RUSSELL SHOR
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Perlen

By Elisabeth Strack, 696 pp., illus., publ. by Rühle-Diebener-Verlag, Stuttgart, Germany, 2000 (in German). €66.00

Originally published in 1982, with this revised and updated edition *Perlen* has grown into one of the most comprehensive textbooks on pearls. The first half of the book is devoted to an in-depth discussion of the occurrences, formation, distribution, and evaluation of natural pearls. The opening chapters cover the history of the pearl and the important role it has played throughout the centuries. The next chapters provide an extensive review of the taxonomy and biology of all pearl-forming mollusks and their occurrences (organized by region). These are followed by a description of the physical and optical properties of pearls and their evaluation on today's market. A complete account of the most famous pearls concludes the first part of the book.

The second part starts with a detailed history of the culturing process. Over the course of the next 12 chapters, the author elaborates with the same thoroughness on cultured pearls, assembled cultured pearls, and imitation pearls. Again, occurrences, formation, evaluation, and distribution are discussed by region. A brief chapter focuses on the physical and optical properties of cultured pearls, followed by a description of the countless imitation pearls. The remaining chapters deal with the various techniques developed to identify the different types of pearls encountered on today's market. A chapter on the care of pearls concludes the book.

The comprehensive bibliography at the end of each chapter further underscores the value of this publication. This new edition represents a major contribution to the literature on pearls and is essential in any gemological library. Although written in German, an English language version will be available in the near future.

KARIN N. HURWIT

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Diamonds: In the Heart of the Earth, in the Heart of Stars, at the Heart of Power

By Hubert Bari and Violaine Sautter, Eds., 351 pp., illus., publ. by Vilo International, Éditions Adam Biro, Paris, 2001. US\$60.00

To understand diamonds is to understand the structure and history of the Earth itself. That premise is the cornerstone for this book.

The 2001 exhibit for which this served as a catalogue debuted at the French National History Museum in Paris, itself a monument to mineralogy. The book's 15 contributors reflect the museum's scholarly tradition across a range of disciplines that includes archivists, curators, gemologists, geologists, historians, academics, and researchers from astrophysics to industrial diamond science.

The book succeeds in capturing the enormous, perhaps unequalled,

scope of the exhibit. Whether culled from ancient civilizations, modern-day sirens, or meteoric dust, the beautifully portrayed diamonds in this book mark and illuminate the global history of rulers, adventurers, art, science, religion, human passions—and of the Earth itself.

Chapters are organized to reflect the many lives of diamonds, from jewels to tools and from the reaches of intergalactic space to the depths of diamond mines and the Earth's core. A few technical chapters deliver concise synopses of topics such as diamond grading, synthetics, and the evolution of diamond cuts. Other chapters explore diamond's sacred nature in the world's religions, magnificently illustrated by a treasure trove of rare manuscripts, religious texts, and lapidaries. Diamond's regal stature at the heart of power is examined in chapters that chronicle the gem's unique role in civilizations around the world and across centuries, best illustrated in the accounts of the diamonds of maharajahs, mughals, and monarchs.

Crisp, high-quality photographs deliver a visual feast of famed as well as rarely seen gems, along with precious artifacts such as a handwritten copy of the *Diamond Sutra*, one of the most important texts in Buddhism. De Beers's contributions include important photodocumentation of the history of modern mining as well as the company's collection of unusual crystals. Artful photographic images of some of the world's most revered diamonds are accompanied by enlightening text and a refreshingly unencumbered layout. Color is used tastefully and with striking fidelity to the gems still sparkling in this reviewer's memory. Where appropriate, superb diagrams, tables, and renderings provide further explication and add visual interest for the reader.

In addition to featuring an unprecedented collection of many of the most important diamonds in history, *Diamonds* provides a rare glimpse of some of the most dazzling jewelry ever created. Beyond the gathering of such major jewels as the Incomparable, the Star of South Africa, the Nassak, both

Sancys, and the uncut Dutoitspan, readers are treated to seldom-seen pieces from the houses of Mouawad, Tiffany, and Cartier. A sampling of these other notables includes the 69.68 ct Excelsior I, set in a fabulous bracelet, and the 287.42 ct Tiffany diamond crowned by a Schlumberger setting. Contemporary masterpieces, if somewhat whimsical, include Cartier alligator brooches and a pair of Cartier diamond-and-rock-crystal bracelets worn by Gloria Swanson.

Michael Hing's translation is competent, if occasionally quaint. The very minor stylistic deficiencies seen with multi-authored books—the staccato-like flow of an occasional chapter, an author's excessive fondness for exclamation—are quibbles beneath the book's ambitious scope and triumphs. Although limited to 50 terms, the glossary still manages to capture the essence of diamond. Lacking an index (the book's single noteworthy flaw), the reader has no choice but to rediscover the exhibit's magic by flipping one breathtaking page after another.

For any jeweler, historian, gemologist, or diamond devotee, this affordably priced catalogue will provide a lasting treasure from which to learn and savor the wonder and magnificence that is diamond.

MATILDE PARENTE, G.G.

Rancho Mirage, California

The Jewels of Jean Schlumberger

*By Chantal Bizot, Marie-Noël De Gary, and Évelyne Possémé, translated by Alexandra Bonfante-Warren, 157 pp., illus., publ. by Harry N. Abrams, New York, 2001. US\$39.95**

Originally published in French, this book served as the catalogue for the 1995–1996 exhibit "A Diamond in the City, Jean Schlumberger 1907–1987, Jewelry and Objects," which was held at the Musée des Arts Décoratifs in Paris. The book also serves as a visual testament to the creative genius of one of the 20th century's greatest jewelry designers.

Schlumberger's designs were often inspired by flora and fauna, which is evident in the many photographs and original design sketches printed throughout the book. The first nine chapters divide Schlumberger's work into loose categories such as "Sea," which features fanciful sea creatures; "Flowers and Fruit," which highlights jewelry and other objects inspired by plant life; and "Wings," which features brooches of feathers and wings. Light on text, these chapters are a delight to flip through. Each page leaves the reader wondering what wonderful jewel or object of great beauty lies on the next. Most of the items featured were created during Schlumberger's long and illustrious tenure with Tiffany & Co.

Following these chapters are three sections, each written by one of the three authors, in which the author gives her own interpretation of Schlumberger's designs and some insight into his inspirations and influences. The book finishes with a chronology of Schlumberger's life, a catalogue of the exhibit, and a bibliography. Beautiful and satisfying, this book is a "must have" for anyone who appreciates creative and fanciful design.

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OTHER BOOKS RECEIVED

Glossary of Obsolete Mineral Names.
By Peter Bayliss, 235 pp., publ. by The Mineralogical Record Inc., Tucson, AZ, 2000. US\$32.00. Three years ago, Dr. Anthony Kampf published a glowing review of J. de Fourestier's *Glossary of Mineral Synonyms (Gems & Gemology*, Summer 1999, pp. 158–159), referring to it as "an essential reference." He pointed out that this compilation of about 35,000

entries of mineral and gem synonyms, variety names, names for synthetics, and trade terms that have been used throughout history was a marvelous resource for collectors, curators, researchers, and others in the gem trade. Now available is another extremely valuable book, which covers the same ground with approximately 32,000 entries.

Professor Bayliss's book (like de Fourestier's) is based on strict adherence to the rules of modern mineralogical nomenclature, which allow only one name to be applied to a mineral species; variations based on color, or physical or chemical properties, are relegated to "obsolete" status. Therefore, the "obsolete" terms *ruby*, *sapphire*, *amethyst*, *rubellite*, *hyacinth*, and a great number of other common and rare gemological terms, which have been placed in the mineralogical rubbish bin, are included here. This volume, in contrast to that of de Fourestier, gives a reference for every entry, which is of great value for those desiring to research a term further.

