

Gems & Gemology

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Gems & Gemology

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ABOUT THE COVER: Fine rubies have been the object of admiration—and imitation—for centuries. The three rubies illustrated here represent excellent examples of natural stones; the new Ramaura synthetic ruby described by Robert Kane in this issue represents the latest in gem ruby synthesis.

The ring (a 10.02-ct ruby surrounded by diamonds) and earrings (rubies totaling 14.54 ct, again surrounded by diamonds) are courtesy of Ballreich and Kantor, Inc., Los Angeles, CA. Photo © 1983 Harold and Erica Van Pelt—Photographers, Los Angeles.

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Carroll Chatham 1914–1983

One of the pioneers of the man-made gem industry passed away recently. Carroll Chatham was a remarkable scientist and, for a portion of his early career, a controversial figure in the jewelry industry.

As a boy, Chatham conducted chemistry experiments in his parents' garage. He soon gained the reputation of being a "mad scientist," and was said to have come close to blowing up the neighborhood once or twice. He pursued his love of scientific experimentation throughout college, and in 1938 received his degree in chemistry from the California Institute of Technology. Upon graduating, he worked in industry for several years, and in 1946 he set up his own laboratory. Chatham realized one of his greatest dreams shortly thereafter when he became the first person to produce gem-quality synthetic emeralds on a commercial basis. It has been said that Chatham's milestone breakthrough helped spur Pierre Gilson's efforts in producing his own synthetic emerald.

Chatham abhorred the widespread misuse of the term *synthetic*, particularly during the 1940s when a proliferation of substitutes and imitations were incorrectly, and often misleadingly, labeled as synthetics. He felt that the public perceived the terms *imitation*, *substitute*, and *synthetic* as being synonymous, and he therefore marketed his new product as "cultured emeralds." When the Jewelers Vigilance Committee questioned the use of the term *cultured* as it applied to his product, a long, controversial dispute over terminology resulted. The dispute was eventually brought before the Federal Trade Commission, which ultimately rejected Chatham's use of the term. Chatham won the war, however, when the Commission ruled that the designation "Chatham Created" emerald was acceptable for his product.

Chatham retired recently to let his son John operate the laboratory and manufacturing end of the business. His other son, Tom, now handles the marketing for Chatham Created Gems. Chatham's health had worsened during the past few years, most of which was attributed to the effects of the beryllium compounds and toxic gases he was exposed to throughout his career. In spite of his failing health, he continued his activity in the trade, and was a speaker at GIA's 50th Anniversary Gemological Symposium in 1982.

Carroll Chatham was one of the truly remarkable men in the jewelry industry. He was a man of strong convictions, whose innovative intelligence and integrity contributed to the advancement of his field. He will be missed.

Richard T. Liddicoat, Jr.

A

THE RAMAURA SYNTHETIC RUBY

By Robert E. Kane

A new synthetic ruby grown by a process involving high-temperature flux with spontaneous nucleation has been developed. This new synthetic ruby is currently commercially available under the trade name Ramaura. The Ramaura synthetic exhibits some internal characteristics that are distinctly different from those observed previously in commercially available synthetic rubies. Some of the Ramaura synthetic rubies are readily identifiable, while others could present a serious cause for concern in the world's ruby markets and call for extreme care on the part of gemologists in the examination of rubies. In this article, the author examines in detail the gemological properties of the Ramaura synthetic ruby and discusses means of identifying this new synthetic.

ABOUT THE AUTHOR

Mr. Kane is research and gem identification supervisor of GIA's Gem Trade Laboratory, Inc., Los Angeles, California.

Acknowledgments: The author wishes to thank Peter Flusser and the staff of the Ramaura division of Overland Gems, Inc., for the loan of the synthetic material; Shane McClure, Robert Crowningshield, and Dr. George Rossman for useful suggestions; John Koivula for his help in photographing figures 17 and 24, and in selecting the other photomicrographs; Chuck Fryer for performing the short-wave U.V. transparency tests and supplying figure 5; Dr. Anthony R. Kampl for providing the crystal morphology descriptions and preparing figure 2; and George Bosshart, Dr. H. A. Hänni, Dr. W. B. Stern, and B. Suhner for the spectrophotometric examinations.

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In 1877, Edmund Frémy and Charles Feil reported their discovery of a technique for crystallizing small, thin transparent rubies from a flux. With the introduction and successful marketing of Verneuil (flame-fusion) synthetic rubies in the early 1900s, however, there was little incentive to further develop other methods of synthesizing ruby. It was not until the early 1960s, when the use of synthetic ruby crystals for laser research was initiated (Maiman, 1960), that the study of the flux growth of ruby was vigorously resumed in an attempt to produce crystals possessing higher optical qualities than those found in the Verneuil product.

One of the first modern flux methods of producing synthetic corundum was described by J. P. Remeika in U.S. Patent 3,075,831, recorded January 29, 1963. Since then, more than 30 different processes for the flux growth of corundum—each using slightly different conditions for growth and different fluxes—have been reported (Nassau, 1980). Many of these methods were intended specifically for industrial applications (such as for lasers, semi-conductors, etc.) and not for use as synthetic gemstones.

Until recently there were only two major producers of flux-grown synthetic rubies that were commercially available for use as gemstones: Chatham Created Gems, Inc., of San Francisco, California, and Kashan, Inc., of Austin, Texas. A relatively new synthetic ruby developed by Professor P. O. Knischka of Styer, Austria (Knischka and Gübelin, 1980; Gübelin, 1982) is now commercially available in the form of rough crystals (P. O. Knischka, personal communication, 1983). Kyocera International, Inc., of Kyoto, Japan, is also producing and marketing faceted synthetic rubies, under the trade name Inamori, but the method of synthesis has not yet been confirmed (it does not show characteristics of flux growth). Likewise, synthetic rubies grown by the Verneuil method are still available on the market.



Figure 1. Ramaura synthetic rubies: the 8.77-ct uncut specimen is a rare example of a large, nearly equidimensional rhombohedral crystal; the faceted stone weighs 3.67 ct. Photo ©1983 Tino Hammid.

In early 1983, the availability of yet another flux-grown synthetic ruby intended specifically for use as synthetic gem material was announced by the Ramaura division of Overland Gems, Inc., of Los Angeles, California (figure 1). The distributor reports that this new synthetic ruby is being marketed under the trade name Ramaura, primarily in the form of faceted stones. The Ramaura firm also reports that they intend to market lower-grade (heavily included) rough material for fashioning into beads and cabochons, as well as single crystals and crystal clusters (Peter Flusser, personal communication, 1983).

The Ramaura synthetic ruby was developed

by a southern California chemist who has extensive experience in industrial crystal growth. Although specific details of the Ramaura process have not been disclosed, we do know that it involves a high-temperature flux method with spontaneous nucleation.

The purpose of this article is to first examine the mode of synthesis of the Ramaura ruby and then present the gemological properties of the material, as well as means of distinguishing this synthetic ruby from its natural counterpart. The author conducted this study by careful examination of 160 faceted Ramaura synthetic rubies of various shapes and cuts, which ranged in weight

from 0.15 to 7.98 ct, and 82 Ramaura synthetic ruby crystals, which ranged in weight from 0.21 to 86.73 ct.

SYNTHESIS OF THE RAMAURA SYNTHETIC RUBY

One important difference in the current growth process of the Ramaura synthetic ruby from that of other commercially available flux-grown synthetic rubies is that seeds are not used. Specifically, the Ramaura process allows spontaneous nucleation (also referred to as self-nucleation) of crystals as the flux melt cools slowly.

For example, Chatham synthetic rubies are grown on seed crystals or seed plates (as reported by Thomas Chatham, personal communication, 1983, and from the author's study of rough materials), which may be either natural or synthetic corundum (synthetic ruby is commonly used at the present time). The seeds are selectively chosen crystals or portions of crystals that are added to the flux-melt mixture, either suspended in the mixture itself or placed in one of a variety of positions within the crucible. The use of seeds enables better control over the growth rate as well as over the perfection and orientation of the crystals grown. The growth rate of the crystal is directly proportional to the surface area of the seed. Since an individual crystal can result in any of several different proportions, the predisposition of the seed can also help modify the growth of the crystal to produce a somewhat predetermined shape and size. Consequently, the use of seeds gives the manufacturer greater control over the end result, that is, the ability to produce larger, cuttable crystals at a faster rate of growth and with proportions that yield faceted stones with desirable weight retention percentages.

In contrast, spontaneous nucleation often produces crystals that grow in uncontrolled directions and yields several different crystal habits (which will be addressed later in this article). One important advantage of this type of growth, however, is that the tabular crystals that are used most often for faceting material contain areas that are much less included than those synthetic rubies grown by flux methods that use seeds. Interestingly, Kashan has reported using spontaneous nucleation as well as seed crystals (Mallas, 1979), although this may be a case where spontaneous nucleation has occurred in the same crucible where seeds have been used, which is common.

Because crystal growth by spontaneous nucleation is much less controllable, the process often results in crystal clusters that are too thin or rhombohedral crystals that are too small to be fashioned into gemstones. Also, the growth time for large cuttable crystals with spontaneous nucleation is often greater than it would be if seeds were employed.

CRYSTAL MORPHOLOGY

As a result of its unusual growth process, the Ramaura synthetic ruby exhibits several different forms. To facilitate the identification of synthetic ruby rough grown by the Ramaura method, a discussion of crystal morphology is provided here. The following morphology descriptions were prepared by Dr. Anthony R. Kampf, curator of mineralogy at the Los Angeles County Museum of Natural History.

Ramaura synthetic ruby crystals grow in three basic habits. In the first, nearly equidimensional crystals are found attached to the crucible walls. An idealized drawing of one such crystal is shown in two views in figure 2. An exceptional example of a Ramaura synthetic ruby crystal exhibiting this type of nearly equidimensional rhombohedral form is shown in figure 1. Only three crystallographic forms (sets of faces) have been observed on these crystals. The rhombohedral forms $R(01\bar{1}2)$ and $r(10\bar{1}1)$ are generally predominant, and the basal $c(0001)$ form is subordinate. Crystals in this habit are remarkably perfect and inclusion-free, with the exception of textural growth features and color zoning; however, they seldom exceed 1 cm in maximum dimension.

In the second habit, ruby crystals growing on the melt surface develop as clusters of very thin plates. The $c(0001)$ form is universally predominant and is bounded by a combination of $r(01\bar{1}2)$, $d(10\bar{1}2)$, and $n(22\bar{4}3)$ forms. The plates typically range from 1 to 3 cm in diameter and from 0.01 to 0.30 cm in thickness. Flux is often trapped along the edges of the rapidly growing plates, resulting in lines of inclusions paralleling the bounding faces. One cluster that consisted of very thin, clean plates measured nearly 9 cm in length and 2 cm in height. This crystal cluster also exhibited a very curved nature that reflected the curvature of the crucible.

The crystals that lend themselves most to faceting, the third group, are similar in morphology to the plates described above, but attain sig-

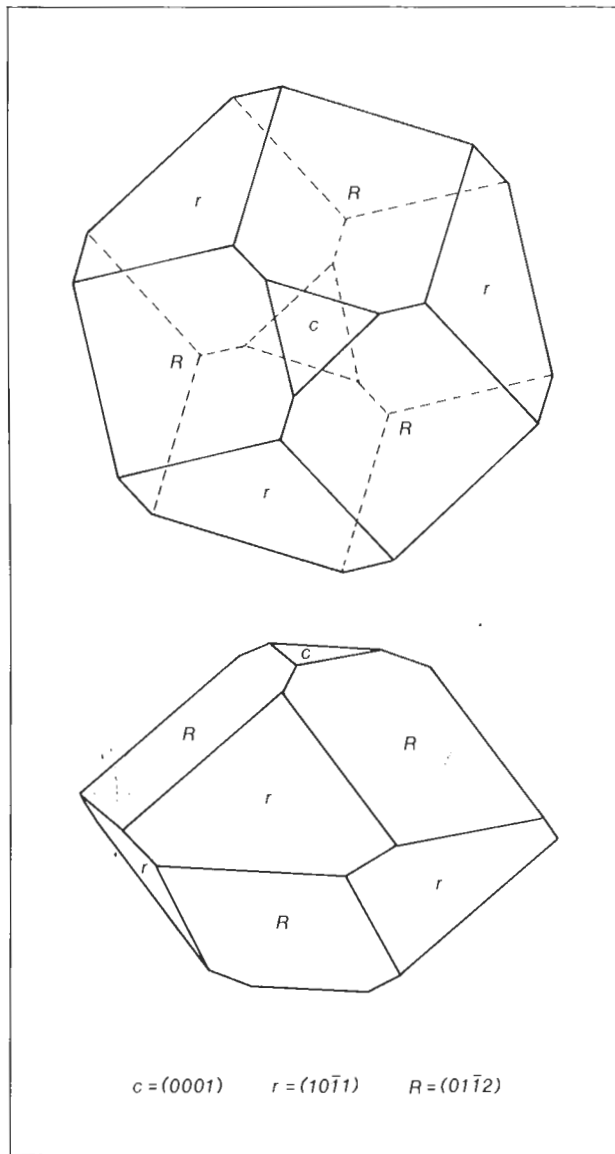


Figure 2. An idealized drawing of the crystal morphology of a nearly equidimensional rhombohedral Ramaura synthetic ruby crystal. Drawing by Dr. Anthony R. Kampf.

nificantly greater thickness. They may be up to 4 cm across and are usually between 0.5 and 3.0 cm thick (occasionally they occur thicker). These ruby crystals grow attached to the sides and bottom of the vessel and consequently may exhibit a slightly curved attachment surface. They usually contain some trapped flux, but very large areas are free of inclusions except for growth features and color zoning.

GEMOLOGICAL CHARACTERISTICS

The new Ramaura synthetic ruby exhibits many characteristics that are typical of flux-grown synthetic rubies, in addition to some that are distinctly different from any observed thus far in other commercially available synthetic rubies. In some situations, the gemologist will have to carefully examine several of the gemological properties and meticulously study the frequently observed subtle internal characteristics to conclusively identify this new synthetic ruby. The following discussion examines in detail the gemological characteristics of the Ramaura synthetic ruby. These characteristics are summarized in table 1.

Visual Appearance. As the faceted Ramaura synthetic rubies are examined with the unaided eye, several features can be noted, in particular, color, transparency, and clarity.

With regard to color, the Ramaura synthetic rubies examined by the author varied from nearly pure red, to slightly orangy red, to slightly purplish red and purple red; all varied in saturation from moderate to vivid. Also examined were faceted stones that exhibited slight to moderate saturations of light red secondary hues (thus, giving a distinct pink appearance). Figure 3 shows many of the hues that the Ramaura synthetic ruby may exhibit. As is the case with the Kashan synthetic rubies, the color range of the rubies synthesized by Ramaura overlaps to some degree with the wide range of colors produced in their natural counterparts from several different geographical localities.

Also very evident to the unaided eye in many of the faceted Ramaura synthetic rubies is an unusual degree of transparency. This is perhaps caused in part by the unique growth process. Since none of the growth is forced (as it is in techniques involving the use of seeds), fewer impurity ions are trapped, so there are fewer dislocations or defects in the crystal lattice. The growth process also minimizes the inclusions that are visible to the unaided eye or observed under the gemological microscope.

The clarity of the faceted Ramaura synthetic rubies, when examined with the unaided eye, varies from stones that appear to be completely free of inclusions to those that have areas of visible flux inclusions and still others that exhibit only slight textural growth features and color

zoning. The growth features and color zoning are most easily observed when the faceted stone is tilted at an angle.

Optic Axis Orientation. With the Ramaura synthetic ruby, the direction of optic axis orientation is variable. Since the synthetic growth process involves spontaneous nucleation, which produces many different external crystal forms, the faceted stones can be cut with various orientations to obtain the greatest weight retention. In the faceted stones examined by the author, the direction of the optic axis orientation varied greatly from stone to stone: in some it was parallel to the table, in some perpendicular to the table, and in others at various angles between these two.

Some faceted synthetic rubies, such as many produced by the Verneuil process, are typically oriented with the optic axis nearly parallel to the table. Specifically, Verneuil boules often split lengthwise to ease internal strain (Barta, 1957), which produces rough that yields the greatest weight retention when the table of the faceted stone is oriented parallel to the length of the boule. With this orientation, the optic axis is usually only about 30° from parallel to the table (R. T. Liddicoat, Jr., personal communication, 1983). It has been reported that natural ruby rough, in contrast, often yields the most attractive color and the greatest weight retention when

the optic axis is oriented perpendicular to the table (Liddicoat, 1977).

The fact that any natural or synthetic ruby could be fashioned into a faceted stone with any one of several possible optic axis orientations means that the direction of this orientation should not be used as even a vague indicator of natural or synthetic origin.

Refractive Indices and Birefringence. Refractive indices were determined using a GEM Duplex II refractometer in conjunction with a monochromatic light source equivalent to sodium vapor. Testing revealed that most of the Ramaura synthetic rubies showed refractive indices of $\omega=1.762$ and $\epsilon=1.770$, while some of the material had values of $\omega=1.760$ and $\epsilon=1.768$ (this variation is also observed in natural ruby). These values give an optic character of uniaxial negative and a birefringence of 0.008.

Pleochroism. A calcite dichroscope was used to examine this property. In the faceted Ramaura synthetic rubies examined by the author, the dichroic effect was observed as moderate to strong in various hues depending on the color of the stone being examined. Commonly observed was dichroism that ranged in various saturations of the following hues: reddish purple and purplish red parallel to the c-axis, and orangy pink (occasionally higher saturations of pink made the

TABLE 1. The gemological properties of faceted Ramaura synthetic ruby.

R.I. and biref.	Pleochroism	Luminescence ^a		X-rays	Absorption Spectrum ^b (4000 Å–7000 Å)	S.G.	Inclusions
		Long-wave U.V. radiation	Short-wave U.V. radiation				
$\omega=1.762$ $\epsilon=1.770^c$ and $\omega=1.760$ $\epsilon=1.768^c$ 0.008	Moderate to strong. Reddish purple and purplish red parallel to the c-axis. Orangy pink, orangy red, and pinkish orange perpendicular to the c-axis.	Variable: intensity ranges from moderate to extremely strong; overall fluorescent color ranges from a dull, chalky red to orangy red. Some stones exhibit small zones of chalky yellow. No phosphorescence.	Intensity ranges from weak to strong; nearly the same fluorescent colors as long-wave reaction, with the addition of chalky, slightly bluish white zones observed in a few stones. No phosphorescence.	Variable: some areas inert, others range in intensity from extremely weak to weak; fluorescent colors range from dull, chalky red to orangy red. No phosphorescence.	Absorption lines at 4750, 4765, 4685, 6592, 6680, 6928, and 6942 Å; broad absorption blocking out all of the violet and some of the blue, all of the green and yellow, and a small area in the orange portion of the visible spectrum. Not diagnostic.	3.96–4.00	Various forms of residual unmelted flux that may be angular or rounded and white to orange-yellow; flux "fingerprints" that range from flat to very wispy (wispy veils), fine to coarse, near colorless to white, and are seen in low to high relief; and numerous forms of growth features and color zoning. "Comet tails" occasionally seen.

^a Luminescence reactions listed are for faceted stones only and may change if the manufacturer changes the amount of type of dopant added to the flux-melt mixture.

^b The visible light absorption spectrum as observed through a normal "hand-held" type of gemological spectroscope.

^c This variation is also observed in natural ruby.

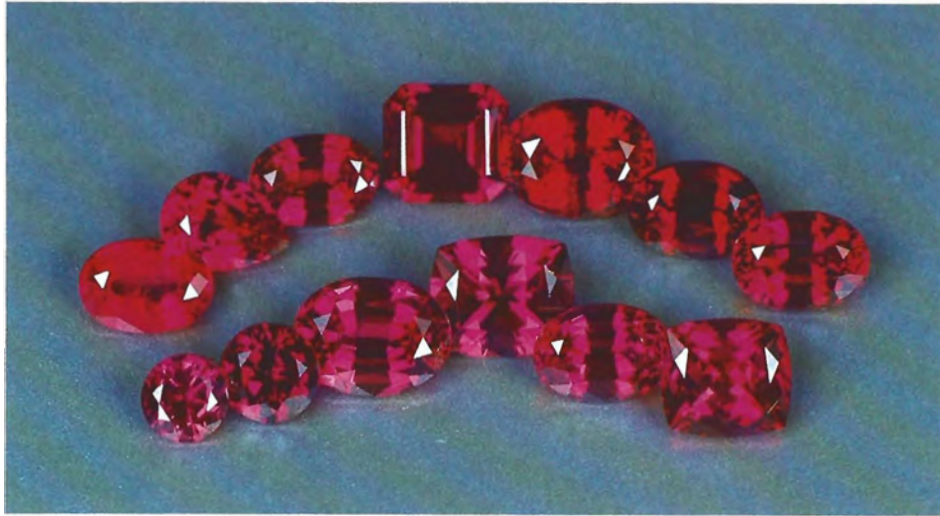


Figure 3. The Ramaura synthetic ruby is produced in several different hues, many of which are illustrated here (the stones range in weight from 0.50 to 2.00 ct). Photo by Michael Havstad.

hue orangy red) and pinkish orange perpendicular to the c-axis (slight overtones of brown were also observed).

Reaction to Ultraviolet Radiation. One interesting feature of the Ramaura is that the manufacturer has attempted to produce a characteristic fluorescence in the material, with the intended purpose of rendering the Ramaura synthetic ruby easily identifiable when exposed to ultraviolet radiation. It is well known that fluorescence in a gemstone may be strongly influenced by the presence of small amounts of trace-element impurities within the gem material (Nassau, 1980). The manufacturer of the Ramaura synthetic ruby has attempted to cause a fluorescence shift with the addition of minute amounts (several parts per million) of a dopant to the initial flux-melt mixture. The dopant that is currently being used is reportedly a rare-earth element (the identity of which the manufacturer wishes to remain undisclosed at this time). The dopant is absorbed in the growing crystal by replacing aluminum (Al) ions, causing the fluorescence in some areas of the rough material to shift toward orange-yellow when the synthetic ruby is exposed to ultraviolet radiation.

It is important to note at the present time that the majority of the faceted stones the author has examined to date do not show evidence of this dopant in the form of a characteristic orange-yellow fluorescence. In addition, electron microprobe analysis and energy dispersive spectrophotometry-X-ray fluorescence (EDS-XRF) analysis revealed no indication of the reportedly added dopant. If it is present, it is in concentrations below the detection limits of these very sensitive

tests. The fluorescent reactions observed and the problems encountered in the doping process are discussed below.

Luminescence: Rough Material. Exposure of the Ramaura synthetic ruby crystals to long-wave ultraviolet radiation (3669 Å) revealed variable fluorescence reactions, ranging in intensity from moderate to very strong. The overall color of the fluorescence ranged from a dull, chalky red to an orangy red through slightly reddish orange (nearly pure orange) to a pure red that was similar in nature to the fluorescence often observed in Verneuil synthetic rubies.

Most of the crystal clusters and tabular single crystals exhibited areas of fluorescent zoning that also varied in intensity from strong to very strong. The zoning ranged in color from a distinct sulfur yellow through a yellowish orange to a nearly pure orange. Although generally quite thin, these zoned areas also possessed a dull, chalky, translucent nature. The fluorescent zoning was most frequently observed in concentrated, thin areas parallel to the external surfaces of the crystals (figure 4). The dull, chalky fluorescent zones were observed on nearly all of the surfaces of the crystal clusters and tabular single crystals [with the (0001) faces having a thicker concentration]. The only surfaces that consistently did not exhibit this fluorescent zoning were those that had grown attached to the crucible surfaces.

The fluorescent zones (and their absence on surfaces that had been attached to the crucible) would indicate a change in the environment toward the end of the growth process. If the assumption that the chalky yellow and orangy yel-

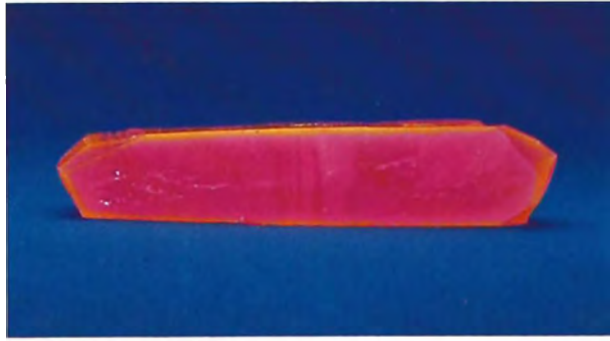


Figure 4. The strong yellow long-wave fluorescent zoning shown here paralleling the edges of this 56.14-ct Ramaura synthetic ruby crystal (the crystal surface in the foreground of the photograph grew attached to the crucible, and thus is absent of this fluorescent zoning) is reportedly induced by the addition of trace amounts of a rare-earth dopant. Photo by Michael Havstad.

low fluorescent zoning was caused by the addition of a rare-earth element is correct, the zoning is most probably caused by a dominating concentration of the dopant in the melt solution and the rapid rate of growth at the end of the growth process.

Exposure of the Ramaura synthetic ruby crystals to short-wave (2537 Å) ultraviolet radiation revealed similar reactions to those observed with long-wave ultraviolet radiation, although one of the crystal clusters examined (which the manufacturer reported had a greater amount of dopant than the material grown previously), behaved differently. In this cluster, the dull, chalky yellow fluorescence was predominant, quenching most of the orange-red fluorescence that had been seen under long-wave ultraviolet radiation. With this one exception, the major difference of the short-wave fluorescence as compared to the long-wave reaction was the intensity, which ranged from very weak to moderate in the former.

Exposure of the Ramaura synthetic ruby crystals to X-rays also revealed a variable fluorescent reaction. Some areas were inert, while others ranged in intensity from very weak to weak. The color of the X-ray fluorescence ranged from patchy areas of dull chalky red to orangy red with a few smaller areas of dull, opaque chalky white and yellowish white. No visible phosphorescence was observed after exposure to X-rays for 10 seconds.