A very detailed comparison of both books by Dr. J. A. Mandarino (*Canadian Mineralogist*, Vol. 38, 2000, pp. 768–771) showed that there are differences in the categorization of some obsolete terms by the two authors, and, not unexpectedly given the magnitude of these compilations, certain rare terms are found in one but not in the other. In agreement with Dr. Mandarino, I recommend both glossaries to gemologists. Fortunately, both are very reasonably priced. Considering the staggering effort that goes into such compilations, it is extremely unlikely that another competitor will surface within the next few decades and render the present glossaries obsolete.

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MEDIA REVIEW

Modern Gemmology, SSEF Tutorials 1 & 2

By SSEF Swiss Gemmological Institute, www.ssef.ch, Basel, Switzerland, 2001. Available in PC or Mac format. US \$150 each/\$250 for both.

These two CD-ROM tutorials contain a wide and interesting variety of topics from diamond grading to synthetic gems. The first CD contains four separate presentations: (1) natural, synthetic, and imitation diamonds and diamond treatments; (2) the identification of emerald treatments; (3) pearls; and (4) ruby. The second CD continues with presentations on four different topics: (1) synthetic gem materials, (2) diamond grading at the SSEF Swiss Gemmological Institute, (3) gem treatments, and (4) determination of locality of origin for corundum.

The information on the CDs is presented in slideshow form, with still images and accompanying text. Especially interesting for this reviewer was the ruby discussion on the first CD, which goes into considerable depth on the process of "healing" fissures and fractures with heat treatment. Macro- and microphotographs supplement the information in both tutorials.

Individuals using the GIA Diamond Grading system should keep in mind that the diamond grading system discussed on the second CD is that of CIBJO, so there are noticeable differences in terminology and technique. A few grammatical errors are present in both CDs, but they are not distracting and they do not interfere with the delivery of information. Both of these tutorials contain information that is timely and useful for the gemologist.

JANA E. MIYAHIRA-SMITH
Gemological Institute of America
Carlsbad, California

2002

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COLORED STONES AND ORGANIC MATERIALS

Akoya pearl culture in China. W. O'Connor and A. Wang, *World Aquaculture*, Vol. 32, No. 3, September 2001, pp. 18–20.

Harvesting of saltwater pearls in China extends back to 200 BC, but only in the last 30–40 years have cultured saltwater pearls been farmed there. Production is mostly from the Akoya pearl oyster *Pinctada imbricata* and is limited to the southern provinces of Guangxi, Guangdong, and Hainan, which have suitable water temperature. The first private saltwater cultured pearl farms were established in 1986. Production grew rapidly, and by 1995 it reached ~15 tons/year. Production subsequently reached ~20 tons/year, but recently it has decreased in both quality and quantity due to several factors (e.g., environmental degradation).

This article provides details of the Chinese Akoya pearl culturing and farming processes, which have many similarities to those used in the production of freshwater cultured pearls. Unfortunately, the industry now faces a number of serious infrastructure and environmental challenges. The existing farms are aging, and there is little capital available for improvements in facilities or techniques. Efforts to increase production have caused overcrowding and a further reduction in the quality of the cultured pearls. JEC

Conjuring blue magic. T. Redgrave, *Readers Digest (New Zealand)*, Vol. 158, No. 950, June 2001, pp. 40–48.

Cultured mabe pearls from the abalone species *Haliotis iris* (*paua* in the Maori language), which are unique to New Zealand, were introduced to the world markets a decade ago. Highly acclaimed for their iridescent colors, they commonly show vivid blues, greens, and purples. They are produced in five farms (one land-based), located about 60 km east of Christchurch. Details of the operations at one farm are presented, including the gathering of

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

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

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

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paua, nucleation with a piece of plastic, harvesting after two years, grading the mabe, and finally fashioning them into jewelry.

Currently, 44,000 New Zealand cultured mabe pearls (6–20 mm) are harvested annually; production is expected to reach 100,000 a year by 2005. The great challenge is to produce cultured whole (spherical) pearls from *paua*, something that has been attempted for decades without success.

Michelle Walden

Culturing blister pearls in abalones. P. V. Fankboner, *Canadian Gemmologist*, 2002, Vol. 23, No. 1, pp. 10–21.

The author discusses the process involved in producing gem-quality blister pearls in abalones. Abalones should be kept near their normal environmental temperature range when removed from seawater for drilling and implantation. A semi-spherical nucleus (composed of any of a number of materials, such as plastic or mother-of-pearl) is tightly secured to the portion of the shell's inner surface that features the highest quality of shell nacre. This site is usually the most inaccessible, but it can be reached with the use of a diamond-core drill. Great care must be taken, however, since the curved surface of the shell could cause the drill to grab and bounce off.

Conchiolin is secreted around the base of the nucleus within several weeks of implantation. Nacre forms at the outer borders of the conchiolin foundation and then grows inward toward the nucleus. Last to be covered with new nacre is the top of the nucleus. Since the nucleus is repeatedly covered by new layers of conchiolin and nacre, the challenge is for the grower to remove the pearl at a point just prior to the formation of a new layer of conchiolin. A 0.37 mm minimum thickness of new nacre is necessary to achieve a pearly quality. Finishing of the blister pearl requires cutting it away from the abalone's shell and backing it with mother-of-pearl.

MT

Digging deep. S. Pecover, *Australian Jeweller*, October 2001, pp. 30–31.

Geologist and gemologist Simon Pecover has formulated a geologic model to explain the formation of common opal in sedimentary rocks of the Great Australian Basin. It is hoped that this model will help uncover more opal deposits by providing an understanding of the relationship between fault structures and opal veins.

A dynamic process is envisioned, one that involves rapid precipitation of opal in fault-generated hydraulic extension fractures (i.e., spaces in the rock forced apart by water under pressure) by warm-to-hot waters that are supersaturated with silica. Tectonic processes are thought to be responsible for the formation of faults and associated breccia pipes. These form pathways for the silica-laden fluids, which move upward through the rock mass under hydraulic pressure. Opal deposition and vein formation occur at sites of lower pressure in fissures opened up by the faulting. Hence, the

model is based on a direct genetic relationship between faults and vein opal deposits in the near-surface sedimentary rocks of the Great Australian Basin.

MT

Edelsteine der Feldspatgruppe [Gemstones of the feldspar group]. U. Henn, *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 50, No. 4, 2001, pp. 179–192 [in German with English abstract].

This article provides a comprehensive and clearly structured description of the feldspar family. The basic mineralogical and gemological properties of each gem variety are described, and the varieties are assigned to the appropriate feldspar species. In addition, information is given on the geographic sources of gem-quality feldspar, the color treatment of labradorite, imitations, and methods for the identification of feldspar minerals. Although this article does not contain much new information, it does give a well-organized overview of this rather complicated mineral family and is a valuable reference.

RT

Edelsteine aus Sambia—Teil 3: Amethyst [Gemstones from Zambia—Part 3: Amethyst]. C. C. Milisenda, V. Malango, and K. C. Taupitz, *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 50, No. 3, 2001, pp. 137–152.

Zambia is an important source of high-quality amethyst. Commercial exploitation started in 1959 in the Kalomo-Mapatizya field. Since then, hundreds of occurrences have been found in an area of approximately 750 km². However, only an area of about 15 ↔ 2–3 km, which contains the richest deposits, is being worked intensively. The deposits formed about 200 million years ago, after the extrusion of the Batoka Plateau Basalt, and can be divided into two basic types. Type 1 deposits form long quartz veins (up to 2,000 m), but are only 10–60 cm wide. They contain most of the high-grade amethyst. Type 2 deposits are called "stockworks" (large rock masses that contain many small irregular veins and lenses of quartz and amethyst); these generally produce lower-quality amethyst.