Luminescence: Faceted Stones. Exposure of the faceted Ramaura synthetic rubies to long-wave ultraviolet radiation (3660 Å) revealed variable fluorescence, with the majority ranging in intensity from strong to extremely strong and a few exhibiting a moderate intensity. The overall color of the fluorescence in the faceted stones varied from dull chalky red to orangy red. Also seen in a few stones was an orange-red to pure red fluorescence that was very similar in nature to that often observed in Verneuil synthetic rubies, in that it was very vibrant and transparent in contrast to the dull, chalky (translucent, nearly opaque) nature of the fluorescence observed in many flux-grown synthetic rubies.

As would be expected, most of the thin yellow fluorescent zones were removed during the cutting process. Some of the faceted Ramaura synthetic rubies, however, exhibited small areas of dull, chalky yellow fluorescent zoning near the outer edges of the stone (frequently observed at the culet and girdle edges). There was not a sharp delineation between the dull, chalky yellow fluorescent zones and the red to orangy red fluorescence; rather a subtle blending of the two fluorescent colors was most commonly observed. If the property of fluorescence is hastily examined, the chalky yellow fluorescent zones could be overlooked; if it is carefully examined, however, these zones are readily apparent and provide the gemologist with a good indication of the synthetic origin of the material.

Exposure of the faceted Ramaura synthetic rubies to short-wave ultraviolet radiation (2537 Å) also revealed a variable fluorescence. The intensity ranged from weak to strong, with the majority of the stones exhibiting a moderate intensity. The zoning and color of the short-wave fluorescence was similar to that of the long-wave fluorescence. The faceted stones exhibited a dull red to orangy red fluorescence. Of the few stones that exhibited a pure red fluorescence similar to that often observed in Verneuil synthetic rubies when exposed to long-wave ultraviolet radiation, only three showed the same overall reaction to short-wave ultraviolet radiation. The remainder in this group exhibited very easily visible zones of strong chalky, slightly bluish white zoning, confined either to the table or to areas near the culet of the faceted stone. This fluorescent zoning also blended gradually into the overall red to orangy red areas. The same stones that exhibited the

chalky yellow zones when exposed to long-wave ultraviolet radiation also showed nearly the same reaction to short-wave ultraviolet. The major difference was the intensity of the yellow zoning, which was stronger with short-wave than with long-wave.

Exposure of the faceted Ramaura synthetic rubies to X-rays revealed an extremely weak to weak fluorescence, with a few stones exhibiting a fluorescence of moderate intensity. The color of the X-ray fluorescence ranged from a dull, chalky red to an orangy red. In some of the faceted material, the centers of the stones showed a nearly inert reaction to X-rays, with only the edges of crowns fluorescing very weakly. This was particularly noticeable when the faceted stones were placed table down. The same reaction is also observed in many other synthetic rubies as well as in natural rubies. No visible phosphorescence was observed in the faceted stones after X-ray excitation for 10 seconds.

Although at this time the reported addition of a dopant to produce a characteristic fluorescence in the Ramaura synthetic ruby cannot always be considered conclusive in identifying this new synthetic ruby, the distributor reports that the manufacturer is continuing experimentation in this area (Peter Flusser, personal communication, 1983).

Several conclusions can presently be drawn from the reactions to ultraviolet radiation of the faceted Ramaura synthetic ruby:

- The intensity of the overall fluorescence is ambiguous, in that it overlaps with the fluorescent reactions of some natural rubies, with the exception that some natural rubies reveal an inert reaction, while all of the Ramaura synthetic rubies exhibited some degree of fluorescence.
- If the chalky yellow and chalky, slightly bluish white fluorescent zones are observed with long-wave and/or short-wave ultraviolet radiation, the gemologist has a very good indicator of the synthetic origin of the material.
- It is extremely important to note, however, that if the chalky fluorescent zoning is not present, because of its initial absence in the rough material or its removal during the cutting process, nothing conclusive concerning the synthetic or natural origin of the material in question can be determined on the basis of its luminescence.

Transparency to Short-wave Ultraviolet Radiation. Synthetic ruby in general transmits ultraviolet radiation more readily than does natural ruby. One method of determining the degree of transparency to short-wave ultraviolet radiation is to record it on photographic print paper. This method is often referred to as the short-wave ultraviolet transparency test.

For this test, seven faceted Ramaura synthetic rubies were selected, two that reportedly were undoped and five that reportedly contained the added dopant. The latter five stones were chosen on the basis of their wide range of hues and varying degrees of clarity. For comparison purposes, a selection of synthetic rubies of different manufacture and several natural rubies from various geographical localities were also included.

The subject stones were immersed table down in water over the emulsion side of a piece of contact-positive printing paper in a darkroom. The short-wave ultraviolet unit was positioned 18 inches above the vessel and the paper was exposed for approximately one-half second. Developing and fixing were done in the usual manner. The results are shown in figure 5 (top row = natural rubies, bottom row = Ramaura synthetic rubies; middle row = synthetic rubies of various manufacturers). At this point, it would appear that there is not sufficient difference in transparency between some natural stones and some synthetics to use this test as the only basis for identification.

Spectral Examinations. The visible light absorption spectra of several faceted Ramaura synthetic rubies were examined with a GEM spectroscopy unit. The observed spectra appeared to be essentially the same as the absorption spectrum described by Liddicoat (1977) for natural and synthetic ruby, as shown in figure 6. For more detailed examinations, the previously mentioned group of seven Ramaura rubies (specifically chosen on the basis of whether or not they were doped and the range of hues and clarity represented) were subjected to the following tests: (1) ultraviolet and visible light spectrophotometry, (2) infrared spectrophotometry, (3) fluorescence spectrophotometry, and (4) energy dispersive spectrophotometry-X-ray fluorescence (EDS-XRF) analysis.

Ultraviolet and Visible Light Spectrophotometry. Examination of the ultraviolet and visible

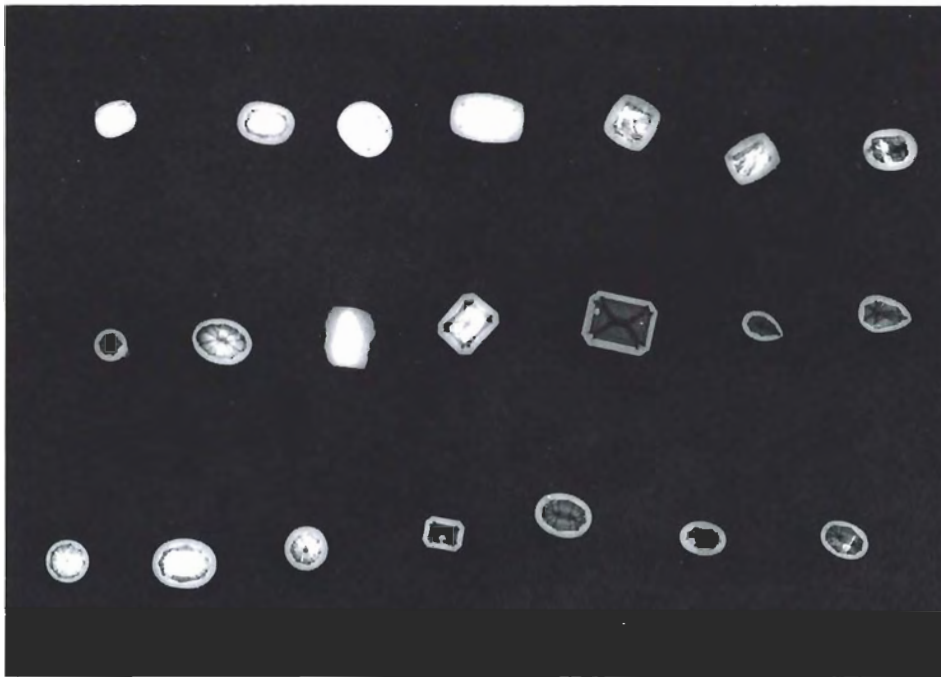


Figure 5. The results of a short-wave ultraviolet transparency test performed on a carefully selected group of natural and synthetic rubies. Top row, natural rubies (left to right): 1, 2, and 3 are from Southeast Asia; 4, 5, and 6 are from East Africa; and 7 is from Burma. Middle row, synthetic rubies (left to right): 1 and 2 are Kashan, 3 is Knischka, 4 and 5 are Verneuil process (manufacturer unknown), 6 is Inamori, and 7 is Chatham. Bottom row, Ramaura synthetic rubies (left to right): reportedly 1 and 2 are undoped and 3 though 7 are doped with trace amounts of a rare-earth element.

light absorption spectra of the seven faceted Ramaura synthetic rubies was conducted on a Pye Unicam, SP8-100 UV-VIS spectrophotometer by G. Bosshart, laboratory director at the Swiss Foundation for the Research of Gemstones, Zurich, Switzerland (see figure 7).

A procedure has been described by Bosshart (1982) which evaluates the differential transmission behavior in the ultraviolet region of natural and synthetic rubies. This method is a refined version of the short-wave ultraviolet transparency test discussed above (see figure 5).

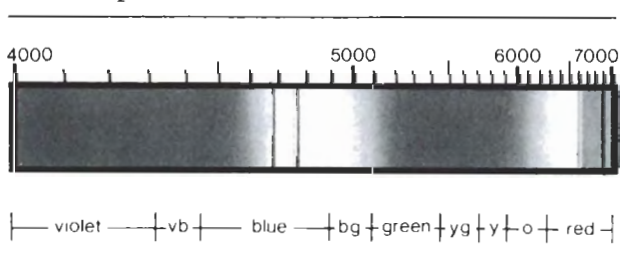
Using this method to examine many natural rubies from various geographical localities and synthetic rubies of different manufacture, Bosshart was able to show many differences in ultraviolet transmission. The "population" dis-

tribution of natural and synthetic rubies as determined by Bosshart's testing is reproduced in figure 8. His testing of the seven selected Ramaura synthetic rubies revealed interesting results. Five of the seven fell within or near the natural population (depending on the optic axis orientation); one stone fell barely within a synthetic population, while the other was near it. The latter two stones were both reportedly undoped.

Infrared Spectrophotometry. B. Suhner, of Herisau, Switzerland, used a beam condenser to examine the infrared spectra of three of the seven selected samples. All three stones absorbed heavily below 1500 cm^{-1} . The only safe statement that can be made concerning the infrared examination is that the Ramaura synthetic rubies, like other natural and synthetic corundums, are free of H_2O and OH.

Fluorescence Spectrophotometry. The fluorescence spectra were recorded on a Perkin-Elmer fluorescence spectrophotometer 650-10, also by B. Suhner. Although Suhner recorded extreme variability in the relative excitation-peak intensities, qualitatively he found them to be identical: the spectra showed the same number of peaks in the same wavelength positions except for a band at 318 nm in one of the samples. The excitation peak at 268 nm, which has been observed in other synthetic rubies as well as in many natural rubies from Burma and Sri Lanka, but is absent in most

Figure 6. Drawing of absorption spectrum for Ramaura synthetic ruby, as observed on a direct-vision spectroscopy (in angstroms) at room temperature.



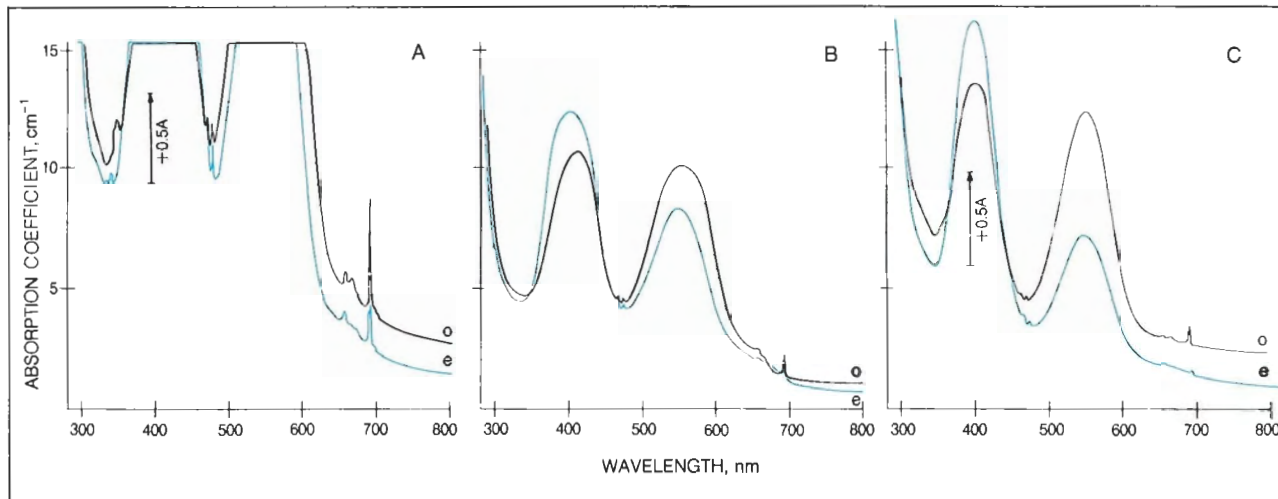


Figure 7. Polarized ultraviolet-visible absorption spectra of three faceted Ramaura synthetic rubies recorded at ambient temperature. Vibration *o* (of the ordinary ray) perpendicular to the optic axis (black), vibration *e* (of the extraordinary ray) parallel to the optic axis (blue). The absorption coefficient is approximate. Profiles at +0.5 *A* (absorbance unit) level above absolute absorption minimum in the ultraviolet. Spectra particularities are as follows: (A) Peaks at approximately 405 nm and 550 nm well off-scale due to high chromium dotation producing a dark red color. This 0.84-ct stone was reportedly undoped. (B) Low chromium dotation leading to a pale violetish red color. (Peak heights reduced by sample-related straylight influence, except for the *e*-peak at about 548 nm.) This 0.92-carat stone was reportedly doped. (C) Low chromium and iron dotation giving a slightly violetish red color. Note: The absorption maxima and minima below 460 nm are influenced by iron content alone. No straylight effects: proper peak height ratios for ruby. Also note that absorption in the blue region (480 nm) is lower than in the ultraviolet (350 nm), contrary to stone A. This 0.94-carat stone was reportedly doped. Spectra and legend provided by G. Bosshart.

other natural rubies (Bosshart, 1982), was not present in the Ramaura synthetic rubies that were examined. Any details related to the re-

ported rare-earth dopant were also not observed. Low-temperature fluorescence spectra may yield more specific information.

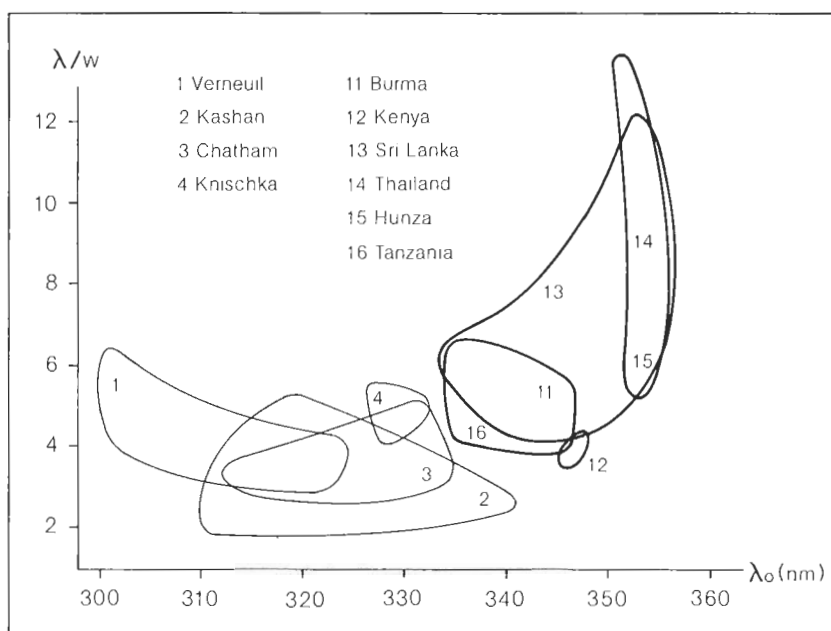


Figure 8. "Population" distribution of natural rubies (top right) and synthetic rubies (bottom left), determined from the ultraviolet absorption minima (vibrational component $e > o$); after G. Bosshart. Seven specifically chosen Ramaura synthetic rubies were tested with this method: the five reportedly doped stones fell well within the natural population areas; the remaining two reportedly undoped Ramaura synthetic rubies were plotted very near the synthetic population areas.

EDS-XRF Analysis. The seven selected Ramaura synthetic rubies were examined using EDS-XRF analysis by Dr. H. A. Hänni of the Swiss Foundation for the Research of Gemstones and Dr. W. B. Stern of the Geochemical Laboratories, Institute for Mineralogy and Petrography, Basel, Switzerland. For a detailed description of this method of analysis, the reader is referred to Stern and Hänni (1982). The analyses revealed extremely variable results on the seven stones. Trace-element contents and concentrations varied considerably among the seven samples.

In a recent paper (1982), Hänni and Stern reported on their investigation of gallium (Ga) as a trace element in a small selection of natural and synthetic corundums. All of the natural corundums contained Ga concentrations in excess of 200 ppm. In the synthetic corundums examined in that study, Ga could not be detected.

Their initial examinations of the seven Ramaura synthetic rubies indicated the presence of Ga in concentrations near the detection limit of EDS-XRF analysis in six of the seven stones. The remaining stone showed greater concentrations of Ga.

Because of the presence of Ga in the seven Ramaura synthetic rubies tested, the occurrence of this element in trace amounts should not be considered a conclusive indicator of natural origin at this time. In fact, from the above discussion, it is evident that none of these spectral examination techniques currently offers a definitive means of identifying the Ramaura synthetic ruby from its natural counterpart.

Specific Gravity. The specific gravity values for the Ramaura synthetic ruby were determined by means of the hydrostatic technique, using a Voland diamond balance equipped with the necessary specific gravity attachments. The synthetic material showed slight variations in density, from 3.96 to 4.00.

Inclusions. With the exception of the luminescent reactions of a small percentage of the faceted stones tested by the author, all of the previously discussed gemological properties of the Ramaura synthetic ruby overlap to some extent with those of its natural counterpart. Therefore, at the present time the most important means of distinguishing the new Ramaura synthetic ruby from natural ruby is provided by the presence of characteristic inclusions.

Because of controlled environments for crystal growth, synthetic rubies in general exhibit a somewhat limited variety of inclusions in contrast to the seemingly limitless multiplicity of inclusions found in natural rubies. The current growth process of the Ramaura synthetic ruby produces material that contains an even narrower variety of internal characteristics than is frequently observed in other commercially available faceted flux-grown synthetic rubies, such as the Chatham and Kashan products.

Despite the small number of basic inclusion types found in the Ramaura synthetic ruby, most of the internal characteristics can be considered diagnostic of synthesis to the experienced gemologist. To date, the following types of inclusions have been commonly observed by the author in faceted pieces of Ramaura synthetic ruby: various forms of flux, fractures and healed fractures, and numerous forms of growth features and color zoning. In a small number of the stones examined, "comet tail" inclusions were observed.

Platinum was not observed as an inclusion in any of the 160 faceted Ramaura synthetic rubies examined. However, one very small, thin metallic flake, presumably platinum, was seen positioned very near the surface of one of the Ramaura crystals. Platinum crucibles reportedly are used in the Ramaura growth process. However, the type of flux currently used by the manufacturer does not usually attack the platinum crucible (Peter Flusser, personal communication, 1983); thus, platinum does not commonly occur as an inclusion, and at this time it should not be considered as one that is characteristic of the Ramaura synthetic ruby.

The faceted stones examined ranged from those with prominent and easily identifiable flux inclusions, color zoning, growth features, and fractures, to those that appeared to be flawless. The seemingly flawless stones, however, revealed distinctive subtle growth features when they were carefully examined with the gemological microscope.

Flux. Typically observed in other flux-grown synthetic rubies are various forms of residual unmelted flux, which commonly range from transparent and near colorless to opaque and white. Many of the new Ramaura synthetic rubies also contain several forms of flux inclusions. These flux inclusions are distinctive from those ob-



Figure 9. A distinctive orange to yellow color characterizes many of the flux globules and flux-filled voids in Ramaura synthetic rubies. The "crackled" appearance seen here is also quite typical of the Ramaura growth process. These flux inclusions can range from very rounded to very angular with straight, parallel steps. Dark-field and oblique illumination, magnified 35 \times .

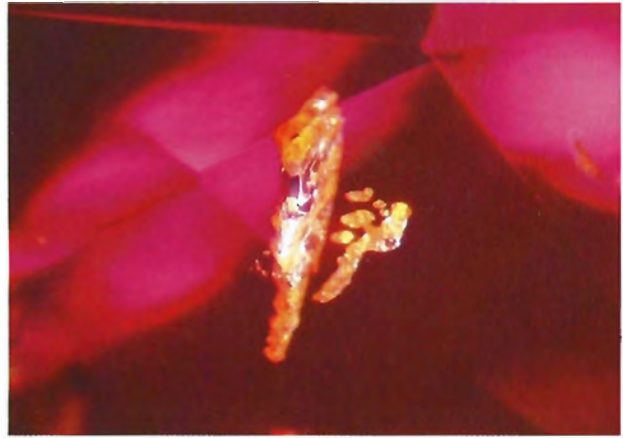


Figure 10. Flux-filled voids exhibiting portions that range from near colorless and highly reflective through white to orange-yellow. Dark-field illumination, magnified 55 \times .

served in other flux rubies in that they frequently appear orange-yellow, although they may also range from near colorless to white.

The flux typically observed in the Ramaura synthetic rubies ranged in size from minute, nondescript particles to very large, "drippy"-appearing globules to primarily flux-filled negative crystals. These can be very angular with straight, parallel steps, or they may be very rounded in appearance (see figure 9).

Although these flux inclusions are frequently orange-yellow, opaque, and seen in very high relief, they may also exhibit portions that range from near colorless to white and semitransparent to opaque, observed in low to very high relief with highly reflective surfaces (see figure 10). They exhibit several forms that may take on a "rib-like" arrangement or have a "rod-like" appearance and can also be either angular or rounded. They may be observed singularly, randomly interspersed among one another, or in somewhat parallel clusters or groups (see figure 11).

Many of the predominantly orange-yellow flux inclusions are observed as partially filled flux channels or voids. This type of inclusion forms when molten flux is trapped within the rapidly growing crystal and later crystallizes or partially crystallizes as the synthetic ruby crystal cools. This often results in a "crackled" appearance (again, see figures 9 and 11). These inclusions may

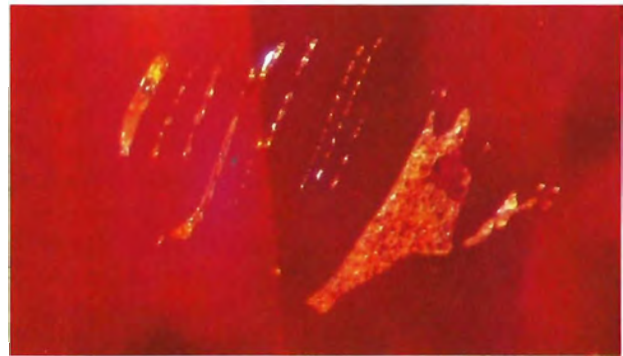


Figure 11. Somewhat parallel groups of voids filled with orange-yellow flux. Some of these inclusions exhibit a two-phase-like appearance; however, they are most probably solid in nature. Dark-field and oblique illumination, magnified 45 \times .

also exhibit a two-phase-like appearance; however, they are probably not, by definition, two-phase inclusions but, rather, are completely solid in nature (see figure 11).

Also observed, though rarely, were flux-filled voids that ranged from mostly white to those with small portions of highly reflective, near-colorless areas. These were both rounded and angular in appearance and were interspersed among one another in groups or clusters.

Some of the Ramaura synthetic rubies frequently revealed a residual unmelted flux in the form of "fingerprints" that ranged from transparent to opaque, and near colorless to white, in low to high relief. None of the flux fingerprints was orange-yellow. These fingerprint patterns also



Figure 12. Healing fracture filled with white flux forming a flux "fingerprint" composed of a combination of tiny, closely arranged droplets and more loosely arranged mesh-like patterns. Dark-field and oblique illumination, magnified 32 \times .



Figure 13. White, wispy veils, fine to moderate in texture, betray the synthetic origin of this Ramaura synthetic ruby. Dark-field and oblique illumination, magnified 40 \times .

varied from very tightly arranged drops or grains, which formed mesh-like patterns that remarkably duplicated the appearance of natural fingerprints, to loosely arranged, wide, flat mesh- or lace-like patterns that were easily identifiable as flux. These forms were also observed together in one fingerprint pattern (see figure 12). Both types of flux fingerprints were observed to range from flat to very curved forms, often referred to as wispy veils, that sometimes intersected in several planes (see figure 13) or radiated outward from a central point (see figure 14). As with the previously discussed orange-yellow flux inclusions, the individual grains or drops that form the fingerprint patterns may give the appearance of minute two-phase-like inclusions, but it is probable that these, too, are completely solid. The orange-yellow flux inclusions and the white flux fingerprints were occasionally seen in association with one another (see figure 15).

Fractures. Many of the Ramaura synthetic rubies contained fractures and healed fractures, which were often iridescent and reflective at certain viewing angles when examined with either dark-field or oblique illumination. Many of these fractures and healed fractures were also very similar in appearance to the epigenetic staining that is observed in many natural minerals. At the present time, these fractures cannot be considered diagnostic of synthesis, since they are often remarkably similar to those seen in natural rubies.