On average, only 5 kg of "high-grade" amethyst (facetable and good cabochon quality) and 35 kg of "low-grade" amethyst (suitable for beads) are recovered from each ton of ore. Production is from many small-scale open-pit mines. The potential of the amethyst deposits appears to be substantial, but underground mining is recommended to ensure more profitable operations. Gemological aspects of this material are presented, and it is noted that heat treatment of Zambian amethyst does not produce citrine but only greenish colors of little economic value.

RT

Gemmology of abalone shell and analysis on the origin of its iridescence. L. Li and J. Zhang, *Journal of Gems and Gemmology*, Vol. 3, No. 2, 2001, pp. 1–5 [in Chinese with English abstract].

The gemological properties and cause of iridescence in abalone shells (*Haliotis iris*) from New Zealand were inves-

tigated mainly by polarization microscopy and scanning electron microscopy. The gemological properties were compared to those obtained from nacre layers of both saltwater and freshwater cultured pearls from China.

The density of the abalone shell (2.61) was lower than that of most of the mollusks used to produce saltwater and freshwater cultured pearls (general range: 2.68–2.74). The chemical composition and crystal structure of the abalone shells were very close to those of the nacre layers of the Chinese saltwater cultured pearls. However, the abalone shells contained more K, Na, Mg, and Sr and less Mn than was found in the Chinese freshwater cultured pearls. In the abalone shells, aragonite occurs as minute (0.15–30 µm) spheres associated with interstitial voids. The arrangement and size of these tiny spheres are similar to those of the silica spheres found in opal. Therefore, the authors conclude that iridescence in the abalone shell from New Zealand most probably results from the diffraction of light from layers of minute aragonite spheres, analogous to the cause of iridescence in opal. TL

Investigation of manganese in salt- and freshwater pearls.

D. Habermann, A. Banerjee, J. Meijer, and A. Stephan, *Nuclear Instruments and Methods in Physics Research B*, Vol. 181, 2001, pp. 739–743.

Several advanced analytical techniques were used to study Chinese freshwater tissue-nucleated cultured pearls, natural freshwater pearls from the Mississippi River, and natural saltwater pearls from the Persian Gulf and the South Pacific. Thin sections of these samples were analyzed by micro-PIXE, as well as by cathodoluminescence microscopy and spectroscopy; sawn half-samples were used for electron spin resonance measurements.

The various pearls could be distinguished by their manganese contents, cathodoluminescence features, and the relative abundance of aragonite and calcite. The Chinese freshwater tissue-nucleated cultured pearls contained domains (regions in the crystal structure) of calcite that emit orange Mn²⁺ cathodoluminescence; these characteristics are almost absent from Mississippi River natural freshwater pearls. The freshwater samples contained relatively high concentrations of Mn (up to 1,100 ppm) compared to the saltwater pearls (<1 ppm). MT

Smaragde der Welt (Emeralds of the World). *extraLapis*, No. 21, 2001, 96 pp.

This issue in the *extraLapis* series is devoted to emeralds (an earlier issue of *extraLapis*, No. 1 of 1991, also featured this mineral). The volume starts with the story of "The Ring of Polykrates," first told by early Greek historian Herodotus. Then, C. Behmenburg discusses the origin of the words emerald and beryl, and their history and uses.

R. Hochleitner reviews the mineralogy of beryl and its varieties, including trapiche and cat's-eye emeralds. D. Schwarz, G. Giuliani, G. Grundmann, and M. Glas discuss the main theories on the formation of natural emeralds

(presenting geochemical, petrological, and tectonic data in support of each one) and the resulting types of emerald deposits. A comprehensive list (compiled by Grundmann) is presented of emerald deposits worldwide, including several small occurrences such as Val Vigezzo in the Italian Alps and the recently discovered Finlayson Lake deposit in Canada. This is followed by detailed descriptions of important emerald deposits in Colombia (mainly Coscuez), Brazil, and Asia (by Schwarz and Giuliani), as well as Africa and Madagascar (by J. Kanis). This section also includes comments by Schwarz on the difficulty of obtaining accurate emerald production data from the mines.

The remaining articles primarily address gemological topics. Schwarz discusses the origin of color, chemical composition, types of inclusions, and determination of locality of origin using, as examples, emeralds from Jos (Nigeria), Malyshevo (Russia), Swat (Pakistan), Santa Terezinha de Goiás (Brazil), and the Cordillera Oriental (Colombia). K. Schmetzer and Schwarz consider the problem of distinguishing between emerald and other green beryls. They maintain that "emeralds are yellowish green, green or bluish green natural or synthetic beryls whose absorption spectra show distinct chrome and/or vanadium bands in the red and blue-violet area of the spectrum." L. Kiefert reviews the controversial matter of fracture filling and its implications, and Schmetzer traces the history of the various emerald synthesis techniques and explains how synthetic emeralds are identified. The volume concludes with discussions by M. Zachovay on how emeralds are priced and by K. Fischer on the emerald cut.

As usual, this edition of *extraLapis* contains numerous diagrams and sketches and is lavishly illustrated, including a fascinating photograph of small snail shells from Colombia fossilized by—believe it or not—emerald. RT

Supply and demand. *Australian Jeweller*, October 2001, pp. 24–25, 29.

The Australian opal industry, which produces 95% of the world's opal supply, is currently facing a number of problems. Production has decreased by about 50% since 1992, while mining costs have doubled and only a few new fields have been discovered. Because of taxation issues, some miners have engaged in a cash economy, further reducing the opal's value. Ironically, opal prices have not increased along with the diminished supply because there have been fewer buyers. This combination of factors has resulted in a weak and fragmented industry, but now the opal community (led by the Australian Jewellery and Gemstone Industry Council and the government) is working together to reverse the trend.

The reduction in supply has been the catalyst for extensive research on the genesis of opal. Solving the mystery of the geologic process of opal formation and deposition is an important step in resolving the supply crisis. Once an increased supply is assured, an increase in

demand will certainly follow. Although cracking and crazing affect a small percentage of Australian opal, education should help alleviate their negative impact.

Anh Nguyen

DIAMONDS

Diamonds: Forever or for good? The economic impact of diamonds in southern Africa. R. Hazleton. Occasional Paper No. 3 of Partnership Africa Canada's *Diamonds and Human Security Project*, 2002. Available at www.partnershipafricacanada.org, and *Mazal U'Bracha*, No. 145, May 2002, pp. 20–56 (passim).

The furor over “conflict diamonds,” which have prolonged wars in Angola, Sierra Leone, and the Democratic Republic of the Congo, also has highlighted the positive role that diamonds play in the development of Botswana, Namibia, and South Africa. This paper analyzes that role and how it relates to De Beers.

Botswana, the world's largest diamond producer by value, earned US\$1.9 billion (~33% of GDP) from diamond mining operations that produced 24.65 million carats (Mct) in 2000. These operations are run by Debswana, a 50–50 venture between De Beers and the federal government. Ultimately, the Botswana government receives 70% of the profits from additional taxes and royalties. Although 85% of the country's foreign revenues are derived from diamonds, efforts to generate employment and added value through diamond cutting have met with only modest success. Nevertheless, as a result of diamond mining, and a stable and responsible government, Botswana has achieved a higher average annual growth rate (9.2%) than any other country *in the world* over the past 30 years. Mr. Hazleton notes that not all have benefited from this prosperity, however, with a third of the country subsisting on less than \$1 per day.