Growth Features and Color Zoning. Observed in all the faceted Ramaura synthetic rubies examined were various forms of growth features and

color zoning. The term *growth feature* is used here to refer to other irregularities in the internal appearance of the material that are not inclusions in the narrow sense of the word. They include optically detectable inhomogeneities such as twinning, parting, and structural defects, and growth phenomena such as "phantoms." The growth features and color zoning were extremely variable in appearance. They were observed in one or a combination of the following forms: straight, parallel, and uniform; curved; angular; hexagonal; very swirled and irregular, resembling "phantom" or "scotch and water" graining in diamonds; or intersecting in various planes (see figures 16 through 26). Some of these growth features were reminiscent of those often observed in many Chatham (Fryer et al., 1981) and Kashan synthetic rubies (Kane, 1979; Gübelin, 1983). The growth features and color zoning ranged from being very easily seen with the unaided eye to being difficult to locate under magnification even when several different lighting techniques were used. Although many of the faceted stones (some as large as 5 ct) contained no flux inclusions or were such that the flux could be easily removed with recutting, they all contained some form of growth features or color zoning. In some stones, the growth features or color zoning were barely perceptible; in others they were easily seen throughout the entire stone.

As is the case with most natural or synthetic materials, the nature of these growth features can be very elusive. When a faceted stone is held in a certain manner and is viewed at specific angles, the growth features may be very evident. At other positions and viewing angles, they may totally

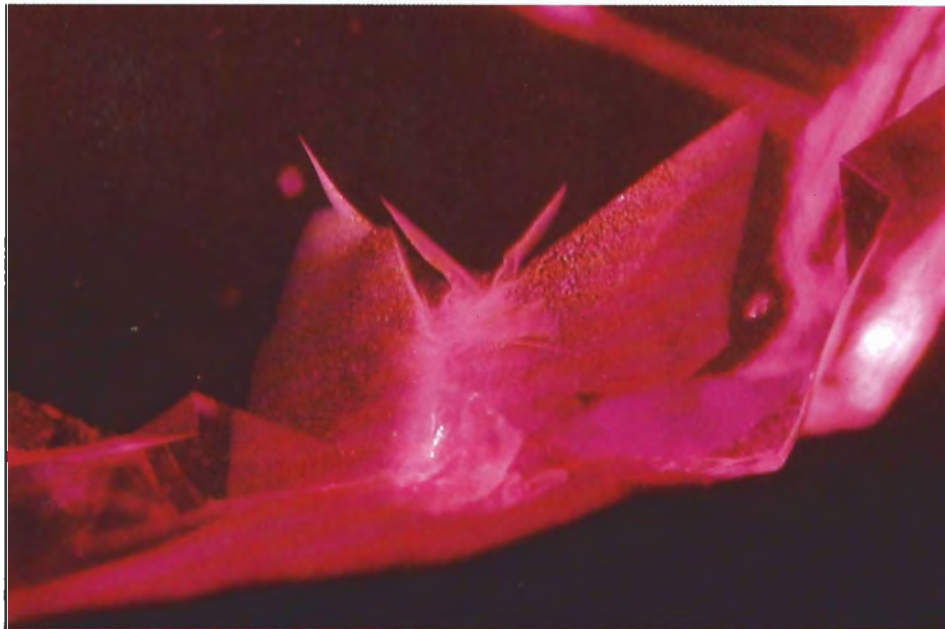


Figure 14. White flux "fingerprints" radiating outward from a central point in a Ramaura synthetic ruby. Dark-field and oblique illumination, magnified 25 \times .

disappear from view (see figure 16). Certain growth features may be seen only through the pavilion and not through the crown or vice versa; others may be readily apparent when the stone is held table to culet, but will not be seen at all when it is held girdle to girdle.

Likewise, the appearance of an inclusion can be changed dramatically by employing different types of illumination. For routine examination, dark-field illumination usually provides the most effective means of lighting the interior of a gemstone. However, the most effective for examining color zones and growth features in synthetic and natural rubies are oblique, transmitted, and diffused illumination, as well as shadowing (often used in combination with one another or with dark-field). The reader is referred to Koivula (1981, 1982a, and 1982b) for a detailed discussion of oblique and transmitted illumination and the shadowing technique. Diffused illumination is produced by placing some type of diffuser (e.g., a tissue) over dark-field illumination or transmitted light. Similar to, but softer than, transmitted light, the results of diffused illumination approximate those obtained with immersion techniques, which are often far more troublesome.

Because many Ramaura synthetic rubies exhibit only growth features and color zones, it is extremely important to be familiar with these inclusions and how to locate them. Although some features are similar to those observed in other flux-grown synthetic rubies, others will un-

doubtedly be new to many gemologists. Among the potentially most confusing are the uniform, nearly straight parallel growth bands (see figures 16 and 17) which can also be observed forming an angle (see figure 18). These growth features are

Figure 15. Orange-yellow flux globules interspersed among white, wispy flux "fingerprints" in a Ramaura synthetic ruby. Dark-field and oblique illumination, magnified 20 \times .



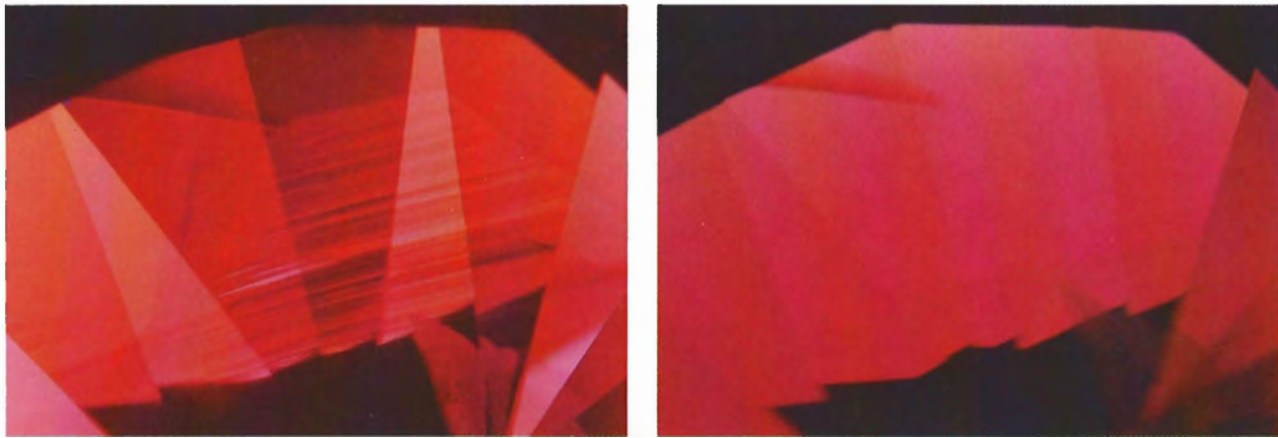


Figure 16. These two photomicrographs of a Ramaura synthetic ruby fully illustrate how dramatically the appearance of some growth features can change with slight movements of the stone. On the left are seen prominently visible, nearly straight parallel growth bands. On the right, the stone has been tilted very slightly, causing nearly all of the growth features to disappear from view. Dark-field illumination, magnified 20 \times .

easily distinguishable from the polysynthetic twin-lamellae that can occur in natural ruby; therefore, they are diagnostic of synthesis. The planes of the twin-lamellae, or laminated twinning, extend deep into the interior, often completely through the natural ruby, in contrast to some of the synthetic growth bands which disappear from view when the microscope objective is raised or lowered. In this respect, the nearly straight, parallel growth bands react very comparably to the familiar curved striae that are typical of Verneuil synthetic rubies. This particular reaction and type of inclusion is also observed frequently in Kashan synthetic rubies (Gübelin, 1983).

Various types of angular growth zoning are also observed in the Ramaura synthetic ruby. They may be similar in nature to those growth features previously discussed or may extend deep into the stone and closely resemble laminated twinning (figure 19). This angular zoning often seems confusing to gemologists; however, it can be considered diagnostic of the Ramaura if the differences from natural growth features are understood.

Although angular zoning planes that do not intersect one another (V-shaped) are quite common in some varieties of corundum, especially blue sapphire, they have not been observed by the author in natural transparent ruby. Only laminated twinning planes that intersect one another at an angle or rhombohedral twin lamination even approach this type of zoning. Strongly defined "hexagonal" or angular growth zoning that

does not intersect has thus far been observed only in natural rubies that are translucent or opaque; usually they are asteriated.

The angular or "hexagonal" zoning in synthetic rubies may appear to meet in sharply defined angles or, more commonly, at slightly rounded or blurred junctions, depending on the viewing angle and type of illumination used. This characteristic provides the gemologist with an easily identifiable and diagnostic inclusion.

Single, straight growth planes that extend deep into the interior of the stone are sometimes observed in the Ramaura synthetic ruby. If isolated, these growth planes are nearly indistinguishable from laminated twinning in natural rubies. However, they are commonly associated with curved or irregular growth features, such as is shown in figure 20, and the synthetic origin of the stone is betrayed.

Many other growth features and color zones that may be curved, swirled, and irregular are also characteristic of the Ramaura synthetic ruby (see figures 21 through 28). Very swirled and irregular growth features resembling "phantom" grain in diamonds or the "heat-wave" effect seen in many gemstones are shown in figure 21. These should not be confused with the very distinctive "treacle" color zoning seen in many natural Burmese rubies.

"Comet Tails." Also observed in a few of the Ramaura synthetic rubies examined were fine, straight lines and V-shaped arrangements of stringers composed of minute, white, particles

(presumably undissolved flux). These features, often referred to as "comet tails," also occur in other synthetic rubies, such as those produced by Kashan (Kane, 1979; referred to as "hairpins" and "comets" in Gübelin, 1983), as well as in many natural gemstones and, very rarely, in natural rubies. In natural gemstones, they almost always are seen trailing behind an included crystal and are the result of directional growth disturbance caused by the included crystal. In synthetic rubies, comet tails are most commonly seen isolated, that is, not trailing behind an inclusion. In one of the Ramaura synthetic rubies, however, several comet tails were observed trailing a flux fingerprint. Because of their distinctive appear-

ance and the rare occurrence of this type of inclusion in natural rubies, comet tails provide an excellent indication of synthesis in rubies.

As is evident from the above discussion, in the separation of synthetic rubies from their natural counterpart it is of equal importance to examine the other side of the coin: the characteristics of natural rubies. Unlike the somewhat limited nature of inclusions found in synthetic rubies, natural rubies provide a seemingly endless variety of inclusions. The more of these natural inclusions the gemologist is familiar with, the easier the identification of the material will be.

CONCLUSION

The new Ramaura synthetic ruby has many characteristics that closely correspond to those of natural ruby. With the exception of the luminescence reactions of a small percentage of the faceted stones tested by the author and most of the internal characteristics, the gemological properties of the Ramaura synthetic ruby overlap, at least to some extent, with those of its natural counterpart. Therefore, at this time the most important means of distinguishing the new Ramaura synthetic ruby from natural ruby is provided by the inclusions present. To date, the following types of inclusions have been commonly

Figure 17. This Ramaura synthetic ruby displayed unusual growth features: at some viewing angles the nearly straight, parallel growth bands appeared similar to the left view in figure 16; at others, a complete iridescence was exhibited; and at still others, as is shown here, both features were observed. In this view, the very slight differences in angle between facets causes the growth features to be iridescent in one and not in the others. Dark-field illumination, magnified 50x.



Figure 18. With the built-in iris diaphragm on the Gemolite microscope stage partially closed (over dark-field illumination) to create a shadowing effect in this Ramaura synthetic ruby, several different forms of growth features become evident. Particularly notable is the straight growth band that forms an angle in the center of this photomicrograph. Magnified 30x.



Figure 19. V-shaped or "hexagonal" growth band in association with curved growth features in a Ramaura synthetic ruby. Dark-field illumination and shadowing, magnified 25 \times .

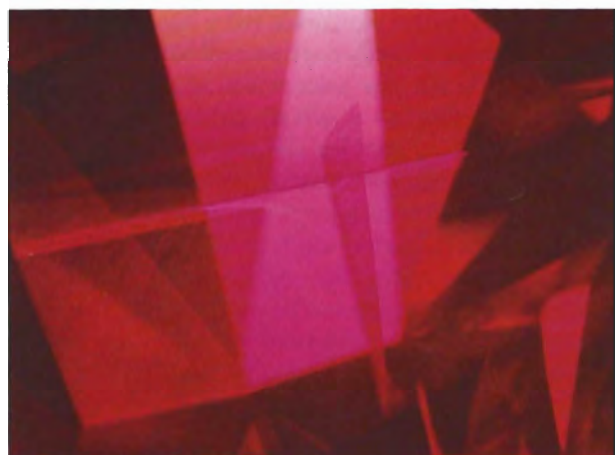
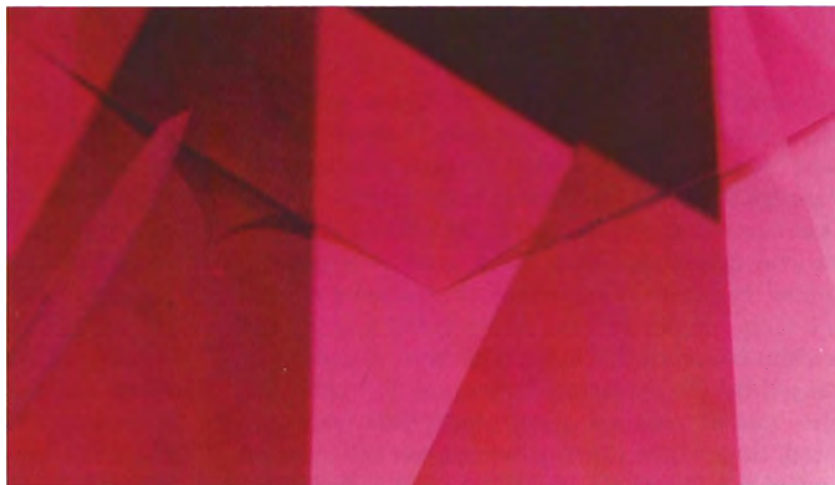


Figure 20. The straight growth plane that extends into the interior of this Ramaura synthetic ruby is intersected by a flux "fingerprint" and a small curved growth feature. Dark-field illumination, magnified 20 \times .

Figure 21. The shadowing technique accentuates the swirled and irregular growth features in this Ramaura synthetic ruby. Magnified 40 \times .

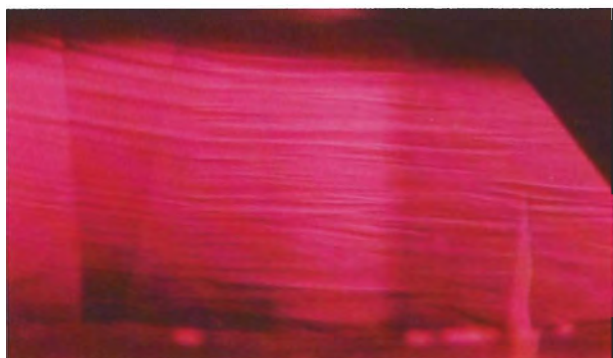


Figure 22. This Ramaura synthetic ruby is host to several different forms of growth features and color zoning. Dark-field illumination and shadowing, magnified 20 \times .

Figure 23. Prominent color zoning is revealed in this Ramaura synthetic ruby by placing a diffuser over dark-field illumination. Magnified 15 \times .



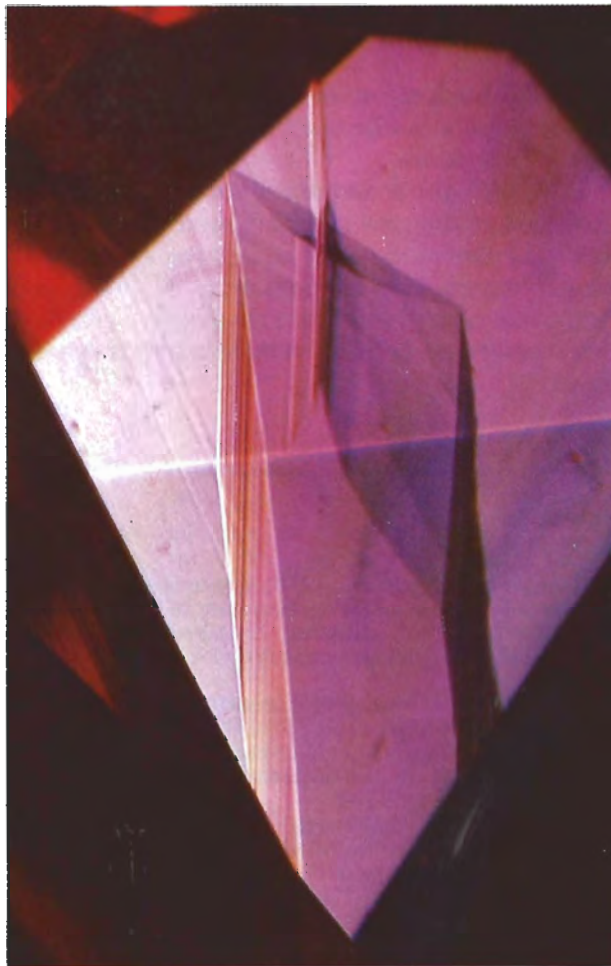


Figure 24. Several forms of color zoning and growth features extend deep within the interior of this Ramaura synthetic ruby. Dark-field, oblique illumination and shadowing. Magnified 40 \times .

observed in the Ramaura synthetic ruby: various forms of flux, particularly distinctive orange-yellow flux and white flux "fingerprints"; in some stones, fractures and healed fractures; and numerous forms of growth features and color zoning. "Comet tail" inclusions were observed in a few stones. The fractures and healed fractures should not be considered diagnostic, while the flux, growth features, color zones, and comet tails in many cases can provide the gemologist with conclusive proof of synthesis.

Although some of the Ramaura synthetic rubies are readily identifiable, others may be particularly difficult to distinguish from their natural counterparts. If, however, the modestly equipped professional gemologist makes the effort to thoroughly familiarize himself or herself



Figure 25. Curved and straight growth features associated with color zoning in a Ramaura synthetic ruby. Diffused and fiber-optic illumination, magnified 30 \times .



Figure 26. Diffused illumination accentuates different forms of color zoning and growth features in this Ramaura synthetic ruby. Magnified 15 \times .

with the inclusions that are characteristic of this new synthetic ruby as well as with those typical of natural rubies, and employs meticulous study of even the most subtle internal characteristics, he or she should be able to identify this new material. Perhaps equally important is the ability to recognize problem stones (clean material that is questionable), and in these situations obtain a second opinion, whether it be from another experienced gemologist or from a qualified independent gemological laboratory.

In the event that entirely flawless material is encountered in the trade, sophisticated techniques such as neutron activation analysis (Fesq et al., 1973; D.V. Manson and J.E. Shigley, personal communication) and energy dispersive spectrophotometry-X-ray fluorescence (EDS-

XRF) analysis (Hänni and Stern, 1982; Stern and Hänni, 1982) may be required. These and other techniques can reveal subtle variations in the trace-element content of the material that may help determine the specific growth environment.

High-resolution spectrophotometric analysis of the ultraviolet (Bosshart, 1982), visible light, and infrared portions of the spectrum, in addition to fluorescence spectra (Schwarz, 1977), are also currently being investigated to determine if

subtle differences between natural and synthetic gem materials can be used as diagnostic criteria for identification.

Although these and other tests have thus far produced ambiguous results in some areas, investigations continue in the search for a means of identifying entirely flawless material and developing testing methods that the jeweler/gemologist can use to conclusively identify this synthetic.

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THE OIL TREATMENT OF EMERALDS IN BOGOTÁ, COLOMBIA

By Ron Ringsrud

It is well known in the trade that most emeralds on the market today are oiled. This article focuses on Colombian emeralds and gives a detailed explanation of the oiling process as observed by the author. Sophisticated laboratory procedures are compared with common "back porch" methods. The methods used often vary from parcel to parcel, and the success of the treatment depends in part on the experience of the treater, although the process itself appears to be relatively permanent. Observations are also presented on methods of detecting oiling as well as on the use of colored oils.

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The application of treatments and processes to enhance the beauty of gemstones is almost as old as the discovery and appreciation of gems themselves. Records of actual oiling of gem crystals go back as far as ancient Greece (Sinkankas, 1981). The principle of oiling is simply that while air-filled fractures in gemstones are highly visible, a fracture filled with a transparent oil or some other suitable material will be much less apparent. While the oiling changes only the clarity characteristics of the gemstone, the color will naturally be intensified because of the fewer apparent flaws blocking the passage of light. Figure 1 shows the change in both clarity and color in three lower-quality emeralds.

Although it is common knowledge in the gem trade that Colombian and other emeralds are oiled, the process itself is not widely understood. This article will attempt to clarify some of the details of the oiling process as it occurs in Bogotá.

On a June 1983 visit to Bogotá, Colombia, the author had the opportunity to interview several emerald treaters and visit two laboratories in which emeralds were treated by a process that involved the penetration of a colorless oil into the fractures of the stones. One of the laboratories visited represents the most common "back porch" treatment lab. The other, Bargar Gemological Laboratories, directed by gemologist Antonio Barriga del Diestro, is highly sophisticated and complete, providing not only emerald treatment but also cutting, cabbing, gemological quality reports, gem photography, and an attractive gem and mineral display.

While arranging the interviews, the author found that emerald treatment, rather than being a clandestine activity or secret process, is quite freely disclosed. This openness was demonstrated when the author purchased rough emeralds in Chiquinquirá in the Muzo district. When the seller discovered that the stones would be taken to the



Figure 1. The top photo shows three lower-quality emeralds (0.94–1.85 ct) before they were treated with colorless cedarwood oil. The photo below shows the same stones two weeks after oiling. The visibility of all the fractures has been reduced considerably by the oiling, thereby giving the appearance that the color has improved. On borderline stones, the process could help a green beryl grade up to emerald. Note the heavily fractured areas in the stone on the right and in the center stone. Approximately one month after oiling, the stones were placed in an ultrasonic cleaning tub with warm cleaning solution for three minutes. Except for the one large fracture in the center stone, the effects of oiling proved stable.

United States, he not only stressed the importance of careful cutting but also sincerely emphasized proper acid treatment and oiling, implying that the emeralds were not "finished" until they had been treated. In Bogotá as well, the largest treatment laboratory, Bargar Labs, posts a fixed pricing schedule for treatment of cut stones and also issues a disclaimer upon receipt of stones for treatment. The disclaimer outlines the possible risk to the stone from "the acids and other elements used in the cleaning process . . ."

The treatment process, though performed differently from one person to the next, usually begins after the emeralds have been cut. The stones are treated either by the cutter or the dealer himself, or they are sent out for treatment. The actual procedure, though, usually follows a basic five-step program of preliminary cleaning, acid treatment, acid removal, oiling, and final cleaning. Each of these steps is described in detail below. Also discussed is the permanence of the oiling treatment, detection, and the use of colored oil.

THE OIL TREATMENT PROCESS

Cleaning. The most common set-up of a treatment lab in Bogotá is similar to that in the house of Mr. Jorge Murcia, whose family has been in the emerald business for nearly two decades and who has personally been treating emeralds for eight years. Murcia begins the treatment process by cleaning the freshly cut stones, that is, putting them in a test tube with methyl alcohol or ethyl alcohol, bringing them to a boil, then letting them cool slowly (figure 2). They may be boiled and cooled up to three times. This first step is not always necessary (Barriga begins directly with the acid treatment), but Murcia explained that occasionally the emerald rough is oiled to facilitate its sale. Such oil in the fractures of the stone often reacts with the acid, leaving permanent brown stains inside the stone (which resemble the common brownish iron stain inclusions found in some emeralds). If Murcia is certain the rough was oiled before cutting, he leaves the stones in the alcohol overnight. One major cutter in



Figure 2. The alcohol used as fuel for the burner also serves as a solvent to clean the recently cut emeralds prior to treatment.

Bogotá's emerald district suggests pretreatment cleaning in acetone.

Acid Treatment. Tin oxide and chromic oxide that have built up in the fracture openings during cutting and polishing are removed during this and the next step of the process in order to allow for the penetration of the oil into the fractures. In this step, the stones are treated with a mixture of hydrochloric and nitric acids. Murcia uses a 2-to-1 mix of concentrated HCl to concentrated HNO₃ in a wide-mouthed pyrex test tube with a screw-on cap. This cap maintains pressure buildup within the test tube, which Murcia feels is beneficial to the penetration and cleaning action. Other treaters use rolled-up newspaper moistened with water as a stopper, which relieves the pressure very slowly but will not pop out as a cork or rubber stopper would. The Bargar Labs puts the stones in a vacuum test tube apparatus (figure 3) rather than under pressure, and leaves them overnight, heating but not boiling. Murcia leaves the stones in the acid overnight but does

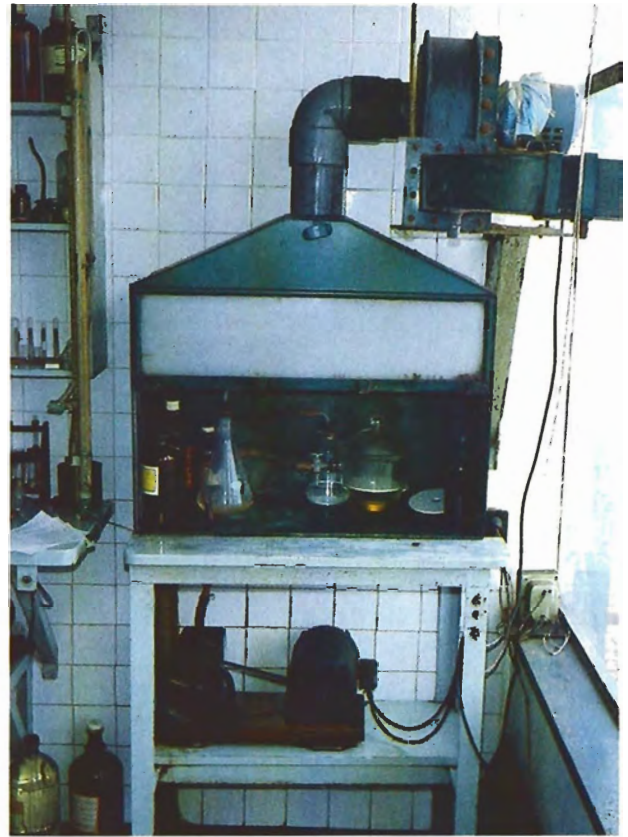


Figure 3. Fumes from the acid treatment are drawn away by this apparatus at Bargar Gemological Laboratories. The pump below draws a vacuum in the heated beakers.

not heat them. The stones bubble slightly for about two hours as the acid reacts with impurities, residual cutting compounds, and replaces any air left in the fractures.

The pressure buildup in the test tube can be excessive, particularly if the acid is boiled; the treater should, therefore, relieve the pressure periodically, taking care not to breathe the fumes. At this stage of the process, some treaters use an ultrasonic cleaning tub to help the acids penetrate the fractures (figure 4). However, both Barriga and Murcia feel that this is unnecessary. During these early steps, great care is taken with the solvents, which are flammable, and with the acids, which are extremely corrosive and dangerous.

Acid Removal. The process continues with the cleaning of the acid from the stones. Generally, this is accomplished by boiling the emeralds or heating them slightly in alcohol, ethyl alcohol, acetone, or paint thinner. However, Barriga feels that water is the best substance for removing the acids. It is also safer because acid-wet stones

Figure 4. An ultrasonic cleaning tub is sometimes used to help the acid mixture penetrate and clean the emeralds. The cutting and polishing oxides left in the fracture openings would otherwise block the penetration of the oil.



should not come into contact with solvents unless they are first rinsed and dried. In his treatment lab, Barriga uses small beakers to hold the emeralds in a solution of water with detergent. The beaker is then put in an ultrasonic tub for half a minute and stirred slightly. After the beaker is removed, the stones are left to soak in the solution for several hours. The stones are then rinsed and dried.

Oiling. The next step, oiling, is the one that probably varies the most from person to person. Although there are reports that "3 in 1" oil, clove oil, mineral oil, and the like, have been used, the one most highly recommended in Bogotá is the Merck brand cedarwood oil (refractive index, 1.515) or Merck Canada balsam (R.I., 1.52). Although the refractive index of these two oils is below that of emerald (1.577–1.583), it is so close that the oil appears invisible within the stone. The *Merck Index* (Merck, 1976), a standard chemical reference book, describes Canada balsam as a transparent, slightly fluorescent liquid that upon exposure to air gradually solidifies to a solid, noncrystalline mass. It is used either alone or mixed with a small amount of cedarwood oil. Although the properties of Canada balsam are well known in Bogotá, the cedarwood oil is still used the most, since the majority of fractures in emeralds need only a minute amount of oil to reduce their visibility and the cedarwood oil is much less expensive.

Because the oils are quite thick, they must be

heated in order to penetrate the stone well. As with the acids, Bargar Labs places the emeralds in with the oil and creates a vacuum in the test tube with the equipment shown in figure 5. The stones are then heated, but not boiled, for several hours. Then, without vacuum, they are baked at 83°C for four hours. Although boiling the oil is more common among independent treaters, Murcia prefers the less harsh treatment of 45 minutes in a "baño maria," that is, placing the test tube in boiling water. The test tube is then immediately exposed to the heat of a 75 watt bulb overnight. To prevent burning, it is placed no closer than one or two inches above the bulb. A tight screw cap or stopper is used to maintain pressure. Low-quality or cabochon material may require several days over the light (figure 6). A less sophisticated method of producing a vacuum in a test tube involves the use of a rubber stopper placed beneath the screw-on cap. A syringe needle is inserted several times through the stopper in order to draw the air out. If done correctly, this method creates such a high vacuum that the oil begins to boil at room temperature. The test tube is then placed in boiling water.

In terms of immediately perceptible results, it seems that treatment with the oil and acid under slight pressure is essentially the same as treatment under vacuum. In terms of long-term results, the vacuum method is probably the most thorough and long-lasting. This process is also faster and more suited to the high volume of emeralds that Bargar Labs treats on a day-to-day



Figure 5. In Bogotá, Merck cedarwood oil is considered to be most effective for emerald treatment. In this apparatus at the Bargar Gemological Laboratories, the emeralds are soaked in the oil and then heated in a vacuum.

basis. The majority of dealers send their parcels of emeralds to Bargar Labs, an indication of the quality of the method of treatment performed there. The rest of the independent dealers, like Murcia, treat their stones themselves with variations of the same basic process and with different levels of experience.

Final Cleaning. The last step is to dry the emeralds in a paper towel and polish them on a cloth. One dealer, Hernando Castro, says, "Rub them with a handkerchief until they pick up your own charm and they'll sell themselves." One cutter recommends polishing the stones with Vaseline, especially if they were oiled in the thicker Canada balsam. Dealers in Chiquinquirá sometimes carry stones around with them in Vaseline tins for just this reason.

The treaters, by virtue of their experience subjecting many emeralds to the rigors of treatment, become quite familiar with emeralds from different sources and their individual characteristics. For example, all of the emerald treaters with whom the author spoke concurred that Cosquez material is very sound and responds well to treatment. They report that it rarely breaks apart on the wheel or in the ultrasonic tub, and never dries out after oiling.

Muzo material is generally considered less sound, but by no means fragile. Furthermore, emerald mined from different areas and veins of the Muzo mine respond differently to the treatment. For example, stones from the Puerto Arturo section of Muzo are favored by dealers because they respond very well to treatment, whereas those from La Cristaleria have inner feathers that do not disappear even with oiling. Dark inclusions in stones from the Cincha area also do not respond to treatment.

PERMANENCE OF THE PROCESS

The only time treatment is mentioned among wholesalers is if a particular parcel of emeralds has not been treated. Otherwise, on the low- and medium-quality commercial stones it is commonly understood that the stones have probably been treated. Since emerald treatment primarily reduces the visibility of fractures that penetrate the stone from the surface, many fine-quality Colombian emeralds are not treated because of their higher clarity.

Several dealers explained that the treatment is considered a common and acceptable practice since the majority of emeralds have such fine fractures that the oil seldom dries out or, at the very least, the natural oils of the wearer replace the oil in the stone. They maintain that the treatment only slightly enhances the natural beauty of these stones. When confronted with the fact that a small percentage of emeralds do dry out and have had their value misrepresented by the oiling, the dealers replied that the oiling should have been detected by the buyer, either from close inspection with a trained eye (see below for a discussion of detection of oiling), or from the suspiciously low price of the merchandise. As is the case with treated stones from other parts of the world, it is safest to deal with wholesalers who depend on repeat business for their contin-



Figure 6. The lightbulb of an ordinary table lamp provides heat for maintaining the oil at a constant high temperature.

ued success and who therefore do not willfully misrepresent stones.

The use of Canada balsam versus cedarwood oil, the amount of heat, and other factors vary from parcel to parcel. In this same way, the permanence of the treatment varies with the material and the experience of the treater. In actuality, the percentage of stones that do dry out is impossible to calculate. Probably the only means of determining the extent to which oiling has affected the appearance of the stone is to let the emerald sit overnight in warmed acetone. However, this would be considered a "destructive" test on stones in which the oil would otherwise be stable (i.e., under conditions of normal wear). After drying, all fractures would be visible. Since the maximum drying occurs in the first month after oiling, one might simply determine how long the emerald has been in the jeweler's or dealer's inventory.

One large-volume emerald purchaser in Bogotá says that when he is in doubt he leaves the

stones on the windowsill or in a dry, airy place for about two weeks before deciding on the parcel. This is similar to the "fade test" used in the trade for testing the stability of irradiation-induced colors in gemstones, by which stones are placed in sunlight for a number of days to check for color change.

The claims made by Barriga to the author that emeralds oiled by his process can withstand even an ultrasonic cleaning proved to be true in the case of the emeralds shown in figure 1. After three minutes in an ultrasonic cleaner, followed by several hours of drying under heat, there was no significant change in the clarity of the emeralds with the exception of one particularly large fracture.

DETECTION OF OILING

The gemological literature states that some oils fluoresce a dull yellow under long-wave fluorescent light. Stones oiled by the author with the Merck cedarwood oil did not fluoresce. However, the emeralds oiled with the Merck Canada balsam fluoresced yellow in the oiled areas.

The presence of fractures will interrupt the passage of light somewhat even with oiling. If the stone is less transparent than it seems it should be, sidelighting with a pinpoint illuminator may reveal dull indications of the oil-filled fractures. Since emeralds commonly have numerous subtle liquid-filled inclusions that could resemble oil-filled fractures, the investigation should be confined to fractures that reach the surface of the stone. If an oil with a refractive index significantly different from that of the stone was used, careful manipulation of the lighting while the stone is viewed under magnification will reveal an iridescent effect. If the oil has not penetrated completely, then gaps will be seen. Also, the careful use of the heat from a thermal reaction tester may cause a drop of oil to bead up on the surface of the stone from the fracture (Liddicoat, 1981). A prominent emerald buyer in Bogotá suggests holding the stone papers up to the light and looking for oil spots and signs of oil that may have seeped from the stones.

In rough stones, the dealers smell the stone for the characteristic cedar smell of the oil. They pay close attention to the transparency of the stone. Also, any shale matrix on a stone that has been oiled will appear glossy black from the oil rather than the normal dull black.

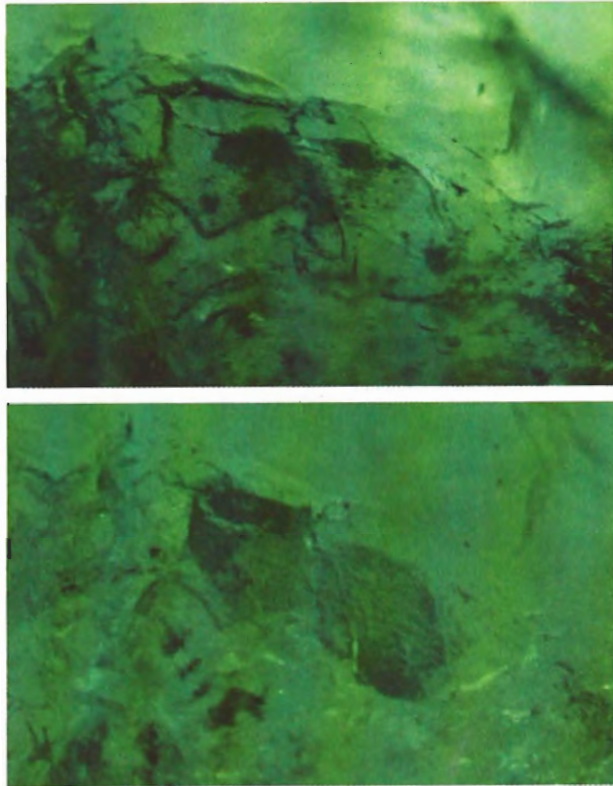


Figure 7. The upper photo shows a typical air-filled fracture at $40\times$ magnification. The lower photo shows how a slight change in the angle of the stone to the light source causes the fracture to darken and appear as if it contained dye or colored oil.

USE OF DYED OIL

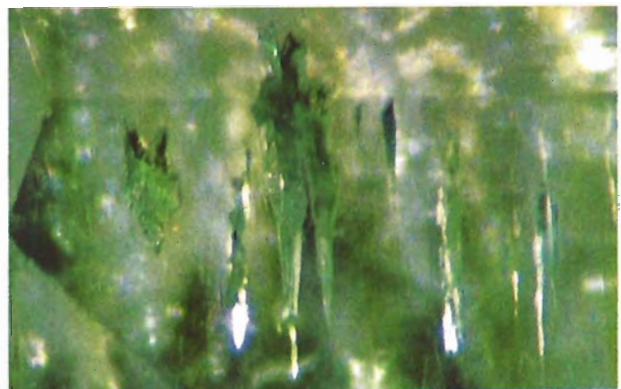
All dealers interviewed held that the introduction of green dye into the oil for the purpose of deepening the color of light stones is an uncommon practice. One reason why the use of green oil may be thought to be more common is the reflectant nature of fractures. The air-filled spaces in the fractures will reflect light from many areas of the stone, thereby magnifying the color that gets reflected. This often gives fractures in emeralds a dark green appearance, and the common conclusion is that green stain or dye has been introduced (figure 7). Richard T. Liddicoat, Jr., commented on this phenomenon in the Summer 1964 issue of *Gems & Gemology*: "These air-filled openings were acting as mirrors and were reflecting a zone of slightly more intense natural coloration, thus creating the illusion that color was in the fracture."

A common method used to reveal dye concentrations in emerald fractures is to place the stone on

translucent white plastic over an intense light source (Fryer et al., 1981). The diffused light will reveal any color concentrations. If color concentrations are found in the fractures, they should be investigated further at $10\times$ magnification with transmitted light. It is important to turn the stone in every possible direction in order to determine if the color concentration is from reflection or dye. Generally, when the fractures are turned and light is allowed to pass at a straighter angle (within the critical angle of emerald), the fracture suddenly changes from dark green to colorless. Fractures that are perpendicular to the table of the stone and close to the crown will seldom achieve the necessary straight passage of light because of the refraction of light as it enters the crown. In this case, a conclusion can be reached on the stone on the basis of a survey of fractures in other areas of the emerald. If dyed oil is present, the fractures will seem slightly opaque and will remain green at any angle.

The polishing compound most commonly used by cutters in Bogotá is chromic oxide, which readily enters fractures or hollow tubular inclusions that reach the surface of gemstones and is difficult to remove (Sinkankas, 1972). If this material is tightly compacted, the acid treatment and cleaning process may not remove it, and it may be seen under magnification as dark gray-green forms going in from the surface (figure 8). These buildups of polishing compound, being dark, very localized, and confined to the larger

Figure 8. The dark material filling the surface fracture in the center of the photomicrograph is actually residual chromic oxide from the polishing process. Normally, this is removed during acid treatment; if not, it may give the appearance of an attempt at dyeing. Magnified $60\times$.



openings on the surface, should not be considered as attempts to color the stone.

CONCLUSION

Although the oil treatment has been explained here as a basic five-step process, the experience and skill of the treater still have much to do with the success and permanence of the treatment.

While boiling and the use of an ultrasonic cleaner may seem harsh, the treaters have found that if the emerald survives the rigors of cutting, in most cases it can withstand the oil treatment process as well. While permanence will continue to be a problem in some oil-treated Colombian stones, better use of known testing methods and care in buying will lessen the risk.

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NOTES • AND • NEW TECHNIQUES

A COMPUTER PROGRAM FOR GEM IDENTIFICATION

By Peter G. Read

Following a feasibility study of computer-aided gem testing, which resulted in a student-level gem identification program, the author has developed a professional version containing data on over 200 gem materials and gem simulants. The program sections include Gem Identification (using test inputs for R.I. values, optic sign, S.G., etc.), Gem Data Tables (arranged in alphabetical, R.I., and S.G. order), Gem Data Comparisons, Gem Data Pages, and Gem Calculations (for determinations of S.G., reflectivity, critical angle, and Brewster angle). This type of computer program provides rapid access to gem constants and characteristics, and can assist the less experienced gemologist by identifying unfamiliar or rare stones and indicating the various alternatives.

The use of the computer as a convenient means of storing and retrieving data on gemstones is becoming more practical as the cost of the associated storage medium falls. At the 1980 Federal Conference of the Gemmological Association of Australia, a paper was read which proposed, among other things, the use of the computer as a library catalogue of mineral specimens for a university (Barrington, 1981). Another proposal has been to use the computer to suggest a sequence of identification tests for a particular gem species or variety (Minster, 1981, personal communication).

The author's experiences in computer programming, gained while technical manager of the Diamond Trading Company in London, formed the basis of a feasibility study into the use of

personal computers as an aid to gem identification (Read, 1979).

The two computer programs developed as a result of that study contained data on 80 gem materials. Although these programs proved the viability of the concept, they were sufficiently limited in scope to be of use mainly as a teaching aid to students of gemology (Read, 1980).

One of the problems encountered was the need to tailor the program to fit the built-in memory (typically 32K, i.e., 32 kilobytes or 32,000 letters or numbers of storage) of personal computers available at that time. Another drawback was the amount of time required to read the programs into memory when a tape cassette was used as the storage medium (typically five minutes for a 30K program).

These limitations were subsequently overcome by increasing the size of the computer memory to 52K, and by using three 5¼-inch 315K floppy (magnetic) disks and a disk drive (magnetic disk reader) for program storage (figure 1). The original gem data computer programs were subsequently combined and expanded to better exploit the facilities available with the disk

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Figure 1. The author's Exidy Sorcerer computer installation. To the left of the keyboard is a Micropolis disk-drive unit. To the right is one of the floppy (magnetic) disks containing the computer program.



operating system (a program the computer uses to operate the disk drives) and its associated Extended Basic language.*

The much faster data transfer rate inherent in the disk system made it possible to load a 30K program in five seconds, while the more sophisticated 21.5K version of the Basic computer language allowed additional sections of program to be read from the disk into the computer under the command of the program, thus greatly enlarging the effective size of the memory.

PROGRAM STRUCTURE

The resulting GEM DATA BANK computer program now contains information on over 200 gem materials, including rare gem minerals and collectors' stones as well as gem simulants. The structure of the program consists of an introductory section containing a selection "menu" and the five main sections, arranged as self-contained individual programs, to which the menu provides access (figure 2). The five sections are described below and illustrated in figures 3-14.

1. Gem Identification. When this section has been selected, the computer requests that the user key in information on the gem's refractive

index (R.I.) value(s), optic sign (if doubly refractive), and specific gravity (S.G.) value (figure 3). A "search limit" tolerance, as explained below, must also be chosen and keyed in. If the R.I. or S.G. values are not known, these parts of the program can be bypassed by keying in a 9.

If the gemstone is singly refractive, a 0 is input in response to the request for a second R.I. reading. However, if the gem is identified as birefringent, i.e., doubly refractive (D.R.), on a polariscope, but a second R.I. value cannot be determined, then a 1 is keyed in. Alternatively, if the stone shows a cryptocrystalline response on the polariscope, a 9 is keyed in.

If readings are input for both the highest and

Figure 2. After the master program is loaded into the computer from the disk, a choice of five separate program sections is displayed on the monitor screen.



*Most new-generation personal computers have a minimum of 64K RAM (64,000 characters, random access memory). This program could be entered with only minor modifications in any computer that has Basic and a disk drive for program storage.

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#####
**  GEM IDENTIFICATION PROGRAM  **
#####

The GEM IDENTIFICATION program identifies
gemstones from test data input via the keyboard.

1. First type in the gem's R.I. value(s).
2. Next type in optic sign, if relevant.
3. Then type in the gem's S.G. value.

TYPE IN R.I. (lowest value if D.R., 9 if unknown, 10 for selector)
? _

```

Figure 3. If the Gem Identification program is selected, the refractive index value(s), optic sign, and specific gravity of the stone under test are keyed in as requested by the computer. Various options are available at each step.

lowest R.I. values for a doubly refractive gem, the computer then asks for the stone's optic sign. This is coded as 1 for positive, 2 for negative, or 0 for unknown.

The next request is for the stone's S.G. In addition to a measured value, this input can also be in the form of a number code (from 10 to 18), which covers the range of heavy liquid tests for S.G. approximation (figure 4).

Lastly, the computer program gives a choice of two "search limits" to allow for variations and inaccuracies in test measurements. Search limit 1 compares the keyed-in data against the stored data and permits a possible mismatch of ± 0.005 for R.I., ± 0.002 for birefringence (D.R.), and ± 0.02 for S.G. Search limit 2 allows for twice this amount of mismatch for R.I. and D.R., and three times this amount for S.G. For those stones with an R.I. above the 1.80 limit of the standard refractometer, the mismatch tolerance for R.I. is automatically broadened to ± 0.1 when search limit 2 is chosen, so as to allow for the errors associated with the "direct," or "apparent depth," method of determining refractive index using a microscope (for an explanation of this method, see Webster, 1975, pp. 365-367). When the more precise high R.I. readings from extended-range refractometers such as the Rayner diamond version or the Krüss KR602, which uses a strontium titanate prism, are available, search limit 1 should be chosen.

Once the code for the search limit has been keyed in, the computer program commences its

task of comparing the input data with the stored gem constants. These constants consist of two lists of R.I. values, a list of D.R. values coded with the polarity of the optic sign, and two lists of S.G. values. The twin lists of R.I. and S.G. values enable the maximum expected range of these constants to be specified for each gem material, thus allowing for the effects of impurities and the like associated with each gem. This feature of the program is particularly important to cover S.G. variations, and for R.I. values it only occasionally coincides with the actual birefringence.

Although the speed of computing is fast, the enormous amount of data through which the computer must search during each identification may require several seconds to accomplish, inasmuch as each individual list contains over 200 values. To reduce the search time to a minimum, the computer first indexes down the D.R. list, selecting a 0 line if the input data indicate an isotropic material, a line containing a valid D.R. value if the input data indicate a birefringent gem, or a line containing a 9 for a cryptocrystalline stone. If the input data contain two values for R.I. together with the optic sign information, the computer subtracts the lowest R.I. from the highest to arrive at the stone's birefringence, and only then checks those D.R. values in its list that have the appropriate polarity. If no optic sign is input (code 0), then the computer checks both positive and negative D.R. entries in the list. Once a valid data line is found in the D.R. list, the appropriate birefringence, R.I. range, and S.G. range in the stored lists are checked against the appropriate input data. If all items compare within the tolerances of the chosen search limit, the appropriate gem material is displayed on the monitor screen together with its optic sign, R.I. range, S.G. range, and an index number that can be used for further data retrieval (see program section 4).

The computer then moves down the lists of constants until it either finds another correlation or reaches the end (figures 4-7). It is then ready for the next identification task, or for the selection of another section of the program. If, however, during a narrow search no gem material is identified, the following message is displayed: "For a narrow search, no match has been found with any gem held in memory. Try wide search limits." If the wide search limits fail to identify the gem, the following message appears: "For

```

TYPE IN S.G. VALUE (type 9 if unknown. For heavy liquid tests
type 10 for under 2.85; 11 for 2.85-2.89; 12 for 2.89-3.02;
13 for 3.02-3.32; 14 for over 3.32; 15 for 3.32-3.39;
16 for 3.32-3.39; 17 for 3.39-4.15; 18 for over 4.15).

? 13
CHOOSE SEARCH LIMIT (type 1 for narrow, 2 for wide).
? 1

The following gem material constants are nearest the input data

Index Gem Name      Optic Sign  R.I.(range)  S.G.(range)
-----
112  MAGNESIOAXINITE  +          1.656 - 1.668  3.18

For more information, note Index No. and type in 300 for program
selector (or type 400 to continue with gem identification).

```

Figure 4. For the stone under test, inputs of 1.656 and 1.667 have been keyed in for the R.I. values, a positive optic sign has been input, an S.G. code of 13 has been selected following tests in heavy liquids (i.e., stone sinks in 3.05, floats in 3.32), and a narrow search limit has been chosen.

wide search limits, no match has been found with any gem held in memory. Check test results."

If the display indicates that more than one gem material matches the input data, the appropriate gem index numbers can then be used to display pages of additional data on each of the selected gems (see section 4). While it is feasible to insert the more subjective gemstone qualities of color, transparency, luster and fluorescence as data inputs in this section (initially, color and transparency were included experimentally), the resulting program is too large for normally available computer memories. It was therefore considered more practical to limit the diagnostic search to objective gem data, and then to make

Figure 6. With the same input data as for figure 5, but with the added information that the gem's optic sign is negative, the computer eliminates peridot from its identification and displays only sinhalite.

```

TYPE IN S.G. VALUE (type 9 if unknown. For heavy liquid tests
type 10 for under 2.85; 11 for 2.85-2.89; 12 for 2.89-3.02;
13 for 3.02-3.32; 14 for over 3.32; 15 for 3.32-3.39;
16 for 3.32-3.39; 17 for 3.39-4.15; 18 for over 4.15).

? 14
CHOOSE SEARCH LIMIT (type 1 for narrow, 2 for wide).
? 2

The following gem material constants are nearest the input data

Index Gem Name      Optic Sign  R.I.(range)  S.G.(range)
-----
171  SINHALITE         -          1.67 - 1.71   3.47 - 3.49

For more information, note Index No. and type in 300 for program
selector (or type 400 to continue with gem identification).

```

```

TYPE IN S.G. VALUE (type 9 if unknown. For heavy liquid tests
type 10 for under 2.85; 11 for 2.85-2.89; 12 for 2.89-3.02;
13 for 3.02-3.32; 14 for over 3.32; 15 for 3.32-3.39;
16 for 3.32-3.39; 17 for 3.39-4.15; 18 for over 4.15).

? 14
CHOOSE SEARCH LIMIT (type 1 for narrow, 2 for wide).
? 2

The following gem material constants are nearest the input data

Index Gem Name      Optic Sign  R.I.(range)  S.G.(range)
-----
136  PERIDOT           +          1.654 - 1.69   3.34
171  SINHALITE         -          1.67 - 1.71   3.47 - 3.49

For more information, note Index No. and type in 300 for program
selector (or type 400 to continue with gem identification).

```

Figure 5. R.I. inputs of 1.66 and 1.695, optic sign not known, S.G. code of 14 (over 3.32), and the selection of a wide search limit have resulted in the display of two possible identifications on the monitor screen.

separate reference to the gem data pages when necessary.

Apart from helping to identify a gem under test, this section of the program can also be used to display all gems having a specific R.I. or S.G. range, regardless of other parameters. The program's flexibility also allows for other variations, such as the display of singly refractive, doubly refractive, or cryptocrystalline gems within specified ranges of R.I. and/or S.G.

The construction of this section of the program uses the standard Basic language DATA and

Figure 7. R.I. inputs of 1.616 and 1.625, a positive optic sign, an S.G. code of 14 (sinks in 3.32), and a narrow search limit fall within the tolerance limits of both groups of topaz varieties. Note that the two input R.I.'s are both within the R.I. ranges, and the D.R. of 0.008 and 0.01 (not displayed) match the input value within the ± 0.002 tolerance.