Namibia also has a 50–50 venture with De Beers, Namdeb, which controls the declining shoreline deposits and is predominant in offshore diamond mining. Presently, Namdeb is the country's largest taxpayer and foreign exchange generator, as well as its second-largest employer. Namdeb produced 1.3 Mct worth US\$409 million—or 80% of Namibia's diamond output—in 2000. Diamonds constitute 13% of GDP. The fact that Namibia's diamond production is much smaller than Botswana's and its onshore deposits are close to depletion, raises the prospect of high unemployment among miners in the future.

South African society is still attempting to redress the income disparities remaining from its apartheid system: 53% of the population continues to live in “third world” conditions. Life expectancy has declined, largely because of the high incidence of AIDS. The country is the world's third-largest diamond producer by value (obtained from ~11 Mct), but diamonds account for <1% of both the GDP and total government revenues; however, they constitute

8% of the total value of exports. Similarly, diamonds account for <0.1% of the country's labor force. This year, a new set of regulations giving the state much greater control over resources and giving advantage to local cutting operations will be introduced into its parliament.

The paper concludes that diamonds do play an important and positive role in the economic growth of these three countries, though their benefits are not without controversy and are subject to some reforms. RS

Diamonds: The real story. A. Cockburn, *National Geographic*, Vol. 201, No. 3, March 2002, pp. 2–35.

This cover story is a beautifully photographed, if somewhat long and tortuous, account of the diamond world, both the beneficial and the bad.

The article opens with a tale of a diamond buyer in Lunda Sul, Angola, describing how he evaluates rough diamonds and how they are hard-won by *garimpeiros* (diggers) from the red clay of the mining area nearby. From there, the story brings in De Beers and describes the diamond industry as (p. 12) an “intricate and close-knit worldwide diamond network that operates in some respects on a vast industrial scale [De Beers's mines] and in others like a medieval guild.” The author reports that 120 million carats were mined worldwide last year, with a value of \$7 billion.

The vast industrial scale includes one of the world's largest diamond mines, Jwaneng, operated by De Beers in Botswana. De Beers maintains security so tight that workers (and visitors as well) are not allowed to reach down and touch the ground. Although De Beers now has a number of competitors, the company is still living with U.S. anti-trust litigation and the accusations that it manipulates diamond prices to an artificially high level.

The next section follows the trail of the 265.82 ct diamond found in 2000 near Mbuji Mayi (the “diamond capital” of the Democratic Republic of the Congo), from the machinations of a local dealer, Alphonse Ngoyi Kasanji, to a dealer in Tel Aviv, weaving in then-ruler Laurent Kabila's quest for money to pay for an offensive against the rebels. The diamond ultimately went to New York dealer William Goldberg for \$8 million, less than half of Kasanji's original asking price.

The article also focuses on the brutal civil wars in Africa, and how diamonds have played a role in sustaining them. The war in Sierra Leone, with its excessive cruelty, comes under particular scrutiny. Global Witness, a British-based non-governmental organization, first brought the problem to light in 1998, eventually forcing De Beers and the rest of the diamond industry to confront the problem.

The last section of the article moves to India, with its history of diamond lore dating back several millennia. Starting from a group of Jains just 40 years ago, modern India has developed the world's largest diamond cutting industry. India's industry is built on a cheap labor force that is able to polish economically many diamonds that would otherwise have been classified as industrials. RS

A discussion on the origin of irregular shapes of type II diamonds. I. Sunagawa, *Journal of Gemmology*, Vol. 27, No. 7, 2001, pp. 417–425.

Type II rough diamonds characteristically have irregular or flattened shapes and do not show crystallographic faces, whereas type I rough diamonds normally have octahedral or rounded dodecahedral morphologies. Although the type II diamonds originally had shapes similar to those of type I diamonds, they were fractured during ascent from great depths within the Earth. While both types experience similar amounts of stress during their transport to the surface, the absence of nitrogen from type II diamonds makes them physically weaker than type I diamonds. The irregular shape of type II diamonds correlates to a large proportion of fancy-cut stones. This explains why many of the diamonds subjected to General Electric's high pressure/high temperature color enhancement process are cut in fancy shapes.

AAL

Of judgment and cunning work. Conflict diamonds and the implications for Canada. I. Smillie, *International Journal*, Vol. 56, No. 4, Autumn 2001, pp. 579–594.

Diamond traders cared little about the geographic origin of their stones until the conflict diamond issue surfaced in the late 1990s. While the news media picked up on this story, the diamond industry devised a system to require diamond producers to certify rough diamonds at their source and to insure they come from legitimate channels. Also, Congressmen Tony Hall and Frank Wolf introduced the Clean Diamonds Act, which would require such certificates on any diamond imported into the U.S.

At a meeting in Kimberley, South Africa, in May 2000, representatives from diamond producing, processing, and consuming nations convened to adopt a workable certification system, which became known as the Kimberley Process. However, the Kimberley Process has been compromised by delays, inaction, and the shortcomings of the proposals themselves, which nongovernmental organizations (NGOs) believe are inadequate to stop traffic in conflict diamonds.

For Canada, a new major diamond producer, such inadequate regulation can create opportunities for criminals to launder conflict goods through the "clean" Canadian pipeline. The article concludes by urging the Canadian parliament to adopt legislation similar to the Clean Diamonds Act proposed in the U.S.

RS

Morphology of diamonds as a possible indicator of their genesis. M. D. Evdokimov, M. Y. Ladygina, and A. R. Nesterov, *Neues Jahrbuch für Mineralogie, Abhandlungen*, Vol. 176, No. 2, 2001, pp. 153–177.

This article summarizes the basic arguments in the 200-year-old scientific debate as to whether a relationship exists between the morphology of diamond crystals (i.e., flat vs. rounded faces) and the conditions under which they crystallized (i.e., a growth vs. dissolution environment, and

whether both took place in a liquid environment). Any theory must explain a disparate group of observations, such as the formation of flat-faced crystals in eclogites, the occurrence of morphological features such as polygonal pits and microlamellar textures, and the formation of rounded forms (dodecahedroids, octahedroids, and hexahedroids).

Based mainly on the works of A. A. Kukhareenko and his macroscopic classification of growth forms, dissolution forms, and regeneration forms, the authors attempt to establish differences between the morphology of inferred growth and dissolution features on a submicroscopic level by examining over 1,300 crystals with a scanning electron microscope. They give detailed descriptions of four exemplary crystals and their morphological features. From this, they conclude that it still is not possible to answer two fundamental questions: which processes are responsible for the occurrence of rounded forms, and whether flat-faced or rounded forms are primary. However, they are able to demonstrate that certain morphological features can be attributed to growth or dissolution. The surface morphology also provides evidence that diamond formation processes can be quite complex and are influenced not only by heat and pressure, but also by other factors such as carbon from external sources (methane) and cyclic changes of growth and dissolution.

RT

Nitrogen distribution in diamonds from the kimberlite pipe No. 50 at Fuxian in eastern China: A CL and FTIR study. F.-X. Lu, M.-H. Chen, J.-R. Di, and J.-P. Zheng, *Physics and Chemistry of the Earth. Part A: Solid Earth and Geodesy*, Vol. 26, No. 9–10, 2001, pp. 773–780.

Cathodoluminescence (CL) and FTIR spectroscopy were used to study the internal structure, variable nitrogen contents, and nitrogen aggregation states in diamonds from Fuxian, Liaoning Province, China. Single-stage growth, multi-stage complex growth, and a rare agate-like structure were identified; most of the diamonds showed complex growth histories. Diamonds with bright blue CL had higher nitrogen contents than those with dark green or green-blue CL. One diamond, a 0.26 ct brown octahedron with evidence of at least four growth stages, had nitrogen contents varying from 244 to 679 ppm. Sharp increases and decreases of nitrogen at the growth-stage boundaries imply different conditions during crystallization. Before 1.3–1.4 billion years, unstable conditions produced a rapid rate of growth, whereas after that time stable conditions corresponded to a slower growth rate and enhanced fluid activity.