```

TYPE IN S.G. VALUE (type 9 if unknown. For heavy liquid tests
type 10 for under 2.85; 11 for 2.85-2.89; 12 for 2.89-3.02;
13 for 3.02-3.32; 14 for over 3.32; 15 for 3.32-3.39;
16 for 3.32-3.39; 17 for 3.39-4.15; 18 for over 4.15).

? 14
CHOOSE SEARCH LIMIT (type 1 for narrow, 2 for wide).
? 1

The following gem material constants are nearest the input data

Index Gem Name      Optic Sign  R.I.(range)  S.G.(range)
-----
191  TOPAZ(Blue,White,Yellow)+  1.61 - 1.62   3.56
192  TOPAZ(Brown,White)      +          1.62 - 1.64   3.53

For more information, note Index No. and type in 300 for program
selector (or type 400 to continue with gem identification).

```

```

For R.I.'s from 1.43 to 1.54 type in 1.
from 1.1 to 1.54 type in 2.
from 1.1 to 1.68 type in 3.
from 1.1 to 1.99 type in 4.
from 2.06 to 2.46 type in 5.

? 1
Index Gem Name R.I. (range) D.R. S.G. (range) H.
-----
1 1 UOORSPAR 1.434 46 -- -- 1 8 5 4
2 1 EDITE 1.460 46 .025 2 1 1 5 4
3 1 AMBER 1.540 46 -- -- 1 1 5 4
4 1 RABBIT IVORY 1.470 46 -- -- 1 1 5 4
5 1 LULU 1.470 46 -- -- 2 1 1 5 4
6 1 RHINO 1.470 46 -- -- 2 1 1 5 4
7 1 TORTOISESHELL 1.470 46 -- -- 1 1 1 5 4
8 1 COCO PALM NUT 1.480 46 -- -- 1 1 1 5 4
9 1 COCO NUT 1.480 46 -- -- 1 1 1 5 4
10 1 DEER 1.480 46 -- -- 1 1 1 5 4
11 1 DENTINE 1.480 46 -- -- 1 1 1 5 4
12 1 SCOLLA 1.480 46 -- -- 1 1 1 5 4
13 1 CHAUM 1.480 46 -- -- 1 1 1 5 4

```

Figure 8. A range of stones with R.I.'s between 1.43 and 1.54 are selected and displayed in order of rising R.I. Because of the number of stones within each selected range, the table is scrolled upwards slowly and can be halted at any desired point.

READ statements to store the gem constants and enable the program to sequentially check through the lists of constants. Gems are coded with an index number, and this number is used as a suffix to letter codes which identify the various constants [e.g., for aragonite, the 15th gem in the lists, M(15) and N(15) are the top and bottom R.I. range values, O(15) is the D.R. value, and P(15) and Q(15) are the S.G. range values].

The program starts at index number 1 on each search, and first counts down the indexed list of D.R. values until it finds a figure that matches the input data. It then transfers across to the similarly index-numbered R.I. and S.G. constants, and checks to determine if the input values fall within the listed ranges of these figures. If all the data match for that particular index number, the number is used to extract and display the appropriate gemstone name together with its constants, and the program then continues down the lists looking for additional correlations.

Although the data-search function of the program may appear complicated, the programming techniques employed are standard. Much of the complexity of this section is, in fact, in the control and management of the various input options, which must be mutually compatible for all permutations of the data input and the program functions.

The Gem Identification program is 24K long, and uses 30K of memory when running. The average search time is 20 seconds, and the longest search time is 40 seconds.

```

For R.I.'s from 1.43 to 1.54 type in 1.
from 1.1 to 1.54 type in 2.
from 1.1 to 1.68 type in 3.
from 1.1 to 1.99 type in 4.
from 2.06 to 2.46 type in 5.

? 1
Index Gem Name R.I. (range) D.R. S.G. (range) H.
-----
143 POLYSTYRENE 1.59 -- -- 1 1 1 5 4
144 AMBER 1.540 46 -- -- 1 1 1 5 4
145 RABBIT IVORY 1.470 46 -- -- 1 1 1 5 4
146 LULU 1.470 46 -- -- 2 1 1 5 4
147 RHINO 1.470 46 -- -- 2 1 1 5 4
148 TORTOISESHELL 1.470 46 -- -- 1 1 1 5 4
149 COCO PALM NUT 1.480 46 -- -- 1 1 1 5 4
150 COCO NUT 1.480 46 -- -- 1 1 1 5 4
151 DEER 1.480 46 -- -- 1 1 1 5 4
152 DENTINE 1.480 46 -- -- 1 1 1 5 4
153 SCOLLA 1.480 46 -- -- 1 1 1 5 4
154 CHAUM 1.480 46 -- -- 1 1 1 5 4

```

Figure 9. Stones can also be displayed in order of rising S.G., as shown here, and in alphabetical order.

2. Gem Constants. This section consists of a series of tables of gem constants which can be selected in alphabetical order of the gem, in order of rising R.I. value (figure 8), or in order of rising S.G. value (figure 9). In each case the gem's index number is displayed and can be used for further data retrieval in section 4. Because of the length of the tables, they are divided into alphabetical and numerical sections which can be selected and scrolled individually. The total length of this section of the program is 28K.

3. Gem Comparisons. This facility enables the selection of single-line gem specifications from a self-contained (or printed) index list and their display adjacent to one another for comparison purposes (figure 10). This section of the program is 27K long.

4. Gem Data Pages. This section enables individual "pages" of data to be selected for over 200 gem materials or gem simulants. These are listed both in a self-contained "software" index and in a printed index (table 1).

Each page, or set of pages, commences with a single-line list of gem constants (R.I. range, D.R., dispersion, S.G. range, and hardness). This is followed by the gem's chemical composition, crystal system, and optical clarity. Other characteristics displayed include habit, color, pleochroism, cleavage, fluorescence, and absorption spectrum. The data pages also list the principal occurrences of gem-quality material and known varieties where appropriate (figures 11 and 12).

The Gem Data Pages occupy a total of 780K of disk storage space (i.e., they are contained on two and one-half of the three floppy disks). Each Gem

```

Type in 1 to 6 to view GEM DATA index (A-Z),
400 to chose gem data, or 500 to return to program selector.
(Type in 1 for Ac-Ce; 2 for Ch-Go; 3 for Go-Mi;
4 for Mi-Ru; 5 for Sa-Uv; 6 for Va-Zo).
? 400
Type in Index No. of chosen gem (alternatively, type in 400
for Index Page selection, or 500 to return to program selector)
? 500
Index No. Gem Name R I (range) D.R. S.G. (range) H
-----
1 DIAMOND 2.417 -- 3.52 10
2 GGG 1.97 -- 7.05 6
3 CUBIC ZIRCONIA 2.09-2.18 -- 5.54-6.0 8
4 YAG 1.832 -- 4.58 6 5

```

Figure 10. A Gem Comparisons program enables single-line gem specifications to be displayed adjacent to one another so that their constants can be compared.

Data Page entry occupies an average of 3.5K of formatted storage space, and is automatically extracted from the appropriate disk by keying in the gem's index number. The common "page routing" section of the program advises the user which disk to insert if the requested Gem Data Page is not contained on the disk currently in use.

TABLE 1. Sample gem index numbers.^a

Index no.	Name
1	Actinolite
2	Alabaster
3	Almandine
4	Amber
5	Amblygonite
6	Analcite
7	Anatase
8	Andalusite
9	Andradite
10	Anglesite
11	Anhydrite
12	Apatite
13	Apophyllite
14	Aquamarine
15	Aragonite
16	Augelite
17	Axinite
18	Azurite
19	Bakelite
20	Barite
21	Barium titanate
22	Basalt glass
23	Baydonite

^aOver 200 gems and gem simulants are included in the author's program. This small sample is presented to give the reader an idea of the variety of materials covered.

```

AMBLYGONITE
A collector's stone
R.I. (range) D.R. Disp.(max) S.G.(range) H
-----
1.611-1.637 +.026 -- 3.015-3.033 6
Chemical Composition Xtal System Optical Clarity
-----
LiAl(PO4)2(F,OH) Triclinic Transparent
4
Habit - Large rough tabular crystals. Cleavage - Perfect, basal
Colour - Yellow to colourless; pale purple
Fluorescence - LUV, weak green; X-rays, bright green-white
Absorption Spectrum - Nil
Occurrence - Brazil, USA, Namibia (pale purple)
For access to (other) data pages type in appropriate Index No.
alternatively, type 400 for Index or 500 for program selector

```

Figure 11. A Gem Data Pages program provides between one and three "pages" of information on each of over 200 gem materials. Selection of data on a specific gem is obtained by keying in the appropriate index number (see table 1).

While it is recognized that this method of data storage involves appreciable program redundancy, it has the advantage of programming simplicity and flexibility.

Figure 12. An example of a gem data display that occupies two "pages" on the monitor.

```

CHALCEDONY (Page 1 of 2)
A cryptocrystalline quartz
R.I. (range) D.R. Disp.(max) S.G.(range) H
-----
1.53-1.54 C.C. -- 2.58-2.64 6.5
Chemical Composition Xtal System Optical Clarity
-----
SiO2 Trigonal Transparent to opaque
Varieties - Agate, translucent, all colours, concentric bands
Bloodstone, opaque dark green with red jasper spots
Chalcedony, translucent unbanding grey or blue
Chrysoprase, translucent apple green
Cornelian, translucent orange-red
Fire agate, reddish iridescent in opaque chalcedony
Type 1 or 2 for gem pages. Key in 3 for Index Selection etc

```

```

CHALCEDONY (Page 2 of 2)
varieties (continued)
Moss agate, colourless, green dendritic hornblende inclusions
Onyx, translucent, black and white with parallel banding
Plasma, dark green, containing chlorite
Sard, translucent, brownish-red
Sardonyx, translucent brown/red and white with straight bands
Absorption spectrum - A chrome green chalcedony (similar to chrysoprase) has a sharp band in the red
Occurrence - World-wide
Type 1 or 2 for gem pages. Key in 3 for Index Selection etc

```

```

? 3
Critical Angle of gemstone = Arc sine(A/R.I. of gem)
where R = R.I. of surrounding medium, for air = 1)
Type in R.I. of gem (type 100 for Calculator selector).
? 2 42
Type in R.I. of surrounding medium (for air = 1)
? 1
Critical Angle of gemstone = 24
degrees (to nearest degree) ~~~~~
Type in R.I. of gem (type 100 for Calculator selector).
? -

```

Figure 13. One of the selections available in the Gem Calculations program is the computation of a gem's critical angle from its R.I. and the R.I. of the surrounding medium. In this example, diamond is shown as 24°.

```

Brewster Angle - the angle of incidence and reflection at which
light rays undergo maximum plane polarisation at a flat surface
Brewster Angle = Arc Tan(R.I. of reflecting material).
Type in R.I. of gem (or type 100 for Calculator selector).
? 1 434
Brewster Angle of Polarisation = 55 degrees (to nearest degree)
~~~~~
Type in R.I. of gem (or type 100 for Calculator selector).
? 2 417
Brewster Angle of Polarisation = 67 degrees (to nearest degree)
~~~~~
Type in R.I. of gem (or type 100 for Calculator selector).
? -

```

Figure 14. Another computation available is the Brewster angle of polarization. The two results shown in this example are for fluor spar and diamond.

5. Gem Calculations. This section contains five formulas used in gemology. The first enables calculation of a gem's S.G. from its in-air and in-water weighings. The second incorporates Fresnel's simplified formula relating surface reflectivity to R.I. in a chosen medium. The third is for determining a gem's critical angle (figure 13), and the fourth evaluates the Brewster angle of polarization for a particular R.I. value (figure 14). Section 5 of the program is the shortest; together with the program selector menu, it occupies 3.5K of storage space.

CONCLUSIONS

The extra programming flexibility and speed of data transfer obtained by using floppy disks as the storage medium, together with an expanded computer memory, have enabled the development of a professional gem program for both identification and data reference purposes.

The GEM DATA BANK program can be a useful aid and a time-saver when a difficult stone must be identified. Even after an identification has been made by conventional means, it can sometimes suggest a valid alternative identification. However, an installation similar to that used in the author's laboratory can cost in the region of US\$5,000, which may restrict its economic viability to the larger gem labs or to establishments already possessing a compatible computer installation (e.g., for inventory control, etc.).

Personal computers such as the Tandy TRS-80 Model 4 are now available with 64K to 128K of

built-in memory and self-contained twin disk drives. For the purpose of compatibility with smaller units, a program such as GEM DATA BANK can be slimmed down to fit the available memory by deleting some of the rare and collectors' stones. Computer-language and disk-handling system compatibility is another barrier to the widespread use of a common gem data program. Although Basic has a universal language structure, small differences exist in the versions supplied by the various computer companies. These differences, however, can usually be resolved by referring to the published literature (Lien, 1978).

Taking these various factors into account, it would seem commercially feasible to develop a gem computer program that could run on existing installations and provide a worthwhile addition to gem identification techniques. In common with all data systems, the accuracy of the stored information and its regular updating as new gem materials are discovered or created would be an essential ingredient of such a project.

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THE IDENTIFICATION OF TURQUOISE BY INFRARED SPECTROSCOPY AND X-RAY POWDER DIFFRACTION

By Th. Lind, K. Schmetzer, and H. Bank

A combination of infrared spectroscopy and X-ray powder diffraction methods is suggested for the identification of natural, treated, and synthetic turquoise as well as imitation turquoise. Both techniques require powdering only a very small quantity of the specimen (approximately 3 mg), which means minimal damage to the piece. New experimental results on treated turquoise and imitation turquoise are given.

Turquoise has been subjected to various methods of treatment in order to improve its value as a gem material, for example, enhance color or reduce porosity. In addition, a number of turquoise imitations are found on the gemstone market. Although many of these are called turquoise (Galia, 1977), at present, the so-called Gilson synthetic turquoise, which contains crystalline turquoise material as a component, is the only true synthetic available. The separation of natural, untreated turquoise from its treated counterpart, and the unequivocal identification of imitation or synthetic turquoise, is difficult with the routine gemological methods generally used. However, by applying techniques that are commonly used in mineralogy, e.g., X-ray powder diffraction methods and infrared spectroscopy, the gemologist can obtain the data necessary to sufficiently characterize the material (Banerjee, 1972; Arnould and Poirot, 1975; Williams and Nassau, 1976-1977; Schmetzer and Bank, 1980, 1981).

MATERIALS AND METHODS

The recognition of treated turquoise by infrared spectroscopy was comprehensively described by Banerjee (1972). Since that time, the practice of treating natural turquoise, especially the so-called stabilization techniques, has increased dramatically. Consequently, more and more samples have been submitted for investigation to determine whether or not the material is, indeed, natural turquoise, and, if so, whether it has been

treated in any manner. In an attempt to solve the questions posed by the gemstone industry, we initiated a systematic study of the turquoise and turquoise-like material available on the market in order both to develop criteria to characterize these products and to augment the information available in the literature. A summary of the various methods of treating natural turquoise that are currently used is given in table 1. Two of the most common methods, paraffin treatment and plastic impregnation, were included in this study.

In addition to the 30 specimens of unknown composition submitted by the industry for characterization, we investigated 15 samples of natural turquoise from the United States (Arizona, Nevada), Mexico, Iran, and China; 10 of plastic- and paraffin-impregnated turquoise; 4 of Gilson "synthetic turquoise"; and 5 of "reconstructed turquoise." Figure 1 illustrates some of the different types of stones examined for this study.

X-ray powder diffraction and infrared spectroscopy were used. For the X-ray investigations, powder photographs were prepared using the Debye-Scherrer method. The infrared spectra were recorded on a Perkin Elmer 180 Infrared Spectrometer using the KBr pressed-pellet technique. Both techniques mentioned require the powdering of a very small quantity of the specimen. Normally, Debye-Scherrer photographs can be taken with less than 1 mg of powdered material; for the preparation of a KBr pellet for infrared spectroscopy, 2 mg of the sample were used.

ABOUT THE AUTHORS

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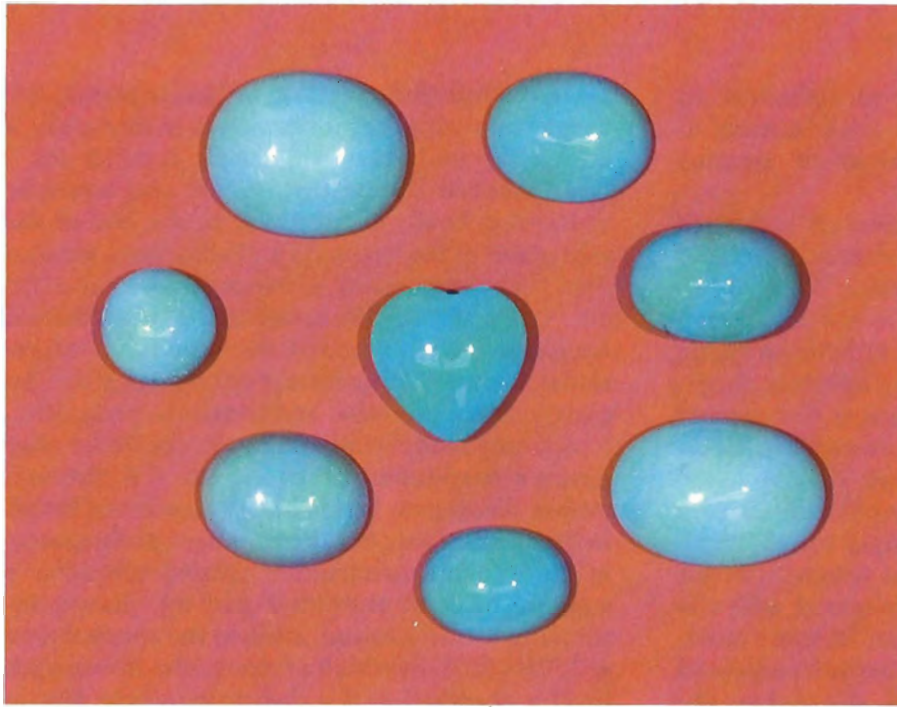


Figure 1. Samples of the different types of turquoise—natural, treated, synthetic, and imitation—studied by the authors. The center, heart-shaped cabochon is a Gilson synthetic, 2.10 ct. Clockwise, starting with the small stone to the left of the center specimen, the others are: paraffin impregnated, from Iran (1.38 ct); Gilson synthetic (4.91 ct); plastic impregnated, from Arizona (2.03 ct); natural, from Iran (2.79 ct); natural, from Arizona (4.50 ct); paraffin impregnated, from Arizona (1.79 ct); plastic-impregnated gibbsite (2.68 ct). Photo by Mike Havstad.

RESULTS

The results of the systematic investigations are summarized in table 2 and discussed in detail below.

Treated Turquoise. When plastic impregnation was first used, in the late 1960s, the so-called stabilized turquoises that resulted (which have nothing to do with the reconstructed turquoises

described later in this article) were considered to be of relatively poor quality. At that time, primarily turquoise too porous for cutting was plastic-impregnated to improve the hardness of the specimen (see Banerjee, 1972; Galia, 1977). Currently, good-quality turquoise is also treated by plastic impregnation in order to improve the durability of the material, since natural turquoise is very sensitive to chemicals and has been known

TABLE 1. Treatment procedures used on natural turquoise.^a

Procedure	Treatment substance	Color change	Other purposes of treatment	Penetration	Advantages/disadvantages
Dyeing, varnishing	Colored organic or inorganic compounds, mixed with epoxy or other resin	Light colors become darker		Surface	
Paraffin treatment	Paraffin of different melting points	Light colors become darker	Impregnation	1–2 mm	Very uniform colors
Stabilization treatment (hardening by plastic impregnation)	Plastics (colorless or blue-dyed) with a polyester or polyacryl base	Light colors become darker	Impregnation, restoration of natural colors, improvement of durability for material of all qualities	>4 mm	Colors vary; enables cutting of weathered and porous material (chalk)
Stabilization treatment (hardening by use of inorganic mineral salts)	Inorganic mineral salts, e.g., colloidal silica		Same as for stabilization treatment by plastic		

^a For further details, see Galia (1977) and Gübelin (1981).

to suffer damage from simple perspiration. At present, plastic impregnation (stabilization) is thought to be the best method of treating turquoise.

The X-ray powder diffraction of stabilized turquoise shows additional diffraction lines which do not belong to turquoise. These additional lines are also observed in the diffraction pattern of some specimens of Gilson synthetic turquoise. The d-values of these lines are identical to those of the strongest lines of the mineral berlinite, the chemical formula of which is AlPO_4 (ASTM 10-423). When we took several X-ray powder diffraction photographs of material from different areas of a single sample of stabilized turquoise, we observed that the intensity ratios of the berlinite lines varied compared with the intensities of the turquoise lines. In some cases, areas with great percentages of berlinite adjoined areas in which no berlinite was observed by the X-ray diffraction method.

The formation of an AlPO_4 phase with cristobalite structure after an exothermic reaction produced by heating turquoise to 840°C was described by Manly (1950). The substance investigated also showed some relicts of an earlier berlinite structure. Banerjee (1972) described the formation of an amorphous phase in turquoise after heating it to 400°C . With further heating (to between 740° and 775°C), an exothermic reaction identical to that described by Manly (1950), in which the AlPO_4 phase with cristobalite structure is formed, was observed. To clarify whether the AlPO_4 phase causing the additional X-ray lines found in the diffraction pattern of plastic-impregnated turquoise might be formed by the stabilization procedure, we conducted heating experiments on natural, untreated turquoise (180°C for 24 hours and 250°C for 24 hours). The X-ray powder photographs of every area investigated in the treated samples showed the strongest diffraction lines of berlinite in addition to the turquoise lines. It appears from these experiments that the AlPO_4 phase with berlinite structure forms at lower temperatures than those previously described in the literature; that is, berlinite can also be formed in the stabilization treatment. The fact that lower temperatures and shorter heating periods are usually used in the plastic-impregnation procedure explains why berlinite forms in some areas of the stabilized turquoise and not in others.

In the infrared spectrum of the six plastic-impregnated turquoises investigated in this study, a strong infrared absorption band at 1725 cm^{-1} was observed in addition to the characteristic absorption bands of turquoise in the area of the vibrations of the hydroxyl and phosphate groups. The absorption band between 1450 and 1500 cm^{-1} , described by Banerjee (1972) in stabilized turquoise, was not found during our investigations. The infrared spectrum of one sample of the plastic used for the stabilization procedure, which was made available to us, showed a very strong absorption band at 1725 cm^{-1} . Additional strong absorption bands of the plastic are found in the spectral area of the turquoise bands; that is, in the infrared spectrum of treated turquoise a superposition of turquoise and the plastic absorption bands is found. Only in the spectral area at 1725 cm^{-1} , in which no turquoise absorption band is observed, is the absorption of the plastic distinctly separated from the absorption of the turquoise. The absorption spectrum of the plastic used for the impregnation procedure is not identical to the spectra reported by Banerjee (1972). The strongest absorption band in our plastic was found at 1725 cm^{-1} , but no absorption band was observed between 1450 and 1500 cm^{-1} . Our industry sources have advised us that in the more than 10 years since Banerjee's article was published, new types of plastic have been adopted for the stabilization of turquoise.*

In the X-ray powder diffraction pattern of turquoise that has been paraffin impregnated (see table 1), the additional lines due to berlinite found in plastic-impregnated samples were also observed incidentally. Additional absorption bands in the infrared spectrum were not found when the KBr pressed-pellet method was used. This method of treatment is not limited to high-quality turquoise specimens as described by Galia (1977). Unfortunately, the use of this procedure is not always identified when the material is sold.

Synthetic Turquoise. At present, Gilson's synthetic turquoise is the only synthetic product found on the market in which the powder pattern

*The kind of plastic investigated in this study, which is commonly used for the stabilization of turquoise, is known to the authors. We respect, however, our source's request that we keep this information confidential.

of crystalline turquoise is observed by X-ray investigations (Williams and Nassau, 1976–1977; Schmetzer and Bank, 1980, 1981). In comparison to the turquoise pattern, however, in all of the samples of Gilson's synthetic product that we investigated, we observed additional X-ray diffraction lines caused by one or more additional crystalline phases. In two of the samples, the diffraction lines of berlinite were also found. When the specimens were examined using spectroscopy, we observed an absorption band at 1725 cm^{-1} in two of them as well, in addition to the absorption bands characteristic for turquoise. This band indicates that the synthetic material has also been treated.

Reconstructed and Imitation Turquoise. In addition to systematic experiments with natural, treated, and synthetic turquoise, we also investigated imitation turquoises. We used samples submitted to us by the trade to determine the composition of the specimens (compare Banerjee, 1972; Williams and Nassau, 1976–1977; Galia, 1977; Gubelin, 1981).

Dyed magnesite has been known for some years to be used as a turquoise substitute. Dyed calcite and dolomite were also observed recently. All three were found among the imitations examined (interestingly, dyed howlite, another common imitation, was not present among the samples studied). X-ray diffraction investigations revealed that most of the specimens called "reconstructed turquoise" in the trade were free of any turquoise component. $\gamma\text{-Al(OH)}_3$ (as a mineral, gibbsite) was the only crystalline phase

found in these samples. In the infrared spectrum, the absorption at 1725 cm^{-1} , known already from the plastic component of stabilized turquoise, was observed. According to Galia (1977), true reconstructed turquoise is produced from finely powdered and cleaned turquoise and has crystalline turquoise as the main component. The "reconstructed turquoise" investigated in our laboratory, however, contained no turquoise; therefore, "reconstructed turquoise" is thought to be a misnomer for gibbsite that has been dyed and plastic-impregnated.

CONCLUSION

This investigation of natural and treated turquoise, of Gilson synthetic turquoise, and of various imitation turquoises suggests that most "turquoise" products found on the market can be identified by a combination of X-ray powder diffraction and infrared spectroscopy. Only paraffin-impregnated turquoise could not be positively identified by the two methods in all instances. Both methods require only very small amounts of powdered substance, which normally can be obtained from cut specimens without causing undue damage. We believe that, for the purpose of gemological nomenclature, the mineral name *turquoise* should be restricted to natural and synthetic turquoise only. In samples without a component of crystalline turquoise, the use of the name *turquoise* without the supplement "imitation" or "simulant" is misleading. In our opinion, the fact that a specimen of natural turquoise has been treated, regardless of the method used, should be disclosed in the trade.

TABLE 2. Results of X-ray powder diffraction and infrared spectroscopy tests on natural (untreated), treated, synthetic, and imitation turquoise.

Sample	X-ray powder diffraction pattern	Infrared spectrum
Turquoise, untreated	Turquoise	Turquoise
Turquoise, plastic impregnated	Turquoise or turquoise + berlinite	Turquoise + absorption band at 1725 cm^{-1}
Turquoise, paraffin impregnated	Turquoise or turquoise + berlinite	Turquoise
Gilson "synthetic turquoise"	Turquoise + several diffraction lines of an unknown phase or turquoise + several diffraction lines of an unknown phase + berlinite	Turquoise or turquoise + absorption band at 1725 cm^{-1}
Some "reconstructed turquoise" specimens from the trade	Gibbsite	Gibbsite + absorption band at 1725 cm^{-1}
Different imitation turquoises ^a of the trade	Magnesite, calcite, or dolomite	Not investigated

^aThe X-ray powder diffraction patterns of other imitation turquoises were published by Williams and Nassau (1976–1977).

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Editorial Forum

DINOSAUR BONE AGATE

I am writing in response to the item about paleontological gemology in the Gem Trade Lab Notes section of the spring 1983 issue of *Gems & Gemmology*. All jewelry is valued because of its intrinsic beauty, and dinosaur bone agate can make a very lovely gem material. It is described by Arem in the *Color Encyclopedia of Gems* as a having "lovely brownish color and interesting pattern," although it has been known to occur in many different colors. In his book *Gems*, Webster states that the material can be found in Colorado, Utah and Wyoming—another American gem! In fact, it was Mr. Stuart Mace of Aspen, Colorado, who first introduced me to "bone."

The hard bone matrix is often darker compared to the other lighter agate that has replaced the bone marrow in the fossil. You can see in the photo of the oval key ring (figure 1) that the black agate (bone matrix) is sparse and thin, indicating that the bone had started to decompose before it was covered with mud and later replaced by agate. Some pieces of bone are dark blue and translucent, with a lovely "spider web" pattern appearing when lighted from the back. The finest pieces I've ever seen have lightly colored agate bone marrow replacement, with a transparency similar to that of moss agate.

James Lestock, G.G.
Paul J. Schmitt Jeweler
Marco Island, Florida

MALACHITE CRYSTALS?

I would like to compliment Dona M. Dirlam, editor of the Gemological Abstracts section of *Gems & Gemology*, on the fine job she is doing on this department, which is both accurate and interesting from issue to issue.

I would, however, like to take issue with a state-

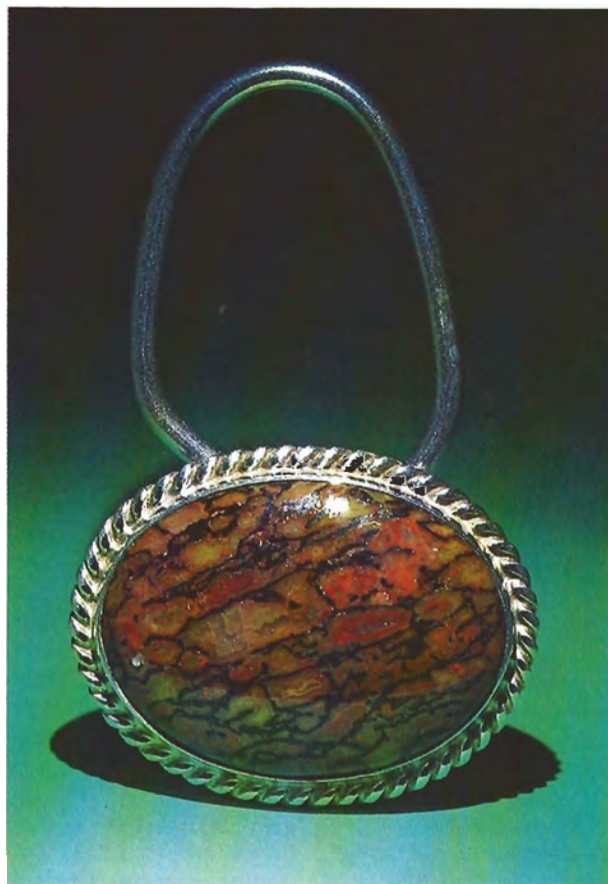


Figure 1. Dinosaur bone agate (29 × 22 mm) set in a sterling key ring. Photo by Mike Havstad.

ment made by Gary Hill in his abstract of S. Frazier's article on vug collecting that appeared in the Summer 1983 issue of *Gems & Gemology*. The passage in question concerns "... oxidized zones ... where crystals such as malachite or azurite may be formed." I do not know of any instance where malachite crystals are

formed, except in the case of pseudomorphs of malachite after azurite (which many mineralogists do not yet consider a true pseudomorph).

Again, thanks for an improved department.

Maurice Weil, M.S., G.G.
M.K. Weil, Import and Wholesale
Shreveport, Louisiana

Mr. Weil is correct in emphasizing that malachite commonly occurs in a massive form. However, crystals have been reported: small crystals from Betzdorf and Horhausen, Germany, and acicular crystals from the Copper Queen mine near Bisbee, Arizona (see C. Palache et al., Dana's System of Mineralogy, 7th Ed., Vol. II, pp. 252-256).

For further discussion of pseudomorphs as well as crystallization, refer to the abstract of "Malachite-azurite" by S. Koritnig, der Aufschluss, Vol. 32, No. 1, 1981, pp. 1-5 (Gems & Gemology, Fall 1981, p. 168). In addition, the cover photo of that issue of der Aufschluss is of acicular crystals of malachite from Tsumeb, Southwest Africa.

We are delighted to receive correspondence regarding the abstracts and encourage our readers to send their comments.—Abstracts Editor

UNUSUAL INCLUSION IN AMETHYST

I am enclosing a photomicrograph of an inclusion I found in a 1-ct amethyst (figure 2). In your Summer 1971 issue of *Gems & Gemology*, page 322, some similar inclusions are shown in a black and white photo, and your writer likened them to moon-shot vehicles. It is interesting to note that this was the only significant inclusion found in my amethyst. The specimen was cut in half in order to get a clear field of vision for the photo. In texture it resembles the cacoxenite inclusions shown on page 173 of Gübelin's *Internal World of Gemstones*.

The photo was taken using an Eickhorst Tri-ocular GemMaster microscope unit, Olympus OM-1 SRL camera, on Kodachrome 64. Lighting was part trans-

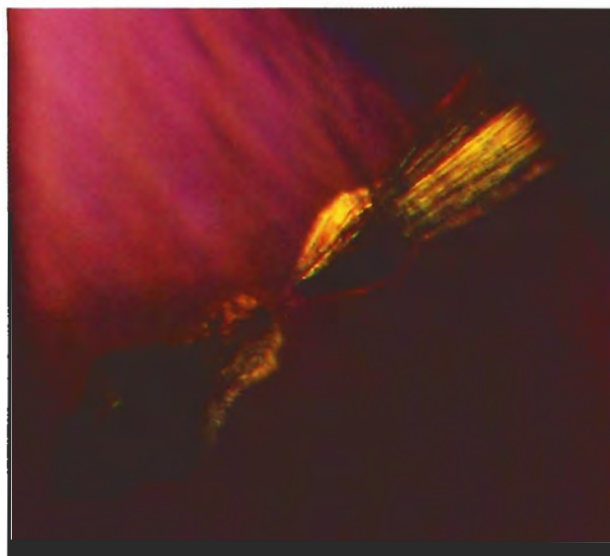


Figure 2. Inclusion in amethyst, magnified 25 \times .
Photomicrograph by A. de Goutière.

mitted light and highlighted with the new GEM pin-point illuminator.

A. de Goutière, G.G.
de Goutière Jewellers, Ltd.
Victoria, BC, Canada

ERRATA

The painting titled *The Red Hat* (Gordon Conway, 1929), which appeared on page 5 of the Spring 1983 issue, is in private hands, not part of the collection of the American Institute of Architects as reported in the figure legend.

The optical absorption spectra illustrated in figure 6 of the article "Peridot from Tanzania" (Summer 1983, p. 106) were inadvertently interchanged. Spectrum A (bands at approximately 452, 470, 483, and 492 nm) belongs to the peridot from Mexico and spectrum B (bands at about 500 and 536 nm), to the East African enstatite.

Gem Trade LAB NOTES

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ALEXANDRITE

A Large Cat's-Eye

The Santa Monica Gem Trade Laboratory had the opportunity to examine another fine cat's-eye alexandrite from Sri Lanka. The large (17 mm in diameter), round cabochon, which weighed 32.69 ct, had a pronounced change of color.

Figure 1 shows the stone as it appeared under incandescent (left) and fluorescent (right) illumination. For its large size, the stone was remarkably translucent. It showed few inclusions other than the long needles that caused the chatoyancy.

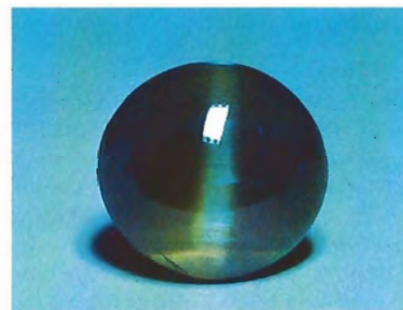


Figure 1. A cat's-eye alexandrite, 17 mm in diameter (32.69 ct) under incandescent light (left) and fluorescent light (right).

der magnification (figure 3). We do not know if this is an isolated piece

or if the material is destined for commercial use.

AMBER, in Plastic

A necklace of graduated barrel-shaped variegated yellow and brown beads (figure 2) came into the New York laboratory for identification. At first glance, it resembled the many amber necklaces we have tested over the years. However, this one proved different and new to us. The refractive index and fluorescence, which varied from spot to spot on the same bead, did not agree with amber, which would have only one R.I. and one color of fluorescence for the bead. The conclusion that the beads were actually composed of bits of amber embedded in plastic was confirmed by the acrid odor of the host material when tested with a hot point, as compared to the resinous odor of the embedded amber, and its appearance un-

Figure 2. A necklace of amber-in-plastic beads.



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Figure 3. An amber-in-plastic bead at 10× magnification.

DIAMOND

Diamond Simulant

Our New York laboratory encountered what may be a new high in potential deception. Figure 4 is a photo of the culet area of a round brilliant-cut cubic zirconia, with a laser hole that reflects in several pavilion facets. At least one appraiser was fooled into thinking he was examining a diamond.

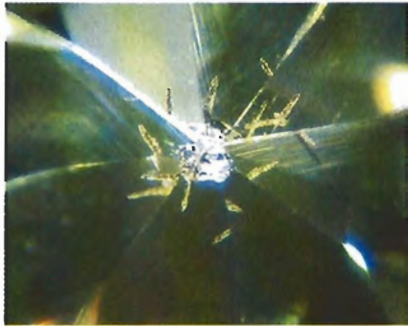


Figure 4. Faceted cubic zirconia that has been laser drilled. Magnified 60×.

Mysterious Wear on a Diamond Ring

Figure 5 shows a gold pavé diamond cluster ring submitted to the New York lab for identification of the stones. The client could not believe that diamonds could show so much wear. Not only did the center stone show obvious abrasions of the facet junctions (figure 6)—as severe as one would expect to see on zircon—but all of the smaller stones set completely around the band showed

equally severe abrasion. It is not known under what conditions the ring was subjected to such severe wear.

Painted Diamonds

When a New York diamond dealer decided to repolish a fancy orange marquise because of a myriad of odd scratches on the pavilion, he was hardly prepared for the result: The stone lost all orange color and proved to be faint yellow. It was obviously a case of a stone that had been "painted"—in this case, on the pavilion only.

This experience prompted his supplier to examine other fancy-colored diamonds in stock. Figure 7 shows an attractive yellow-green diamond that exhibited the same peculiar scratches, again only on the pavilion. When the stone was examined for irradiation stains on naturals, or for evidence of cyclotron treatment, nothing unusual was seen. However, the dealer decided to check to see if the stone was coated by attempting to break through the coating with a hard point. Figure 8 shows that his suspicions were correct; note the patchy area toward the narrow end of the facet where the coating was removed. Toward the girdle, the scratches in the coating are also visible. When the stone was cleaned carefully and the entire surface examined, one small "crater," or ring of color, was seen (as indicated by the arrow in figure 9). This was reminiscent of the craters in the coatings we used to see on near-colorless diamonds that had not been scrupulously cleaned before being coated with vitreous enamel to disguise the yellow. Because the color coatings we have seen recently also seem to be quite resistant, it is possible that they, too, are something like a vitreous enamel or a china glaze.

DIASPORE, A Rare Gem Material

Recently sent to the Los Angeles laboratory for identification was

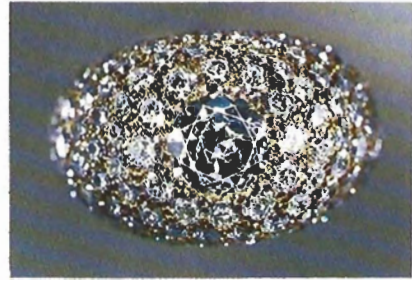


Figure 5. Pavé diamond ring in which the stones have been badly worn.

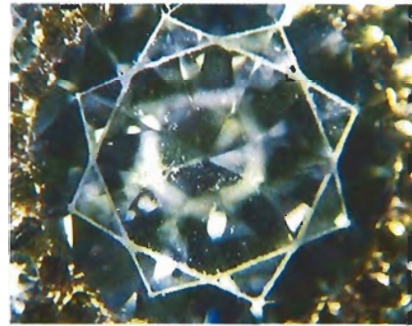


Figure 6. Abraded facet junctions on a diamond from the ring shown in figure 5. Magnified 23×.

the transparent, 1.24-ct, square step-cut gemstone illustrated in figure 10. This stone showed a moderate color change from light greenish yellow in daylight to light pinkish yellow in incandescent light.

Testing with a refractometer and a monochromatic filtered light source revealed that the stone was biaxial positive with a refractive index of 1.702 for alpha, 1.722 for beta, and 1.750 for gamma, with a corresponding birefringence of 0.048. Examination of the visible-light absorption spectrum revealed a weak band from approximately 4500 Å to 4600 Å. The specific gravity was determined by means of the hydrostatic technique to be 3.35 ± 0.03 . Strong pleochroic colors of yellowish green, brownish yellow, and violetish brown were observed. Microscopic examination revealed a partial cleavage, several needles

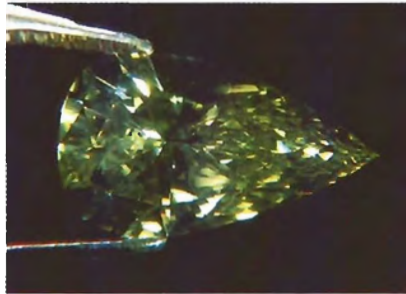


Figure 7. A 1.06-ct pear-shaped "painted" green diamond. Magnified 16 \times .

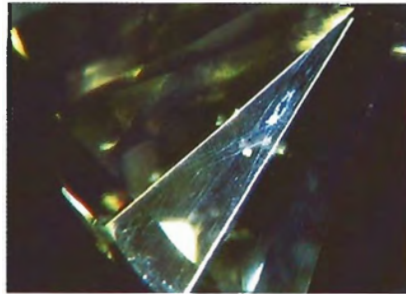


Figure 8. The patchy area the hard point made in the coating of the diamond shown in figure 7 proved it was "painted." The scratches also evident here provided an important clue to the unnatural source of the color.

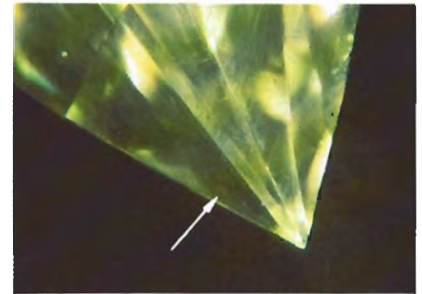


Figure 9. The ring of concentrated color at the point of the diamond illustrated in figures 7 and 8 is similar to "craters" seen in the past on near-colorless diamonds that had been coated with vitreous enamel to disguise the yellow. Magnified 63 \times .

and growth tubes, and a couple of included crystals.

The stone was then sent to our Santa Monica laboratory where a minute amount of powder was scraped from the girdle for X-ray diffraction. The results of the X-ray powder diffraction analysis confirmed that the stone was diaspore.

Diaspore is an aluminum hydroxide with the chemical formula



Figure 10. A 1.24-ct gem-quality diaspore.

$AlO(OH)$. It is commonly found associated with corundum, possibly as an alteration product of the oxide. Diaspore occurs in numerous localities around the world, almost always as small crystals, with gemmy material being quite rare. Particularly notable, however, were crystals found at the emery mines in Chester, Massachusetts, which apparently were suitable for cutting. Gem-quality diaspore reportedly appeared very briefly on the market in Germany several years ago. The locality of the stone we examined is not known. Table 1 summarizes the properties of gem-quality diaspore.

EMERALD

Occasionally a stone will show patterns that provide proof of its

growth process. Figure 11 shows an elongated helix that is the manifestation of the spiral growth that occurs in a natural emerald. The length of the helix parallels the c-axis of the crystal.

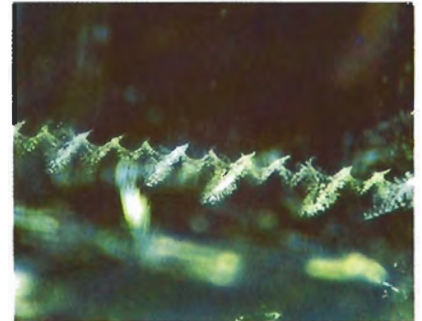


Figure 11. Spiral growth pattern in a natural emerald. Magnified 63 \times .

TABLE 1. Properties of gem-quality diaspore.

Dimorphous with boehmite	Optic character: biaxial positive
Formula: $AlO(OH)$	Refractive indices: α 1.702, β 1.722, γ 1.750
Crystal system: orthorhombic	Birefringence: 0.048
Fracture: conchoidal	Pleochroism ^a : strong; yellowish green, brownish yellow, and violetish brown
Cleavage: perfect one direction	Fluorescence: weak yellow
Specific gravity: 3.3-3.5	Spectrum ^b : weak band at 4500 Å to 4600 Å
Hardness: 6½-7	

^aPleochroism for the stone tested; will vary depending on the color of the material.

^bOne sample only tested.

JADE Substitute

A white metal, closed-back ring that was bezel set with a translucent, mottled green and white, carved and pierced tablet was submitted to the Los Angeles laboratory for identification (figure 12). The client questioned whether the material was in fact jadeite or one of its substitutes.



Figure 12. A glass imitation of jadeite. The ring measures 29.4 × 21.4 mm.

Examination with the unaided eye revealed a somewhat swirled coloration, an overall vitreous luster, and several small conchoidal fractures. With the spot method, the refractive index was determined to be 1.57. Under magnification, the structure of the material was not that of a mineral, but rather was suggestive of glass or plastic. Using a fiber-optic illuminator for oblique illumination, we found the answer: several elongated gas bubbles were observed near the edge of the tablet. Testing with the thermal reaction tester provided no reaction, thus ruling out plastic as the identity of the material. It was then concluded

that this tablet was glass, a common substitute for jade.

LAPIS LAZULI, A New Imitation

The Santa Monica Gem Trade Laboratory was asked to identify the opaque blue cabochon pictured in figure 13. Examination of the cabochon surface revealed pyrite inclusions, easily visible with the unaided eye, some in the shape of well-defined octahedra. Magnification showed the presence, in some areas, of some elongated, rounded dark blue grains (figure 14). Therefore, it was possible that the material could very well be lapis lazuli.