RAH

GEM LOCALITIES

"Desert Ebony." Ein großer schwarzer Opal aus dem Virgin Valley, Nevada ("Desert Ebony." A large black opal from Virgin Valley, Nevada). P. C. Huber, *Lapis*, Vol. 27, No. 1, 2002, pp. 21–23 [in German].

Virgin Valley, the most important opal deposit in the United States, is located in a very remote desert region of Nevada.

About 1.5 million years ago, huge conifer forests were covered by volcanic ashes and tuffs and subsequently petrified, partly as gem-quality opal. Several commercial mines operate in the area, but for a moderate fee amateur collectors can also search for opals. The author describes his trip to Virgin Valley, the landscape, the natural history of the area, living and mining conditions, and his own gem-digging activities. At the Rainbow Ridge mine, he found a large (1,700 ct) black opal, which he named "Desert Ebony." RT

Elba. *extraLapis* No. 20, 2001, 96 pp. [in German].

This issue in the special *extraLapis* series was written by Dr. Federico Pezzotta, and is based on the book *Minerali dell'isola d'Elba [Minerals of the Island of Elba]* (P. Orlandi and F. Pezzotta, Edizioni Novecento Grafico, Bergamo, Italy, 1996). Along with historical and geologic information, and mineralogical data on over 200 species, the book provides detailed descriptions of the island's two main products: ores of copper and iron, and gem minerals. The ore deposits along the eastern coast of Elba have been exploited since at least the 6th century BC; they are famous for their magnificent pyrite and hematite crystals. The gem minerals are found in pegmatites ("filoni") of the Monte Capanne plutonic intrusion. These contain tourmaline, beryls (goshenite, aquamarine, morganite), spessartine, topaz, apatite, petalite, and hambergite. The gem minerals form beautiful crystals but are mostly rather small; the largest known morganite is 5 cm across, and the largest tourmaline is <10 cm. Although treasured by collectors of crystal specimens, most are heavily included and seldom faceted.

Elba is the largest tourmaline occurrence in Europe. The tourmalines occur in a wide range of colors, the typical variety being color-zoned elbaite with black terminations. Most of the tourmalines are schorl or elbaite, but there is also dravite, foitite, and rossmanite, often as zones within the same crystal. While most specimens on the market and in collections originated from such famous old pegmatites as Catri, Fonte del Prete, Grotta d'Oggi, San Piero, or San Silvestro, recent research and collecting activities have shown that there are still a large number of potentially gem-bearing "filoni" to be discovered. RT

A fluid inclusion study of an amethyst deposit in the Cretaceous Kyongsang Basin, South Korea. K. H. Yang, S. H. Yun, and J. D. Lee, *Mineralogical Magazine*, Vol. 65, No. 4, 2001, pp. 477–487.

Fluid inclusions in high-quality amethysts and colorless quartz from granitic rocks at Eonyang, Korea, were studied to determine the geologic conditions under which they formed. Three types of inclusions are recognized. Type I are liquid-rich, low-salinity inclusions that contain a liquid-vapor mixture with or without daughter minerals (e.g., calcite) but no halite. Type II inclusions are liquid-rich and contain halite, calcite, and various opaque minerals; based on petrographic evidence, these formed after Type I and before Type III inclusions. Type III inclusions contain liquid and gaseous CO₂ (>50 vol.%), but no solids.

The colorless quartz formed first, under reducing conditions (corroborated by the presence of pyrite, which contains Fe²⁺), at T=600°C and P=1.0–1.5 kbar. Amethyst formed later, under oxidizing conditions (corroborated by the presence of hematite, with Fe³⁺), at T=280°–400°C and P=1 kbar. During the crystallization of the amethyst, Fe³⁺ was incorporated into the quartz structure, which resulted in the formation of color centers. KSM

Gem-bearing basaltic volcanism, Barrington, New South Wales: Cenozoic evolution, based on basalt K-Ar ages and zircon fission track and U-Pb isotope dating. F. L. Sutherland and C. M. Fanning, *Australian Journal of Earth Sciences*, Vol. 48, No. 2, 2001, pp. 221–237.

Gem-quality sapphire, ruby, and zircon are found in drainages of the Barrington volcano, 100 km north-northeast of Newcastle, New South Wales, Australia. This article integrates new age data with previously published information on the geologic history of the volcano and the origin of the gems. The volcano was formed by multiple basaltic eruptions that occurred intermittently between 59 and 4–5 million years (My) ago. The volcanism evolved in stages as the lithosphere overran a series of magmatic plumes.

The gem-bearing eruptions, associated with quieter eruptive periods, occurred at 57, 43, 38, 28, and 5–4 My. Two main periods of zircon crystallization occurred between 60–50 My and 46–45 My. Zircon and sapphire are attributed to crystallization from minor felsic melts (igneous origin, indicated by corrosive etching) derived from incipient melting of amphibole-enriched mantle rock. Ruby is believed to have formed from metamorphosed ultramafic bodies at depth. Based on structural and seismic studies of the mantle under eastern Australia, which is characterized by a subdued thermal profile, there is little prospect of further gem-bearing eruptions in this area in the future. KSM

Mineral and fluid inclusion study of emeralds from the Lake Manyara and Sumbawanga deposits, Tanzania. I. Moroz, Y. Vapnik, I. Eliezri, and M. Roth, *Journal of African Earth Sciences*, Vol. 33, No. 2, 2001, pp. 377–390.

The solid and fluid inclusions in emeralds from two Tanzanian deposits, Lake Manyara and Sumbawanga, were studied to determine the mineralogy of the solids, the chemical nature of the liquids and gases, and the pressure and temperature conditions under which the emeralds formed. Microthermometry and laser Raman microspectrometry were the primary techniques employed.

Magnesite, Mg-calcite, aragonite, dolomite, calcite, nahcolite, quartz, and chrysoberyl were identified in emeralds from Lake Manyara; the fluids were carbonate-rich and contained ~6 wt.% NaCl. Phenakite, euclase, bertrandite, and helvite were identified in emeralds from Sumbawanga; the fluids were CaCl₂-rich, and contained up to 17 wt.% NaCl.

The inclusion data suggest the Lake Manyara emeralds formed at temperatures of 370°–470°C and pressures of 3–7 kbar. The Sumbawanga emeralds formed at lower temperatures and pressures: 220°–300°C and 0.7–3.0 kbar. *LT*

Primary deposits in Sri Lanka will reinvigorate trade, gem sector notes. J. Henricus, *Jewellery News Asia*, No. 206, October 2001, pp. 55–56, 58–60.

Gem production in Sri Lanka has declined in recent years as the traditional alluvial (secondary) deposits have been depleted and new alluvial deposits become increasingly difficult to find. Yet this trend may be reversed as new *in-situ* (primary) gem deposits are being discovered with the help of modern satellite technology in areas not previously known to have gem occurrences. These primary deposits reportedly are hosted by skarns (carbonate rocks, such as limestone, affected by contact metamorphism accompanied by the introduction of additional elements). One of the new areas, near Kataragama in the extreme southeastern part of the island, is mainly producing blue sapphires, some of fine quality, along with other gems (including yellow and orange-pink sapphire, garnet, and red spinel). Although well-formed crystals have been found, they typically contain abundant inclusions and cracks. Both traditional hand methods and mechanized mining are being used, with careful attention to environmental matters. *JEC*

Quaternary geology and sapphire deposits from the Bo Phloi gem field, Kanchanaburi Province, Western Thailand. M. Choowong, *Journal of Asian Earth Sciences*, Vol. 20, No. 2, 2002, pp. 119–125.

Sedimentological analysis of the sapphire-bearing gravels of the Bo Phloi District (30 km north of Kanchanaburi, Thailand) was conducted in an attempt to understand the paleo-environment of sapphire deposition. From the examination of test pits excavated specifically for this purpose, and open-cuts created by sapphire miners, the author was able to construct stratigraphic sequences of the sediments for three deposits within the Bo Phloi district.

Essentially, each sequence begins with basalt or weathered basalt at the base, grading upward into sapphire-bearing coarse gravel and then into successively finer sediments toward the top. At the Ban Chong Dan deposit, this sequence is approximately 10 m thick. The author concludes that the sediments are channel-fill deposits laid down by a braided river, where sapphires (along with spinel) were eroded from the underlying basalts and then redeposited within the coarser gravels of the channel. No gemological or production data are provided. *Keith A. Mychaluk*

Der Sarawak-Bernstein (Amber in Sarawak). T. Thielemann, A. Arleth, M. Arleth, D. Johari, E. Ong, and D. Kelter, *Zeitschrift für Angewandte Geologie*, Vol. 47, No. 3/4, 2001, pp. 212–217 [in German with English abstract].

In 1987, one of the world's largest amber deposits was discovered in the Merit Pila open-pit coal mine in Sarawak

(Borneo), Malaysia. From an annual production of around 150,000 tonnes of subbituminous coal comes 3,000–7,500 tonnes of amber. The amber and the coal are the remains of tropical deciduous trees (Dipterocarpaceae) and occur in the Miocene Nyalau Formation.

The amber is found as irregular, often loaf-like, pieces within the coal seams—frequently in circular groups (i.e., around the bases of the former trees). Much of the material shows distinct flow structures. The color is dark (brown to black), and only smaller pieces are translucent and yellow to brown. The amber shows intense blue fluorescence and only rarely contains fossil inclusions (centipedes, spiders, and various insects). Unlike Baltic amber, the material from Sarawak is soluble in turpentine and benzene and melts above 200°C. Malaysian artists, who previously had worked only in wood, are now carving objects in amber. *RT*

Tanzanite production to start at Merelani. H. Raats, *SA Mining*, January 2002, pp. 16–18.

Based on new geologic findings at its Merelani tanzanite project in northern Tanzania, African Gem Resources (Afgem) is implementing a revised mine plan. Core drilling has established that the ore body extends to a depth of at least 300 m, and the company is currently developing three state-of-the-art mining shafts to recover the ore from these depths; the shafts are expected to be completed between July and December 2002. The plan also includes a new ore extraction method. When completed and in operation, which is expected to be in the latter part of 2002, Afgem believes that its tanzanite project will be the world's most modern colored stone mining facility.

The company has tanzanite cutting and polishing facilities in Johannesburg and Bangkok, but it plans to develop similar facilities in Tanzania. It will market the top quality of its polished production (about 10% of the volume) under the brand name "Tanzanite Foundation." *MT*

Ti-Fe mineral inclusions in star sapphires from Thailand. S. Saminpanya, *Australian Gemmologist*, Vol. 21, No. 3, 2001, pp. 125–128.

An examination of exsolved needles and mineral inclusions in star sapphires from Bang Kacha [also spelled *Bang-kha-cha*], Chanthaburi Province, Thailand, was conducted using electron microprobe and wavelength-dispersive spectrometry with the techniques of element mapping and spot analyses. Rather than being rutile or hematite, as previously reported, the exsolved "needles" consisted of a mineral of the ilmenite-hematite series, ilmenite, or a spinel; other opaque inclusions were magnetite-hercynite. *RAH*

Zwölfstrahliger Sternsaphir aus Bang-kha-cha, Thailand (Twelve-rayed star sapphire from Bang-kha-cha, Thailand). K. Schmetzer and M. Glas, *Lapis*, Vol. 26, No. 11, 2001, pp. 40–42, 54 [in German].

After a brief overview of some basic facts concerning asterism, the characteristics of black star sapphires from

Thailand are described. As in star corundums from other sources, these stars were found to be diffraction phenomena created by needles or lamellae of rutile or hematite-ilmenite. These inclusions can be oriented either parallel or perpendicular to the second-order prism faces.

Six-rayed star sapphires from Bang-kha-cha [also spelled *Bang Kacha*] show bluish white or, less commonly, "golden" yellow stars. The bluish white stars are caused by Ti-bearing hematite (as are similar black stars from Australia), whereas the nature of the mineral(s) forming the yellow stars is unknown. In the bluish white stars, the band of light (chatoyancy) can be oriented both parallel and perpendicular to the second-order prisms, but they are always parallel to these prisms in the yellow stars.

Rarely, both colors of stars are combined in the same specimen and form 12-rayed star sapphires. The authors studied nine such sapphires and found that the bluish white stars were always oriented perpendicular to the prism faces, whereas the yellow stars were parallel to these faces. The article is illustrated with four excellent photographs and two diagrams, which make the rather complicated phenomena easily understandable. *RT*

INSTRUMENTS AND TECHNIQUES

Complex pearl identification: New possibilities of the X-ray methods. O. Y. Yakushin, M. L. Osipov, and E. V. Kozorezov, *Gemological Bulletin, Publication of the Gemological Society of Russia*, No. 1, 2001, pp. 11–14.

This article advocates that X-ray computed microtomography analysis offers a faster, and more reliable and versatile, technique for investigating the precise nature of pearls than is available with current X-ray methods. According to the authors, X-ray microtomography can differentiate natural from cultured pearls or imitations, determine the thickness of the nacre, and recognize the location, size, and other characteristics of the nucleus of both bead- and tissue-nucleated cultured pearls. It can also analyze pearls that are mounted in jewelry. The microtomographical "picture" of the interior of a pearl is sufficiently distinctive to enable its use to identify specific pearls, especially those that are particularly large or otherwise unique.

Vladislav Dombrovskiy

EPR and optical spectroscopy of impurities in two synthetic beryls. J.-M. Gaite, V. V. Izotov, S. I. Nikitin, and S. Y. Prosvirnin, *Applied Magnetic Resonance*, Vol. 20, No. 3, 2001, pp. 307–315.

Two hydrothermal synthetic beryls, purple and blue-green in color, were studied with electron paramagnetic resonance (EPR) spectroscopy and optical spectroscopy to determine the origin of the colors. The purple specimen contained (in wt.%): Mn = 0.1, Fe = 0.31, and Cu = 1.55. The blue-green specimen contained (in wt.%): Mn = 0.003, Fe = 1.26, and Cu = 1.51. The valence states of these elements and their positions in the beryl structure were

determined, and local properties of the paramagnetic impurities were identified. Detailed analysis of the EPR spectra (both before and after annealing) and data from optical absorption spectra show that in these synthetic beryls, the blue-green color is caused by Cu^{2+} and the purple is due to Mn^{3+} . *Alethea Inns*

Non-destructive NIR-FT-Raman analyses in practice. Part II. Analyses of "jumping" crystals, photosensitive crystals and gems. G. N. Andreev, B. Schrader, R. Boese, P. Rademacher, and L. von Cranach, *Fresenius Journal of Analytical Chemistry*, 2001, Vol. 371, pp. 1018–1022.