However, further testing of the material did not verify our initial observation. Because of a poor polish, we obtained only a vague R.I. spot reading of 1.58. The specific gravity was determined by hydrostatic weighing to be 2.23. There was no reaction to ultraviolet radiation. All of these properties are different from those of lapis lazuli. A small amount of hydrochloric acid applied to the back of the cabochon caused slight effervescence; it also gave off an H₂S, or rotten egg, odor. A slightly discolored white spot remained on the surface that had been attacked by the acid.

The characteristic appearance of the material reminded us of the type of imitation lapis lazuli that is produced by P. Gilson. However, the refractive index and the specific gravity were slightly lower than have been reported for this type of imitation. When an X-ray diffraction analysis of the material was performed, the pattern obtained indicated that the material contained calcite and hauyne. A comparison of this diffraction pattern with that of Gilson's imitation lapis lazuli showed no correlation between the two materials. We concluded, therefore, that this imitation lapis lazuli was different from any we had encountered before.

OPAL, Update on Gilson Synthetic

The Santa Monica lab was shown three parcels containing numerous

Figure 13. This 4.09-ct cabochon represents a new lapis lazuli imitation.



8- × 10-mm cabochons that were labeled "blue opals." They were represented to be the latest synthetic black opals made by P. Gilson.

Our first impression was that these stones (figure 15) had a much more natural appearance than the synthetic material we had seen before. The play of color—predominantly green and blue but also with some red—was less distinct, so the stones had a much softer look than the earlier material, which showed very sharply defined color areas.

Under magnification, all of the cabochons examined showed numerous gas bubbles of various sizes. These bubbles were easier to see in the translucent material than in the more opaque stones. The reaction to ultraviolet radiation was diagnostic: a strong, chalky, yellowish green to short-wave and a faint to no reaction to long-wave. No phosphorescence was seen. All of the cabochons also showed the cellular snakeskin or "chicken wire" pattern that we have already found to be a distinctive characteristic of Gilson synthetic opals.

PEARLS, Cultured Button

We received a pretty, light pink, button-shaped pearl for identification. The pearl, which was undrilled, had a very high luster. It measured approximately 4 × 5 mm in diameter. At the center on the flat side we noticed a quite unusual

Figure 14. Note the pyrite and dark blue grains in the imitation lapis shown in figure 13. Magnified 22×.

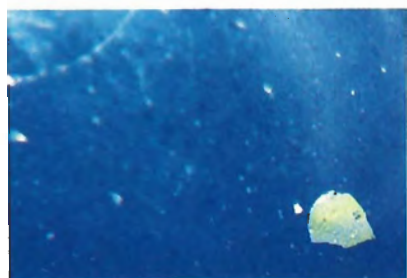


Figure 15. New Gilson synthetic opals (8 × 10 mm each).

structural characteristic. Figure 16 shows a pattern similar to that seen in the cross section of a tree trunk.

The pearl showed no fluorescence to X-radiation. However, the X-radiograph revealed a fairly small, round, mother-of-pearl bead center, proving that the pearl was cultured rather than natural.

PINITE, A Massive Form of Muscovite

Recently sent to the Los Angeles laboratory was an opaque, mottled, dark brown, light brown, and white carving that had a floral motif on one side and was inscribed with Oriental characters on the base and the other side (see figure 17). Examination with the unaided eye revealed an overall dull, waxy luster. A broken portion near the top of the carving showed a dull, waxy, granular fracture.

Given the relatively poor polish, a refractive index reading was difficult to obtain; using the spot method, however, we found an approximate value of 1.57. To determine the approximate specific gravity of the material, we gently immersed the carving in bromoform (which has a density of 2.89). The carving ascended at a moderate rate; a specific gravity near 2.7 was estimated. A hardness test was carefully performed on a partially con-

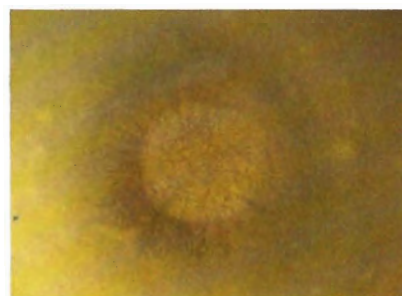


Figure 16. Unusual growth mark on a cultured button pearl. Magnified 30×.

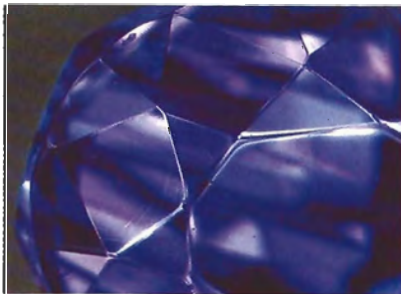
cealed, recessed fractured area; on the basis of the results, the stone's hardness was estimated to be around 3 on the Mohs scale.

Because we were able to perform very few routine gemological tests on this carving, a minute amount of powder was scraped from it for X-ray diffraction analysis. The results of the X-ray powder diffraction showed that it matched one of the patterns of muscovite mica. The carving was identified as pinite, a massive form of muscovite. Pinite is a general term used to describe a number of alteration products, which include muscovite. Pinite is essentially a hydrous silicate of aluminum and potassium, corresponding closely to muscovite in composition, and is generally regarded as its massive variety. It is usually impure from the admixture of clay and other substances.



Figure 17. This carving made from pinite, a massive form of muscovite, measures 53.2 × 20.9 mm.

Figure 18. Rounded facet junctions on a faceted tanzanite. Magnified 30×.



ZOISITE (TANZANITE), Rounded Facet Junctions

Recently submitted to the Los Angeles laboratory for identification was the 2.93-ct bluish purple oval mixed cut illustrated in figure 18. With subsequent testing the stone was identified as zoisite, known in the trade as "tanzanite." The somewhat unusual feature of the stone was the presence of very rounded facet junctions (again, see figure 18).

Rounded facet junctions are typ-

ical of, and usually associated with, molded stones, such as glass or plastic. Such facet junctions are often observed in these less expensive imitations; they are formed by pressure as the molten material is molded to appear as if faceted (the more expensive glass imitations are often faceted after molding).

Molded facet junctions are not nearly as sharp as the facet junctions on most materials that have been cut and polished. This tanzanite, however, exemplifies the fact that a faceted gemstone, like its molded imitation, may have rounded facet junctions.

The presence of rounded facet junctions in faceted materials is often a result of poor polishing techniques. If excess pressure is applied to polishing laps that are soft and flexible, too much polishing powder can build up near facet junctions between the surface of the stone and the lap, thus rounding the facet edges. This characteristic may also occur with stones that are fairly soft, such as fluorite, particularly if wax, pitch, or wood laps are used for polishing. Tanzanite is usually polished on a hard tin lap with aluminum oxide; sharp facet junctions may be obtained easily even though the hardness of zoisite is only 6–7.

Rounded facet junctions may also occur when a stone is repolished with a polishing buff. This sometimes happens when a jeweler polishes a mounting, after repringing or sizing, without removing the stone.

ACKNOWLEDGMENTS

The photos in figures 1, 13, and 15 were taken by Mike Havstad. Andrew Quinlan, from the New York laboratory, took figures 2–9 and 11. John Koivula supplied figure 16. Shane McClure, from the Los Angeles laboratory, furnished figures 10, 12, and 17. Figure 14 was taken by Chuck Fryer. Figure 18 was furnished by Tino Hammid.

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COLORED STONES AND ORGANIC MATERIALS

Application of lattice imagery to radiation damage investigation in natural zircon. K. Yada, T. Tanji, and I. Sunagawa, *Physics and Chemistry of Minerals*, Vol. 7, 1981, pp. 47-52.

Some zircon occurs as dark-colored, opaque material that is unsuitable for faceting. Zircon frequently contains minor amounts of uranium and thorium. The radioactive decay of these elements produces high-energy nuclear particles, the rapid movement of which acts to disrupt the zircon crystal structure. Whereas transparent zircon has been damaged only slightly by the transit of these particles, the opaque type has suffered extensive

radiation damage and is referred to as being in a metamict state.

In this study, the authors applied transmission electron microscopy (TEM) to understand the mechanism of radiation damage in zircon. The TEM technique provides high-resolution electron images of atomic positions in a crystal structure. By examining various types of gem and nongem zircon, Yada and his colleagues were able to obtain images of fission tracks and other kinds of radiation damage in this material. They found that, with increasing radiation damage, the zircon crystal structure is progressively disrupted, leading to the eventual breakdown of the material. Thus, even the treatment of opaque, metamict zircon cannot restore a gem-quality transparency. JES

The genesis of an emerald from the Kitwe District, Zambia. G. Graziani, E. Gübelin, and S. Lucchesi, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 4, 1983, pp. 175-186.

The authors present a mineralogical characterization of emerald from the Kitwe District in Zambia and speculate about its origins. Optical, X-ray diffraction, and chemical data are included. Indices of refraction are $\omega=1.586$ and $\epsilon=1.580$, while the measured density is 2.794 g/m^3 . Microprobe analyses indicate that emeralds from this area have a relatively high content of Fe and Mg but low content of Cr and alkalis.

This material contains a number of different types of inclusions, several of which are illustrated in the article.

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

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

The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names.

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Specific mineral inclusions identified so far include rutile, quartz, muscovite, margarite, apatite, and chrysoberyl. Identification of these inclusions and of associated minerals in the metamorphic host rock in which the emerald occurs enabled the authors to establish the conditions of emerald formation at this locality: at temperatures in the range of 430°C to 650°C and at pressures lower than 4 kilobars. JES

DIAMONDS

Apatite inclusions in natural diamond coat. A. R. Lang and J. C. Walmsley, *Physics and Chemistry of Minerals*, Vol. 9, No. 1, 1983, pp. 6–8.

Diamond crystals often exhibit a thin, light-colored, translucent coating of foreign material. Various minerals have been found in this coating. Using electron microscopy, electron diffraction, and X-ray spectroscopy techniques, Lang and Walmsley investigated the nature of some tiny particles of submicrometer dimensions that are present in some of this diamond coating material. Several of these particles identified so far are the mineral apatite [$\text{Ca}_3(\text{PO}_4)_3(\text{F},\text{OH})$], which has never before been confirmed in this type of occurrence. On the basis of their results, Lang and Walmsley expressed surprise at the present findings that while apatite is not infrequent among the minerals in diamond coatings, it is absent from the lists of inclusion minerals that have been reported in diamonds. JES

Are these diamonds from Orapa or Brazil? J. Harris, *Indiaqua*, Vol. 32, No. 2, 1982, pp. 35–38.

Harris presents an update on a classification system for grading diamond rough that was developed in 1970. The purpose is to be able to sort diamonds into categories not only by shape and color, but also by the individual mine.

The primary division of the rough diamonds in this system is by crystal shape. Ideal growing conditions produce octahedrons, whereas with lower temperatures cubes form. A super-saturated growth environment encourages twinned crystals, such as macles, or crystal aggregates. By slicing and etching a dodecahedron, researchers have concluded that this crystal shape resulted from resorption and is not a growth form of diamond.

The rough diamonds are also categorized into secondary divisions: transparency, crystal angularity, crystal regularity, inclusions, color, surface features, ultraviolet fluorescence, and plastic deformation (deformation of the shape without rupturing). These features are very briefly described, some with statistics.

Ten photographs accompany the text. Eight graphs summarizing the information compiled on individual mines are also included, but are difficult to read and interpret. Harris concludes by suggesting that one day

it may be possible to determine the origin of a particular diamond. FLG

Famous diamonds of the world (XIV): the "Williamson Pink" diamond. I. Balfour, *Indiaqua*, Vol. 33, No. 3, 1982, pp. 125–128.

In part 14 of this series on famous diamonds, Ian Balfour tells the story of the "Williamson Pink." This intensely colored diamond is the most significant pink stone from the Williamson Diamond Mine in northern Tanzania, which is noted for both colorless and fancy-colored diamonds.

The Williamson Pink is important not only in its own right, but also because of the story of the founder of the mine, Dr. John Thorburn Williamson, whose biography Balfour summarizes. This enigmatic geologist discovered the Williamson Mine, at the time the largest known pipe in the world, in 1940. Discovered in 1947, the Williamson Pink weighed 54.5 ct in the rough. In the same year, Dr. Williamson presented the stone to Queen Elizabeth II on the occasion of her wedding. The diamond was eventually fashioned into a fine round brilliant weighing 23.60 ct, and in 1953 Cartier mounted it in the center of a flower spray brooch for the queen.

The author has written a well-researched and interesting article. Eleven illustrations accompany the text. FLG

Kimberlites—a petrologist's best friend. S. L. Bolivar, *Earth Science*, Vol. 35, No. 3, 1982, pp. 15–18.

Bolivar presents a very readable explanation of how the study of kimberlites aids the petrologist. He begins by elaborating on the title, stating that "not only are kimberlites the primary source of terrestrial diamonds, but they also contain xenoliths (inclusions) believed to originate in the upper mantle." Thus, through kimberlites, we can study the materials and processes involved in the formation of minerals in the earth's interior.

Bolivar then focuses on kimberlites in the U.S., giving special attention to the diamonds found at Crater of the Diamonds State Park in Arkansas. Twelve kimberlite localities are marked on a U.S. map. The author also includes two diagrams: one is a profile of the Murfreesboro, Arkansas, kimberlite; the other is a cross section of the kimberlite in Elliott County, Kentucky.

Bolivar concludes with a brief discussion of the petrographic complexity of kimberlites, noting that a single thin-section may contain as many as 30 mineral phases. DMD

Predicting the occurrence of diamondiferous kimberlites.

F. R. Boyd, *Indiaqua*, Vol. 33, No. 3, 1982, pp. 31–34.

Noting that most kimberlites are not diamond-bearing, Boyd presents an interesting account of how geologists determine which kimberlites are likely to contain diamonds. Through theoretical models, scientists have

established that diamonds form within a limited temperature and pressure range now called the diamond stability field. Other researchers discovered that mineral solid solutions reflect the temperatures and/or pressures at which they formed. Since these have been calibrated through laboratory experiments, it is now possible to use them to estimate the conditions at the time of a rock's formation. For kimberlites, the indicator of pressure is a solid solution between two pyroxenes, the enstatite-diopside series. For temperature, the indicator is garnet.

Geologists sample the kimberlite directly or search for nodules, rounded fragments of rock carried up by the erupting kimberlites. Once the minerals in these samples are compared to the calibrated values, geologists can determine whether a kimberlite formed within the diamond stability field.

Boyd concludes by presenting graphs of data on nodules collected from four kimberlites: two that are diamond-bearing and two that are not. The graphs indicate that it is possible to predict the occurrence of diamonds. This information can help to justify further prospecting.

DMD

Spinel zonation in the De Beers kimberlite, South Africa: possible role of phlogopite. J. D. Pasteris, *Canadian Mineralogist*, Vol. 21, Pt. 1, 1983, pp. 41-58.

Micas and spinel-group minerals are common constituents in kimberlite from diamond-bearing pipes such as the De Beers pipe near Kimberley, South Africa. This pipe is known to comprise several distinct kimberlite intrusions which differ in terms of their mineralogic and petrographic features. In this study, Pasteris documents the compositional variations among spinels and the mica, phlogopite, to reveal possible genetic relationships among these several episodes of kimberlite intrusion.

Spinel and phlogopite were found to differ systematically in composition and texture within the root zone of the De Beers kimberlite. These compositional patterns are compatible with the hypothesis that the main type of kimberlite in the root zone represents successive intrusions from a single, fractionating magma at depth. In addition, there may be a single trend defined by the compositions of spinels that precipitate during the normal crystallization of kimberlite. If this is the case, it might be possible to place in sequential order the separate intrusions of kimberlite magma within a pipe, and to compare kimberlites from different districts with respect to their degree of fractionation. Studies such as this provide a better understanding of the geologic history of kimberlite pipes.

JES

GEM INSTRUMENTS AND TECHNIQUES

Contributions to the study of the distinction of natural and synthetic emeralds. H. W. Schrader, *Journal of Gemmology*, Vol. 18, No. 6, 1983, pp. 530-543.

Differences in physical properties (i.e., refractive index, specific gravity) or in types of inclusions have tradition-

ally been used to distinguish natural emeralds from their synthetic counterparts. However, the properties of the natural and synthetic stones may overlap, thus making distinction on this basis virtually impossible. In addition, some synthetic emeralds are completely devoid of inclusions, and therefore may be confused with flawless stones that may occur in nature. New methods of identification are needed. This article presents data on the trace elements in 44 natural and 14 synthetic emeralds from different occurrences and manufacturers.

Chemical differences on the trace-element level reflect the different conditions of origin of natural and synthetic gem materials, and thus may be of value in gem identification. The analytical methods used here to detect trace elements include neutron activation analysis and optical emission spectroscopy. Trace elements found to be indicative of a synthetic origin include molybdenum, rhodium, zinc, platinum, and tungsten, all of which are generally absent in natural emeralds. The presence of iron, scandium, potassium, sodium, rubidium, and cesium seems to suggest that the stone is natural. There are also considerable variations in trace elements for natural emeralds from different localities, which suggests the possibility of using these chemical impurities to identify the origin of a natural stone. For instance, Colombian emeralds have less iron than natural emeralds from other localities. The author concludes by pointing out that slight differences in the green color of emeralds may be due to the presence of vanadium, manganese, nickel, and iron, each of which in conjunction with chromium can influence the hue. This article illustrates the increasing need for sophisticated scientific techniques to solve some current problems in gem identification.

JES

Effects of natural radioactivity on the thermoluminescence of apatite crystals at Cerro del Mercado, Mexico. J. E. Vaz, *Modern Geology*, Vol. 7, 1980, pp. 171-175.

Thermoluminescence is the property of some substances whereby they emit visible light when heated to temperatures lower than those required for incandescence. This light is usually given off at specific temperatures as the material is slowly heated. Apatite is one of several minerals that exhibit thermoluminescent behavior; it has a thermoluminescence peak at 450°C. In this article, the author reports results of a study of this property in gem apatite. Gamma irradiation of apatite from Cerro del Mercado both increases the brightness of the thermoluminescence peak at 450°C and produces additional peaks near 230°C and 110°C. The brightness of these three peaks decays to the natural thermoluminescence level over a period estimated to be about two years. Apatite commonly contains trace amounts of uranium as an impurity constituent, and the radioactive decay of this uranium produces alpha particles. Vaz found that greater levels of alpha activity in an apatite sample tend

to reduce both the natural and gamma-induced thermoluminescence response for material from Cerro del Mercado. JES

Fluorine determination in topaz and relation between fluorine content and 2V value of topaz. H. Konno and M. Akizuki, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 10, 1982, pp. 465-470.

A number of gem minerals have physical properties that can vary over a prescribed range as a result of permissible differences in their chemical composition. In such instances, the composition of a given gemstone would lie somewhere between those of two or more idealized end members in a solid-solution series. The physical properties of these gem minerals can often be correlated with their chemical composition, especially when the composition varies between only two end members. This relationship is particularly valuable where careful measurement of a physical property can provide information on the composition that could not easily be determined by readily available methods of chemical analysis.

Unfortunately, such a direct relationship does not exist for most minerals because of their complex chemistry. However, a simple relationship is present in some gem minerals such as topaz [Al₂SiO₄(F,OH)₂], where much of the (OH)⁻ can be replaced by F⁻. Since the hydroxyl and fluorine contents in topaz can be established otherwise only by tedious methods of wet-chemical analysis, measurement of some physical property as an alternative means to determine the fluorine content would be of great value. The authors of this article describe a relationship between the 2V value (the measured acute angle between the optic axes in a biaxial mineral) and the fluorine content. From data for topaz samples from several localities, a graph is presented that shows how these two variables are related. JES

Surface topography of gem crystals. R. F. Brightman, *Australian Gemmologist*, Vol. 14, No. 11, 1982, pp. 301-304.

The purpose of this article is to build up a photographic record of surface features on gem materials for identification purposes. The faces of gem crystals may exhibit any of a number of surface features such as striations, pits, or areas with a particular geometrical shape. A good example of these are the trigons that commonly occur at certain locations on the faces of natural diamond crystals. These surface features are either the direct result of crystal growth or the indirect result of some natural etching process. In both cases, their shape and orientation are related to the crystallographic structure (or symmetry) of the crystal, and hence they are often distinctive for a particular gem material.

These features on gem crystals can be observed by means of special microscopic techniques. Because of slight differences in height among the various surfaces on a crystal face, a light beam reflected off the surface

suffers destructive interference. This produces bright interference colors that tend to better emphasize the shape of surface features. The author includes photographs of typical surfaces of garnet, beryl, spodumene, and diamond. Although this technique has little value for examining faceted colored stones, on which the surface features have been removed during grinding and polishing, recognition of surface features may assist in the identification of small crystal fragments of gem materials. However, it does not seem likely that this method will replace more traditional gem identification procedures such as refractive index or specific gravity measurements. JES

The use of electron spin resonance spectroscopy to distinguish synthetic from natural gemstones. G. J. Troup and D. R. Hutton, *Journal of Gemmology*, Vol. 18, No. 5, 1983, pp. 421-431.

Electron spin resonance (ESR) spectroscopy involves the examination of spectral features in the radiofrequency portion of the electromagnetic spectrum. Having studied the gemological applications of this technique for a number of years, Drs. Troup and Hutton present some results of their investigations.

Evidence gathered on samples of natural and synthetic golden sapphire, blue sapphire, emerald, and alexandrite at wavelengths around 3 cm reveals apparently characteristic differences between the man-made and natural materials studied. According to the authors, these distinctions arise from greater perfection of the crystal lattice in the synthetics, as well as different types of impurities that are characteristic of either the synthetic or the natural material. The results on golden sapphire and alexandrite appear to be fairly conclusive, involving both the number and the position of spectral bands around 3 cm in wavelength. Blue sapphire and emerald, however, are distinguished more by the size and shape of bands that generally appear in the same locations in both the natural and synthetic samples studied, and would in many cases require interpretation by a trained and experienced ESR spectroscopist. Moreover, the variety of chemical and spectral characteristics of natural blue sapphire and emerald increase the possibility of encountering natural material that provides spectral features too similar to those of the corresponding synthetic to be distinguished. Considerably more work is needed before conclusions can be reached, but so far the technique looks extremely promising. CMS

GEM LOCALITIES

Green fire from the Antarctic. J. E. Anderson and E. J. Zeller, *Lapidary Journal*, Vol. 37, No. 1, 1983, pp. 84-86.

Peridot, noticeable because of its contrast to the otherwise colorless Antarctic landscape, aroused the interest of geophysicists Dr. Edward Zeller and Dr. Gisela

Dreschhoff during a field research project based at Ross Island, Antarctica. In 1981, they collected specimens from Trachyte Hill near the north end of the island and sent them to the senior author of this article for research as part of a project evaluating the mineral resources of Antarctica.

The physical and chemical properties of these specimens are consistent with those of peridot from other localities. Although a few of the samples collected merit faceting, none approaches finest quality peridot because the color is too yellow. Some pieces were sent to a faceter, who discovered veils containing liquid-filled cavities in the stones. Brown mica inclusions were common. Other inclusions were seen, but they were either uncommon or too small to resolve at 10× magnification.

The article is illustrated with photographs of the material and its inclusions at 10× as well as an outline locality map of Antarctica. The geologic environment is reviewed, and there is a detailed description of the cutting and finishing techniques used. CKG

The ruby mines of Burma. H. H. Keely, *Gems*, Vol. 14, Nos. 2-5, 1982, 14 pp.

H. H. Keely is particularly well suited to write this four-part series on the ruby mines of Burma, for he was appointed by the government to manage the Mogok mines immediately after the British-owned Burma Ruby Mines Company went bankrupt in 1931. The series offers some fascinating insights into the history, traditions, and workings of the Mogok Stone Tract. While not as technical as the classic article by Martin Ehrmann published in the Spring 1957 issue of *Gems & Gemology*, it is a most welcome addition to the gemological literature since so little has been written on this classic locality.

The first part is an introduction to rubies and the Mogok area. The article suffers somewhat in general gemological data, i.e., the author's description of the characteristics of natural vs. synthetic stones. However, the glimpses into the Stone Tract's history more than compensate. Also included in part 1 is a rare geological map of the deposits.

The second part, entitled "The Nga Mauk Ruby," is devoted to the legend behind the discovery of this 1¼" × ½" × ¾" (3.1 × 1.2 × 1.9 cm) crystal that was subsequently divided into two unequal pieces by the miners. The miners gave the larger piece to the king as dictated by law, and illegally kept the smaller piece to pay off their own debts. Reportedly, when the king learned of the deception he ordered the massacre of the entire village. After the king's successor was overthrown in 1885, the stones disappeared from public record.

Part 3, "Pigeon's Blood Ruby," presents an interesting account of the color grading of ruby according to various national preferences. This section also discusses the more recent history of the Burma mines, including

some information on the Burma Ruby Mines Company of London-based Edwin Streeter.

The series concludes with an article on "Native Mining and Local Trade." Here, the author discusses the geology and formation of ruby. Again, there are some technical problems, specifically with the geology. But these shortcomings are offset by the detailed descriptions of native mining techniques, as well as by Keely's account of buying and selling practices in Burma.

The series is well worth reading. Keely gives many rare insights that only one who has lived at the locality and managed the mines could offer. Peter C. Keller

Ruby from the Sanbagawa metamorphic belt, in the Hodono Valley, Ehime Prefecture, Japan. T. Minakawa and H. Momoi, *Mineralogical Journal*, Vol. 11, No. 2, 1982, pp. 78-83.

This article provides a preliminary report on a new discovery of transparent ruby corundum in Japan. This locality is in the valley of the Hodono, a tributary of the Dozan River, on the southern slope of Mt. Gongen, Uma-gun, Ehime Prefecture. This occurrence represents the third source for ruby corundum in Japan, and the only one known thus far to produce transparent material apparently of gem quality.

A series of metamorphic rocks (peridotite, amphibolite, eclogite, schist) belonging to the Sanbagawa metamorphic belt are found in the Hodono Valley and its immediate vicinity. The ruby corundum occurs in detrital stream boulders of an amphibole-zoisite metamorphic rock. Although this corundum-bearing rock has not yet been found in outcrop, these boulders are thought to be derived from the Irazu amphibolite which is exposed in the upper parts of the valley. The ruby corundum occurs as large euhedral crystals or subhedral granular masses to 5 cm in diameter. The color ranges from pale purplish pink to dark purplish red, with some crystals exhibiting color zoning.

Although further geologic study is continuing in this area, the corundum-bearing amphibolite and other metamorphic rocks appear to record the occurrence of more than one period of regional metamorphism under conditions of high temperature and pressure. However, definite conclusions as to the origin of the ruby corundum await the discovery of an outcrop occurrence of the corundum-bearing rock.

While there is no indication of the gemological potential of this area, the size of the transparent crystals makes this discovery most interesting. JES

JEWELRY ARTS

Basic metallurgy for goldsmiths. M. F. Grimwade, *Aurum*, Vol. 11, Nos. 1-8, 1980-1982, 45 pp.

Understanding the nature of the noble metals that are used in the jewelry industry is necessary for a total "feel" of how they are going to react in their evolution from

raw material to finished product. In his eight-part series, Mr. Grimwade gives us a basic and practical approach to metallurgy, covering such topics as the behavior of alloys, mechanical properties, cold working, and annealing, to name just a few. This information can aid in recognizing difficulties with porosity, cracking, and brittleness; as well as other problems commonly encountered at the bench.