This article explores the benefits of near-infrared Fourier-transform (NIR FT) Raman spectroscopy, as compared to classical Raman spectroscopy, which uses excitation in the visible range of the spectrum with a focused beam. FT-Raman spectroscopy has been used previously for the investigation of organic gems (e.g., corals, pearls, ivory, and amber) because it avoids potential problems with overheating in the focal range. This article presents some applications of this technique to inorganic gems (e.g., the distinctions between diamond and synthetic moissanite or cubic zirconia). The authors also demonstrate the correlation between FT-Raman spectra and diamond clarity. *Alethea Inns*

Raman spectroscopy—An introduction. M. I. Garland and T. L. Haslett, *Canadian Gemmologist*, Vol. 22, No. 2, 2001, pp. 46–61.

This article introduces two nondestructive, high-resolution spectroscopy techniques, infrared (IR) and Raman, that are increasingly important in gemology, with a comparison of the uses and advantages of each. IR measures the absorption of infrared light by the sample, whereas Raman spectroscopy measures the diffraction of visible light. So that the reader can more fully understand IR and Raman spectroscopy, the authors include a section on molecular behavior and crystalline vibrations, and describe some basic aspects of the instrumentation for both techniques.

IR spectra are collected by a ratio known as the IR transmission spectrum (the relationship between the light intensity as it passes through the material and the original light intensity with no material present). Because the absorption pattern is specific to the molecular structure for a particular material, databases of reference spectra can be compiled. Raman spectra are collected by exciting the material, which then produces elastically scattered light, known as Rayleigh, and inelastically scattered light, known as Raman. Filtering out the Rayleigh scattering, one is left with the Raman shift characteristic of that material.

Raman spectroscopy is used in gemology primarily for the identification of inclusions, epoxy and other fillers, and the gem material itself. The identification of solid and fluid inclusions, especially those just a few microns in

size, can be essential for the determination of the geographic or natural/synthetic origin of a gem.

IR spectroscopy, although effective because of the large database of reference spectra that is available, has a few drawbacks. In particular, it becomes problematic with weak IR absorption—when small signals are difficult to observe due to “background noise”—whereas Raman can more easily read lower-energy vibrations. However, fluorescence can flood the detectors, thus scrambling the Raman signals. Also, until recently reference databases of Raman spectra did not exist, and a lack of a high-intensity monochromatic light source prevented the early use of Raman spectroscopy. With the invention of lasers, the pragmatic monochromatic light source was improved. Coupled with other developments, Raman spectroscopy has become less expensive, easier to use, and a standard technique for many gemological laboratories. JS

JEWELRY RETAILING

Consumers' product evaluation: A study of the primary evaluative criteria in the precious jewellery market in the UK. A. Jamal and M. Goode, *Journal of Consumer Behaviour*, Vol. 1, No. 2, 2001, pp. 140–155.

When purchasing “precious” jewelry products, consumers in the United Kingdom generally preferred subjective attributes such as design, quality of materials, workmanship, and comfort. However, those consumers with a higher degree of sophistication also regarded objective criteria such as country of origin, brand name, information provided, and variety as very important.

This article reports the results of a mail survey taken to determine the nature and type of evaluation criteria used by an individual while purchasing a piece of “precious” jewelry. It is based on a questionnaire sent to 500 individuals on the mailing lists of three retail jewelers in the UK. There were 117 responses: 87% were from women, 80% of whom were between the ages of 25–54 and 60% of whom were married.

As a group, the respondents chose subjective attributes—namely, quality of materials, design, and workmanship—as the three most important factors in evaluating jewelry. Price, an objective criterion, was deemed less important than any of these factors, and the objective criteria of brand name and country of origin were nearly last. Consumers with a low degree of brand consciousness rated durability and comfort much more highly than the group at large. However, more sophisticated consumers—those with high brand consciousness and product knowledge—rated brand name, information, country of origin, and variety of styles more highly.

The study concludes that jewelry brand managers can develop products and strategies geared to audiences with differing degrees of sophistication and knowledge. RS

SYNTHETICS AND SIMULANTS

Gemological characterization of gem-quality synthetic diamonds manufactured in Russia. Y. B. Shelementev, O. Y. Gorbenko, and G. V. Saparin, *Gemological Bulletin, Publication of the Gemological Society of Russia*, No. 1, 2001, pp. 4–9 [in Russian with English abstract].

The authors studied 12 gem-quality Russian synthetic diamonds—some rough crystals and some polished, and in a variety of colors (brown, yellow, blue, and colorless)—to determine the best methods for distinguishing these synthetics from their natural counterparts. Conventional gemological and instrumental methods (e.g., evaluation of shape, color, color distribution, short- and long-wave luminescence, and magnetic properties) do not always yield unequivocal results, in which case more sophisticated instrumental methods such as infrared absorption spectroscopy and colored and spectral cathodoluminescence (CL) must be employed. Especially valuable is CL, since the color, intensity, and surface distribution of cathodoluminescence are proven diagnostic features for distinguishing natural from synthetic diamonds.

Vladislav Dombrovskiy

Growth and characteristics of some new varieties of coloured quartz single crystals. V. S. Balitsky, I. B. Makhina, E. A. Marina, G. R. Rossman, T. Lu, and J. E. Shigley, *High Pressure Research*, Vol. 20, 2001, pp. 219–227.

Growth conditions for producing four new varieties of synthetic quartz in single crystals are described. Two of these synthetic varieties are very rare in nature: ametrine (bi-colored amethyst-citrine), and low-temperature phosphorous-bearing pink quartz. Two varieties have no natural counterparts: high-temperature Ni-bearing synthetic pink-violet quartz, and low-temperature Cu-bearing synthetic “golden” pink quartz that resembles aventurine. With the exception of the high-temperature Ni-bearing variety, all currently are grown in small quantities for use in the jewelry industry.

The growth temperature for the synthetic ametrine (which requires the presence of iron as Fe³⁺ in the solution) is slightly higher (300°–370°C) than for both of the low-temperature pink quartz varieties (220°–320°C), but significantly lower than the Ni-variety (650°–780°C). The synthetic ametrine requires higher pressures (1.2–1.5 kb) and forms larger crystals (0.5–4.0 kg) than the other three varieties (pressures generally <0.3 kb; crystals 0.02–0.15 kg). The synthetic ametrine is grown from traditional alkaline solutions, whereas the others are grown from nontraditional fluoride solutions. The Ni-bearing synthetic pink-violet quartz is grown as high-temperature β-quartz, but on cooling it converts to α-quartz. Details are given of additional conditions and variables required for the growth of these synthetic colored quartz crystals (e.g., temperature gradients, nature of seed plates, radiation dosage, and growth rates). Alethea Inns

Growth of the world's largest sapphire crystals. C. P. Khattak and F. Schmid, *Journal of Crystal Growth*, Vol. 225, No. 2–4, 2001, pp. 572–579.

Commercial crystal growth processes require a temperature gradient built into the heat zone. However, a large temperature gradient can cause defects during crystal growth and subject the crystal to high stress during cooling. To grow large synthetic sapphire crystals with high purity for high-technology applications, in 1970 one of the authors (FS) and a colleague at the U.S. Army Materials and Mechanics Research Center (AMMRC) developed a new technique for growing synthetic crystals from a melt—called the heat exchange method (HEM). After 30 years of improvements in the technique, AMMRC has synthesized the world's largest sapphire crystal (color not specified), a boule that weighs 65 kg and is 34 cm in diameter.

In the HEM furnace, there are no built-in temperature gradients (a feature of other crystal-growth processes, such as Czochralski), so the crucible, seed crystal, molten charge, and boule are in the same heat zone and there is no movement of heat element, crucible, or crystal by the heat exchanger. As a result, large crystals can be grown without cracks and other defects. The high purity is achieved because of volatilization and segregation of the impurities during crystal growth.

The sapphire boules display excellent symmetry and uniformity. They are cylindrical in profile with a flat surface on top, and they exhibit continuous high transparency from the ultraviolet, through the visible, to the mid-wavelength infrared 3–5 micrometers band. A schematic diagram is presented of the HEM furnace. Efforts are under way to produce 50 cm diameter sapphire boules. TL

Synthetic moissanite from Russia. L. Kiefert, K. Schmetzer, and H. Hänni, *Journal of Gemmology*, Vol. 27, No. 8, 2001, pp. 471–481.

The gemological, chemical, and spectroscopic properties of five faceted (round brilliant) yellow, green (2), bluish green, and bluish brown synthetic moissanites grown in Russia are described. The samples were created by the seeded growth of SiC by sublimation from the vapor phase, known as the modified Lely technique. Four of the samples crystallized as the 6H SiC polytype (the same polytype as the colorless synthetic moissanite grown in the United States); the bluish brown sample had the 4H polytype. The samples were all single crystals without any admixture of different polytypes.

Unlike the colorless faceted synthetic moissanite available commercially from the United States, in none of these Russian samples was the c-axis oriented perpendicular to the table facet. This difference in orientation was evident in the orientation of the inclusions (mainly elongated tubes), which were subparallel to the table. The authors attribute the different colors of these synthetic moissanites to varying amounts of nitrogen in the crystal structure. Established techniques for separating colorless synthetic moissanites from colorless diamonds, such as

the doubling of facet junctions, also can be applied in separating these colored synthetic moissanites from colored diamonds. WMM

TREATMENTS

Change of luminescence character of Ib diamonds with HPHT treatment. H. Kanda and X. Jia, *Diamond and Related Materials*, Vol. 10, Nos. 9–10, 2001, pp. 1665–1669.

Luminescence properties of synthetic diamonds grown in a pure iron solvent-catalyst were investigated before and after HPHT treatment. Cathodoluminescence (CL) and photoluminescence (PL) spectra provide new insights into as-grown crystal characteristics as well as changes in optically active centers due to heat treatment, nitrogen concentration, and strain.

CL intensities varied between sectors of the as-grown crystal samples. Subsequent HPHT treatment (6 GPa, 1800°–2000°C, 5 hours) of the as-grown crystals resulted in dramatic changes in the CL spectra, although luminescence intensities remained sector dependent. All bands recorded in the pre-heated crystals disappeared and additional bands appeared, including N3, H3, 575 nm, and a broad band centered around 430 nm (Band A). Analysis of the PL spectra confirmed that the N3 band was stronger in {111} sectors; H3 and 575 nm bands were stronger in {113} sectors. Mapping also revealed that the ratio of the zero-phonon peaks of the H3 and 575 nm bands remained constant throughout the crystal, which suggests a similar formation process.

The treated crystals displayed striated luminescence patterns. This may be related to plastic deformation resulting from HPHT treatment because striations are parallel to <110> directions. Also, luminescence was stronger around the periphery of the crystals where deformation was larger, which indicates that plastic deformation enhances CL intensity. SW

A new screening system for detecting HPHT-treated natural diamonds. K. Schmetzer, *Goldschmiede Zeitung*, Vol. 100, No. 5, 2002, p. 88 [in German].

A Liechtenstein company (Gersan Establishment) has applied for an international patent (publication No. WO 02/06797A1; published January 24, 2002) for an instrument capable of detecting HPHT-treated diamonds. The inventor is S. C. Lawson of the De Beers DTC Research Centre in Maidenhead, England. This article gives a detailed description of the instrument and the theory of its operation, based on disclosures and claims in the patent application. For example, the instrument contains two different lasers (532 and 655 nm) and two spectrometers. Photoluminescence is measured at liquid nitrogen temperature, and a microprocessor determines whether or not the diamond has been treated based on the relative intensities of certain emission lines. The instrument is portable, and because an analysis takes only 15–20 sec-

onds, it is capable of screening a large number of samples. The instrument can also distinguish between natural and synthetic diamonds, and can recognize diamonds that have been subjected to irradiation.

Exactly how this instrument can be used in the trade is not discussed. Nor is there any indication as to whether it is, or will be, commercially available. [Editor's note: This instrument should not be confused with two earlier De Beers instruments, the DiamondSure™ and DiamondView™ (see *Gems & Gemology*, Fall 1996, pp. 156–169), which are designed only to distinguish natural from synthetic diamonds.] AAL

Ruby heat treatment and fracture repair. H. Hänni, *Jewellery News Asia*, No. 207, November 2001, pp. 75–76.

The heat treatment of ruby in a controlled atmosphere, or with the addition of a flux, has three possible objectives: (1) to improve or change the original color (which is dependent on the oxidizing or reducing nature of the heating atmosphere if iron provides the color transition); (2) to increase transparency or clarity (e.g., by dissolving rutile silk); and (3) to increase mechanical stability (by artificially healing fractures with the flux). Details of the procedures used, such as the chemical nature (borates and fluorides) of the fluxes and methods by which the enhancements may be recognized (e.g., microscopic study of characteristic flux residues and gas bubbles), are outlined and photomicrographs of treated fissures are provided.

In gemological reports from the SSEF Swiss Gemmological Institute, of which the author is director, heat-treated rubies are identified as such. In the case of a heat-treated ruby in which a glassy residue has been identified, the report would note: "With indications of thermal enhancement and artificial glassy residues in fissures." The treatment is also quantified with the terms *minor*, *moderate*, or *significant*. JEM-S

MISCELLANEOUS

John J. Kennedy, JCK's Person of the Year. W. G. Shuster, *Jewelers' Circular Keystone*, Vol. 172, No. 12, December 2001, pp. 60–62, 65.

Since 1993, the jewelry industry has seen a sharp drop in murders and other violent crimes, increased prosecution of criminals who prey on traveling salespeople, more federal funding for the FBI's fight against thieves, and greater security and crime prevention information for jewelers and law enforcement officials. Much of the credit for these achievements goes to John J. Kennedy, who became

president of the Jewelers Security Alliance (JSA) that year. Under Kennedy, the JSA has been particularly effective in five areas:

- Forging closer ties with law enforcement agencies to raise awareness of the industry and its needs. This includes a special task force within the FBI and Los Angeles Police Department to help thwart South American gangs involved in the theft of gems and jewelry.
- Political lobbying for tougher action against violent criminals.
- An intensive media campaign to increase awareness of the severity of crimes against the jewelry industry. Jewelry theft losses average close to \$300,000, while the average loss from a bank robbery is \$3,000.
- Expanding crime prevention information in the form of alerts and bulletins. These include a Manual of Jewelry Security published in 1995, a security products directory, and an annual statistical report on crimes against the industry.
- Technological improvements that can disseminate alerts and other important information instantaneously.

JSA membership has grown 118% since 1993, to nearly 19,000 in 2001. RS

A supply chain gem. D. L. Andrews, *ID Systems*, Vol. 21, No. 6, 2001, pp. 32–35.

Shane Co., a diamond retailer and e-tailer, is using supply chain management software from ScanData Systems to track, ship, and secure its products with 100% accuracy.

Each product undergoes a quality control check before reaching inventory. If it passes inspection, it is either assigned to an outgoing order or marked as available and put in stock; if not, it is returned to the manufacturer. Digital photos of the products are taken, and images are associated with product records for further quality assurance. Orders are reviewed for product availability and processed accordingly. If items are not available, the orders go on automatic hold. Completed orders are audited and invoices printed. ScanData sends billing authorization data, telling the system the items have been shipped and billed. A shipping label is generated, and electronic shipment data are conveyed to carriers. The system generates inventory status data and order status messages throughout the day to keep inventory levels updated. At the end of each business day, mass inventory is taken of the merchandise, which is placed on mobile racks and then stored in a vault. MT