The text is well written and lavishly supported, with a total of 78 graphs, line illustrations, and photos. The entire series is being made available in five languages as a reprint; for further information, write Aurum Reprints, P.O. Box 351, CH - 1211, Geneva 3, Switzerland.

Bud Boland

Fabergé: Marvels in miniature. D. Harris, *Connoisseur*, Vol. 213, No. 854, 1983, pp. 63-71.

This article skims lightly over what has become a landmark for Fabergé enthusiasts: the simultaneous exhibition of the personal collection of Queen Elizabeth II, shown for the first time in America at New York's Cooper-Hewitt Museum, and the nonofficial but more opulent show at A La Vieille Russie, a commercial gallery specializing in the finest production of Russian and other European jewelers and artisans.

The author carefully avoids analyzing the taste of Queen Alexandra (consort of King Edward VII), who collected the more than 200 items in the Cooper-Hewitt show. Instead, he explains that the collection, which consists mainly of functional domestic objects and small hardstone figures of pets and farm animals from the Royal estates, reflects the interests of one person—a sentimental lady who probably found chalcedony piglets and jade frogs more appealing than the real thing.

The exhibition at A La Vieille Russie, with loans from major American collections, offers more of the grandeur Americans have come to associate with the name *Fabergé*—a remnant of Imperial Russia, a glimpse of the good life before the First World War.

Harris correctly emphasizes Fabergé's insistence on craftsmanship over ostentation and provides a brief history of the firm from its beginning in St. Petersburg until the death of Fabergé in 1920.

In its graphic design, the article displays a pleasing sense of the Fabergé era while remaining entirely contemporary in its concept. It does not, however, offer much in the way of a critique of the exhibitions for those who did not have the opportunity to see them. In this respect the article is, in many ways, itself like a Fabergé object—ravishingly beautiful, meticulously crafted, but of little intrinsic value. NL

Forbidden treasures. G. Sereny, *Connoisseur*, Vol. 213, No. 853, 1983, pp. 84-93.

When the deposed emperor of China was evicted by the provisional government in 1924, his Beijing palace, the "Forbidden City," held millions of treasures which

scholars were then asked to catalog. In 1931, when Japan invaded Manchuria, 30 of these scholars were chosen to escort the treasures to safety. Eight of the original 30 accompanied the part of the collection that went to Taiwan. Among them were three men, Wu Yu-chang, Han Lih-wu, and Na Chih-liang, who here tell the story of their 16 years of travel through China with 19,550 cases of priceless carvings, paintings, jewels, bronzes, and porcelains.

By truck, train, ship, raft, and ferry, storing their treasures in temples and in caves, stopping sometimes for years and sometimes only for days, they transported and cared for their precious cargo. "We had to save the treasures, but the parting from my wife and children brought me ten thousand shares of pain," said one.

When Japan was defeated, civil war began again. Three shiploads of the treasure were taken to Taiwan, where they are now displayed in the National Palace Museum, while the rest returned to Beijing. Honor bound by their promise to return the treasures, Wu, Han, and Na along with many in the Peoples' Republic of China hope that the entire collection will one day be reunited in what is now Beijing's Palace Museum.

The article is well illustrated with seven photographs and a map, detailing a bit of art history hitherto hidden from us. FS

Lapidary art of Jaipur. S. L. Mandawat, *Arts of Asia*, Vol. 13, No. 1, 1983, pp. 142-146.

Mandawat describes the history of lapidary art in the city of Jaipur, India. Jaipur was founded in 1727 by Sawai Jai Singh, who designed it to be a city of jewelers: The buildings were painted red in honor of the ruby, the main market center was named Jewellers' Market, and the largest square was called Ruby Square. Singh invited renowned jewelers and lapidaries from Delhi to take up their trade in this new city, and offered them a great many incentives. Facilities were built for workers in all phases of the jewelry craft, including drillers, string makers, enamellers, stone carvers, polishers, and mounters. Not only was financial assistance available from the state treasury, but the state also purchased manufactured goods to maintain prices. Jewelers were exempted from taxes, and their wages were sometimes revised and fixed by the state.

As many other lapidary centers vanished, Jaipur became stronger. When the diamonds from Golconda were depleted, the lapidaries began to specialize in the cutting of emerald as well as other stones. Today, at peak level there are over forty thousand lapidaries in Jaipur, the largest work force of its kind in the world. GSH

The peerless Verdura. N. Letson, *Connoisseur*, Vol. 213, No. 853, 1983, pp. 52-62.

"Liz Whitney has, on her bin of manure, a clip designed by the Duke of Verdura," wrote Cole Porter in *Let's Face It*. Porter, a close personal friend of Fulco Verdura's,

himself owned cigarette boxes designed by the Duke, one for each of his shows. Diana Vreeland owns two gold stars he designed in the 1930s. Katherine Hepburn in *Philadelphia Story* and Chanel in real life both wore the Duke's designs.

An innovator both in the use of materials and in the selection of design motifs, Fulco was also noted for the mechanical perfection and durability of his pieces. Though he never skimped, his pieces were not exorbitantly priced.

Color photographs show clearly what he meant by "mineralogy is not jewelry" and why he called solitaire diamonds "swimming pools." Instructive and entertaining, this article teaches principles as well as history of good jewelry design. FS

What has happened to Iran's treasures? G. Norman, *Connoisseur*, Vol. 213, No. 852, 1983, pp. 49-56.

In this handsomely illustrated article that begins with the changing of rulers from the Shah of Iran to the Ayatollah Khomeini, Norman questions the fate of the many fine Iranian collections, from jewelry and rugs to paintings and antiques. Because little official information exists, their current status must be pieced together. The author presents an assortment of stories about the various public and private collections.

In the course of his discussion, however, the author mistakenly states that an inventory of the jewel collection was never written. It should be noted that in 1968, *The Crown Jewels of Iran*, a lavishly illustrated and well-researched book by V. B. Meen and A. D. Tushingham, was published in Toronto, Canada.

Norman concludes by comparing the current situation in Iran to that in the Soviet Union in the 1920s and 1930s. Initially, the Russian crown jewels and other museum treasures were treated with respect by the revolutionaries, but ultimately they were sold to generate revenue. Although this article is very general and raises far more questions than it answers, it makes us aware of how vulnerable national treasures are to political upheaval. JOG

RETAILING

Cartier: sovereign jeweler. N. Letson, *Connoisseur*, Vol. 212, No. 849, 1982, pp. 83-91.

Louis Cartier, "a jeweler by inheritance, a sensitive and inventive artist by instinct, and a consummate salesman by necessity," joined his family's firm in 1898. Under his leadership the name *Cartier* became symbolic of the best that money could buy.

Louis and his assistant, Jeanne Toussaint (who took over the firm when Louis retired in 1932), were important influences on the rapidly changing styles from the Gay Nineties to the Roaring Twenties and beyond. They

introduced platinum settings, revived wrist watches, popularized baguette-cut diamonds, and above all clarified and eventually epitomized the clear, true colors and simplified geometry of Art Deco. The article chronicles the influence of world events and changing lifestyles that, together with Louis Cartier's business genius, were responsible for the growth and expansion of the Cartier business.

Fourteen handsome photographs show Cartier pieces from a collection that was recently on display at the Los Angeles County Art Museum. CKG/FS

SYNTHETICS AND SIMULANTS

Synthetic ruby made by Knischka. M. Gunawardene, *Journal of Gemmology*, Vol. 18, No. 5, 1983, pp. 365-378.

Although much of Gunawardene's article reiterates what has previously been reported on Knischka rubies, it does contain some significant new information. First the author focuses on the crystallography, discussing why this material has an unusually large number of crystal faces. As many as 44 have been observed.

In a later section, he describes the results of his gemological investigation on 12 Knischka rubies. It is interesting to note that when exposed to ultraviolet radiation some of the Knischka rubies fluoresced red on the outer edges, but not in the center. According to Knischka, this unusual pattern of fluorescence, here noted for the first time, results from the presence of an iron-bearing natural ruby seed from India. That different types of seeds occur in Knischka rubies is illustrated in the four pages of photographs depicting residual flux, seed crystals, and two-phase inclusions. Unfortunately, most of the photomicrographs are so indistinct that the inclusions represented are very hard to discern. Finally, the list of references is helpful, as it is more extensive than the citations given in any of the other articles in English. SFM

The recognition of the new synthetic rubies. E. J. Gübelin, *Journal of Gemmology*, Vol. 18, No. 6, 1983, pp. 477-499.

Dr. Gübelin discusses the detection of Chatham, Kashan, and Knischka synthetic rubies in this article. According to Gübelin, the diagnostically important properties of these synthetics are: color, dichroism, behavior under short-wave ultraviolet radiation, absorption spectrum, and inclusions.

The first four properties are briefly addressed. Gübelin notes that dark red Kashan synthetic rubies often show a subordinate tinge of brown to orange that is more intense than in the majority of Thai rubies. In addition, the dark red Kashan material with a brownish or orangy cast characteristically shows an orange hue in the direction of the extraordinary ray. Gübelin mentions

that the luminescence of all these synthetics varies according to the color of the material and the wavelength of the radiation. Last, the spectrophotometer shows a distinctive absorption spectrum for synthetic rubies that the average gemological spectroscope cannot detect. In the ultraviolet end of the spectrum, the absorption curve shows a marked transmission gap of varying width between 250 and 400 nm which reaches its maximum at 335 nm. The shape of the transmission in the blue region, between 465 and 478 nm, is also distinctive.

The majority of the article discusses the inclusions in these three synthetics. Illustrated by 41 color photographs, this section is quite informative. Gübelin states that the inclusions in the new synthetic rubies that are most confusing are the straight, parallel growth bands. Yet, they may be distinguished from twin-lamellae in natural ruby by use of the microscope. "Whereas the planes of twin-lamellae can be followed deep into the interior of the gem, the synthetic growth bands disappear when raising or lowering the objective."

Gübelin concludes that the new synthetic rubies do not present identification problems for those gemological laboratories that have sophisticated equipment, but they could pose problems for the modestly equipped professional. JMH

TREATED STONES

Treated gems: why not face the facts? H. Huffer, *Jewelers' Circular-Keystone*, Vol. 154, No. 5, 1983, pp. 33-47.

As the title of this special report on gem treatment suggests, Huffer emphasizes that jewelers must recognize the problems surrounding gem treatment and learn to deal with them. She begins with a collection of facts, anecdotes, and opinions drawn from a survey conducted with 300 retail jewelers, 300 stone dealers, and 100 jewelry manufacturers. In the next section, industry members discuss the issue of disclosure of treatments, which is followed by an overview of treatments with a brief review of bleaching, diffusion, heat, impregnation, irradiation, staining and dyeing, and surface coating.

The high point of the article is the inclusion of a reference chart of known treatments prepared by Dr.

Kurt Nassau and Robert Kane. Conspicuously absent from the chart, however, is information on the detection of many of the treatments. Joseph P. Graf

What you must know: a primer on treatment ID. C. R. Beesley, *Jewelers' Circular-Keystone*, Vol. 154, No. 5, 1983, pp. 48-56.

Mr. Beesley's article in this special issue on treatment sums up published information on gem identification. His chief contribution lies in his systematic approach to the detection of treated corundum. In this section, Mr. Beesley carefully describes visual traits and fluorescence patterns that are characteristic of heat treated corundum. In addition, he explains standard immersion techniques used in the detection of surface diffusion-colored corundum.

In the remainder of the article, the author focuses on other means of treatment: impregnation (oil and dye), coatings, and irradiation. Unfortunately, this section is not as complete as the first. However, he does present procedures for the fade test, one approach for detecting certain types of irradiation. JMH

MISCELLANEOUS

The Mikimoto special. S. Takamura (ed.), *Jewelry Styling*, Vol. 6, 1983, pp. 1-168.

Of interest to even non-Japanese readers, this special issue of *Jewelry Styling* commemorates the 90-year history of the Mikimoto pearl industry. The text traces the industry's development from the end of the Meiji Era (1908-1912) through five periods ending with the beginning of the Showa Era (1927-1935). The Mikimoto tradition is related to economic, political and social events as well as to changing social customs. The company catalogue, *Pearls*, first published after the opening of the Mikimoto Ginza store in 1901, has preserved chronologically and artistically the many Mikimoto designs, not all of which incorporate pearls. A selection of these designs has been included here. The skill of Japanese craftsmen and the influence of Western fashion can be appreciated in 20 color photographs of exquisite jewelry pieces that also accompany the text. ALS

GEM NEWS

Stephanie Dillon, *Editor*

DIAMONDS

Australia. Following the setting of a buying sample by Argyle Diamond Sales, Ltd. and the Central Selling Organisation (CSO), the first commercial sale of Argyle diamonds took place in Perth in April. Similar sales were expected to occur in Perth approximately 10 times each year. The alluvial deposits of the Smoke and Limestone Creek areas at Argyle are presently producing five million carats annually. Valuation at the first sights was \$11 per carat, based on the classification of 10% gem quality, 35% cheap gem, and 55% industrial quality.

Belgium. In 1982, Belgium saw a 6.3% rise in exports of polished goods, a 2.9-million-carat increase over 1981. Exports to the United States increased 16.1% (an 82% overall rise in two years) and to Russia, 62%. Imports rose 14%. Part of the increase is explained by the abolition of import duties on polished goods in the U.S. and by De Beers's aggressive publicity campaigns, in addition to the growing dependence of the U.S. on foreign markets. Belgian polished exports to Canada rose 55% and to Hong Kong 42.3% during the year. Imports from Russia of over 57.4 million carats of rough, polished (700,000 ct), industrial, and synthetic diamonds represented a 6% increase over 1981. As of this summer, a promised reduction in Russian imports had yet to be arranged between Moscow and Antwerp.

Israel. Exports of polished diamonds for the first quarter of 1983 showed a 7.6% increase in value from the same period last year. Imports of rough for the first quarter rose by 50.9% over last year's figures. Israel's diamond industry is relying more heavily on open-market sources, as demonstrated by a decrease in the Central Selling Organisation's share of rough imports: a decline in dollars from 37.7% to 24.7% for the first quarter.

Thailand. In 1982, Thailand's six-year-old diamond-polishing industry exported approximately \$10 million worth of diamonds. Leaders of the Thai gem industry, upon assurance from the CSO of availability of rough, propose to make Bangkok a major diamond-cutting center. Maintaining that there is an ample supply of experienced Thai gem cutters, Banjong Asavasangsidhi

(president of the Jewellers' Association), Anant Salwala (president of the Gem and Jewelry Traders Association), and W. K. Ho (chairman of the Asian Institute of Gemological Sciences) signed the plan calling for establishment of a central organization to establish and maintain a cottage industry in diamond cutting. This would be in addition to the two diamond-polishing facilities now operating in Bangkok, each of which employs 250 cutters.

United States. Several hundred small diamonds have been mined from a site along the boundary of Colorado and Wyoming by Cominco American, Ltd., a Canadian mining company. Last year, the company built a \$2.5 million processing plant at Fort Collins in expectation of further finds. Superior Minerals Company, a subsidiary of Superior Oil Company of Houston, has also explored the area and built a processing plant, the whereabouts of which are secret. Cominco is also prospecting around Iron Mountain, north of Cheyenne, Wyoming, as well as in Kansas and Michigan. North America's only established diamond mine to date, at Murfreesboro, Arkansas, operated from 1903 until 1919.

New York's three diamond industry associations—the Diamond Dealers Club, the Diamond Trade Association, and the Diamond Manufacturers and Importers Association—have banded together to provide accurate information to diamond merchants. Their organization, the American Diamond Industry Association, was formed to combat damaging media reports on the state of the industry. They have begun by inviting 47th Street retailers into cutting and importing concerns for a first-hand view of the trade.

According to U.S. government estimates, at least 25% of all Russian diamonds are consumed in the U.S. Although there are occasional purchases from Russian agencies in Europe, it is believed that distribution is largely through De Beers (marketer of most Russian rough), since the 10% duty applied to Soviet goods discourages direct importation.

General Electric Company's Special Materials Department has developed a new type of synthetic industrial diamond, a polycrystalline called Formset. It will replace monocrystalline diamond used to dress grinding wheels. The new synthetic is reported to lengthen



Figure 1. Color range of idocrase (californite) now being distributed in large quantities. The average cabochon is approximately 12 × 16 mm. Photo by Mike Havstad.

the life of the dresser while affording higher dressing efficiency and improving the grinding wheel's effectiveness.

The rise in natural diamond production, especially from Australia, is expected to affect synthetic diamond manufacture. In the years since General Electric introduced synthetic diamonds in 1956, production has steadily risen; last year, well over 100 million carats were produced. An additional factor in the anticipated slowdown in this area is the rapid increase in production costs for the synthetics.

Zaire. For a minimum of two years, Zaire has agreed to return to the CSO system to market diamonds from Miba (Société Minière de Bakwanga), the country's main source. This contract voids the five-year agreement of 1981, which gave three diamond concerns (Industrial Diamond Company of the U.K., and Caddi and Glasol of Belgium) exclusive marketing rights. The *African Economic Digest* reports that Zaire will receive a fixed price for its stones, independent of free-market fluctuations. Miba produces approximately 70% industrial and 30% small gem or near-gem stones. At the first sale under the new agreement in March, nearly 300,000 ct from the Miba mines went to De Beers for a total price of \$2,608,425. Miba's output represents half of the nation's diamond product; the remainder is found in alluvial deposits by small prospectors, and much of this has been smuggled into the Congo to avoid Zaire's high dollar-exchange rate. To discourage smuggling, government-authorized traders in Zaire's capital, Kinshasa, will now be able to pay at the same exchange rate as the black market.

COLORED STONES AND ORNAMENTAL MATERIALS

Amethyst. Jack Lowell, of the Colorado Gem & Mineral Company, Tempe, Arizona, reports on the recent amethyst find in Para, Minas Gerais, Brazil: "At one locality, there are large, weathered boulders of very dark to light, heavily zoned amethyst. Some crystal portions (now rounded boulders) weigh up to 20

pounds. I have seen clean stones up to 100 ct of a very deep red-violet. Many of the deep-colored stones are heated in test tubes over an alcohol lamp to lighten the color. Another locality in Para is producing well-formed, sharp crystals with a light to medium color. The material has been found in more quantity than the other locality, but is not as special as the first, which seems to be a surface deposit."

Blue chalcedony. After a ten-year hiatus, the Namibian mine that provided uniformly colored blue chalcedony has resumed production.

Coral. Asian coral, taken from depths greater than 200 m, is being gathered in increasing quantity. The material is not of a uniform pink color, as is Midway coral; it is characterized by irregularities. Beads and cabochons of unusual shapes and in a broad range of colors will be readily available.

Idocrase. A new source of californite promises an abundance of material for beads and cabochons. The stone ranges from a very pale opaque, creamy green to various shades of lime green to a deep, jade-like lime-olive green (figure 1). It is usually uniform in color, but is sometimes mottled with various shades of green or brownish gold. The material is cut in cabochons of up to 12 × 16 mm, on the average. It is distributed by Spectrum Commercial Lapidaries, Inc., of Boulder, Colorado.

Malachite. More rigorous export regulations imposed by Zambia and Zaire have led to a reduction in the amount of malachite available on the market.

SYNTHETICS

Cat's-Eye Chrysoberyl. The first successful synthesis of cat's-eye chrysoberyl is claimed by laboratories of the Sumitomo Cement Company, Funabashi City, Japan. The company filed for worldwide patents on the material, produced from a mixture of beryllium oxide, alu-

minum oxide, and a chatoyancy-producing additive. A company representative reported that the mixture was heated to approximately 2000°C and maintained at that temperature in equipment made by modifying a commercial crystal growth apparatus. Cooling to room temperature, followed by a special heat treatment, completed the process.

C-OX. Produced at the Lebedev Institute of Physics of the USSR Academy of Sciences in 1982, C-OX is a

material similar in properties to cubic zirconia, although entirely different in composition. It is cubic in structure, with a Mohs hardness of 8, a specific gravity of 5.6 to 5.8, a refractive index of 2.0 to 2.1, dispersion of 0.040, and a melting temperature of 2700°C. Supplied only as preforms and faceted stones, the material is produced in a wide range of colors, including intense green and blue not available in cubic zirconia. It is presently being distributed by C. Cerasi of Milan.

ANNOUNCEMENTS

A \$20,000 reward has been offered for information leading to the return of the following collection of 23 gem crystals and mineral specimens stolen from Keith Proctor in Houston, Texas, on May 13, 1983.

1. Aquamarine crystal (sky blue), pointed termination, on host rock (3½" × 1⅜")
2. Aquamarine crystal (sky blue) on quartz and feldspar (2" long)
3. Emerald (1½" high) on calcite
4. Emerald (2½" high) on calcite
5. Large green beryl (3¼" × 1⅞")
6. Lime green beryl, two parallel crystals (2⅜" × 1¼")
7. Green Russian beryl, two parallel crystals (3" × 1"), 26 vertical faces and 17 termination faces, very rare crystallography
8. Yellowish green heliodor beryl (2⅜" × 1¼")
9. Sea green yellow beryl, pinacoid termination (4½" × ⅞")
10. Diamond crystal, 29.23-ct octahedron
11. Olive green chrysoberyl, V-shaped (2" long)
12. Tanzanite (1¼" high)
13. Tanzanite (1¾" high)
14. Silver crystals on calcite (approximately 3" × 2")
15. Dioptase on calcite (4" × 4")
16. Pink gem rose tourmaline crystals with green tips on pink cookite matrix (two crystals, longest is 3")

17. Rubellite (2¾" × 1¼")
18. Emerald green tourmaline, two parallel crystals (3" × ⅞")
19. Bicolor (blue and green) tourmaline (3½" × ¾")
20. Gold crystals on 2" square piece of quartz
21. Imperial topaz crystal (approximately 5½" long)
22. Gold in limonite (1")
23. Twindle (twisted) quartz crystal on plastic stand (2½" × 2") with Smithsonian Institution label and number

Parties who believe they know the whereabouts of any of these specimens are asked to call the FBI in Houston at (713) 224-1511, or Keith Proctor at (303) 598-1233.

The Asian Institute of Gemological Sciences will host a seminar November 9 and 10 in Bangkok, Thailand, on "Diamond (Natural and Synthetic) and Diamond Simulants." Presenting the seminar, which consists of lectures and practical sessions, are Roy V. Huddleston and Peter G. Read, who will cover the history, mining, cutting, and grading of diamonds and the evolution of diamond simulants. "Highlighting Rubies and Sapphires" is the title of a seminar to be held November 24-26. Robert P. Weiser will direct the course, which includes the AIGS color- and quality-grading system, the international market and wholesale pricing factors, synthetics and treatments of corundum, identifi-

cation techniques, and major sources.

The American Gem Trade Association will hold its third annual meeting February 4-9 at the Doubletree Inn, 445 South Alvernon Way, Tucson, Arizona 85711. The theme of the show is "Add more color to your life." Natural, colored gemstones will again be featured, with seminars, social events, and a business meeting of the association to be held at the hotel. A highlight of the event will be the presentation of awards for the Spectrum competition for the design of colored-stone jewelry. The deadline for entries has been extended to January 5. Information on the fair may be obtained from AGTA Executive Director Stuart Woltz by calling (602) 279-7171. Applications for the design contest are available from Alex Bahtiarian, Chairman, AGTA Spectrum Award Committee, P.O. Box 32086, Phoenix, AZ 85064.

The Tucson Gem and Mineral Society's 30th Annual Show will be held February 9-12, 1984, at the Tucson Community Center, 260 South Church Avenue, Tucson, Arizona. Tourmaline will be the featured mineral. There will be exhibits of gems, jewelry, lapidary, and fossils, as well as related instruments, equipment, and publications. The show will provide the background for the annual meeting of the Mineral Museums Advisory Council; the joint symposium of

Friends of Mineralogy, the Mineralogical Society of America, and the Tucson Gem & Mineral Society; and the Neal Yedlin Memorial Micromount Symposium. Further information is available from Sue Angelon, Publicity Chairman, Tucson Gem & Mineral Show Committee, P.O. Box 42543, Tucson, AZ 85733.

EXHIBITS

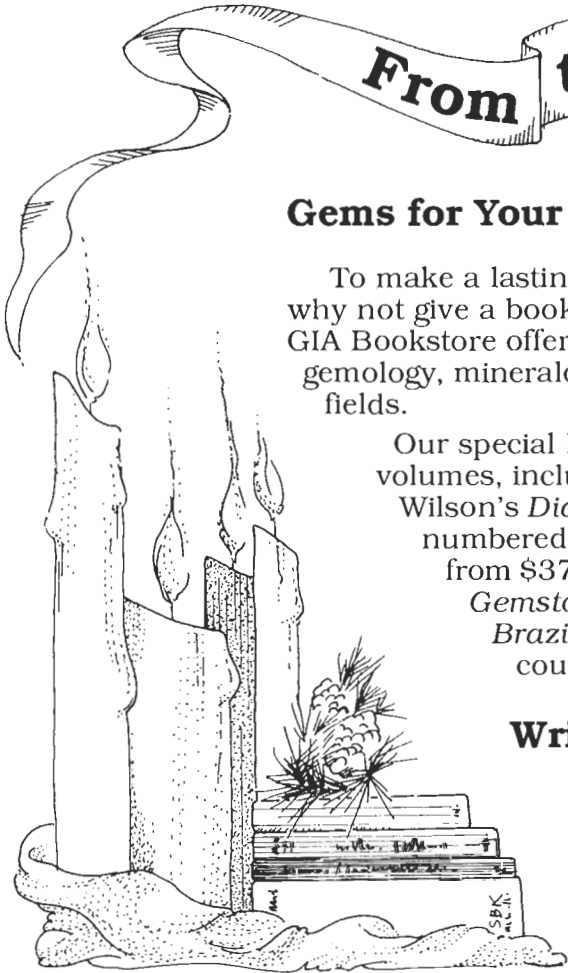
Cooper-Hewitt Museum—2 East 91st Street, New York, NY 10028. Telephone: (212) 860-6868. "The

Art of the European Goldsmith: Silver from the Schroder Collection" is a traveling exhibit of about 95 objects collected by an English family from the 1870s to the 1930s. This first U.S. showing runs from November 1–January 22, 1984.

Smithsonian National Museum of Natural History/Thomas M. Evans Gallery—10th Street and Constitution Avenue, NW, Washington, DC 20560. Telephone: (202) 357-2458. "Ban Chiang: Discovery of a Lost Bronze Age" includes 200 archaeological findings dated 4000 to 200 B.C. from northeastern

Thailand. Pottery, metalwork, ceramic animals, worked bone, weapons, and jewelry are exhibited for the first time from November 1 through January 31, 1984.

Smithsonian National Museum of African Art—318 A Street NE, Washington, DC 20002. Telephone: (202) 287-3490, Ext. 43. "African Islam: The Artistry and Character of Belief" demonstrates the influence of Islam on African life in an exhibit of sculpture (figures, masks, etc.), jewelry, and architecture. November 30 through (tentative) mid-April, 1984.



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GEMS: THEIR SOURCES, DESCRIPTION, AND IDENTIFICATION, 4th ed.

By R. Webster (as revised by B.W. Anderson), 1029 pp., illus., published by Butterworths, London, England, 1983. US\$79.95*

Since 1975, when the third edition of this book was published, a number of significant gemological developments have occurred. A few minerals that were previously unknown in gem quality have made their gemological debuts. The diamond simulant cubic zirconia has proved very successful. New instruments have been developed for testing diamond simulants. New synthetics and simulants of other materials have been produced and marketed. Obviously, a fourth edition of this book was needed.

B. W. Anderson, who was wisely selected for the revision, has generally done an excellent job of integrating the new information into the text. Also, the geographic names and current sources of gem materials have been updated.

It is unfortunate that the publishers did not use the same care in producing the book that Webster and Anderson used in writing the material. The color photographs of jewelry that appeared in the third edition have been eliminated, resulting in a 25% reduction in the total number of color pictures. The remaining eight pages of color have been lumped together and inserted, somewhat incongruously, in the middle of the section on rocks, whereas they were distributed in their proper sections in the previous edition. There are a number of typos and some irritating production details that should not have gotten past the editors. For example, the line drawing of zircon crystals on page 154 should have been centered; the photo in figure 10.14 on page 223 has been reversed from the description in the caption; the last paragraph on page 371 deals with jeremejevite, not zoisite; the caption for figure 33.43 is incomplete and incomprehensible. The most serious mistake is the omission of CZ and the other new materials

BOOK REVIEWS

Michael Ross, Editor

from the tables in the back of the book. Although the properties are given wherever they are described in the text, the data should have been included in the proper order in the tables of R.I., S.G., etc.

On the plus side, the type seems to be easier to read, and several black-and-white photographs have been replaced with others that better illustrate the desired subject. In spite of its few shortcomings, the fourth edition is truly encyclopedic. It is the largest collection of up-to-date gemological knowledge contained in any single volume. Any serious gemologist should have a copy available for ready reference.

C. W. FRYER
Chief Gemologist, GIA

THE GEMSTONE IDENTIFIER

By Walter W. Greenbaum, 184 pp., illus., published by Arco Publishing, New York, NY, 1983. US\$7.95*

In this book, Walter W. Greenbaum skims the surface of gemology by highlighting some basic factors of gem identification. He overviews visual training, optical- and physical-property testing, and common gems and their simulants.

Mr. Greenbaum indicates that his intent is to provide easy-to-use methods of gem identification for quick reference and to "open the door slightly to some of the secrets of stone identification." He assumes that both the jeweler and the layman will benefit from his work. He also hopes to stimulate some readers to pursue a more exhaustive study of gemology. But, despite his good intentions, this book leaves

much to be desired as a practical tool for gem identification.

Many of Mr. Greenbaum's statements are questionable at best; some are, unfortunately, wrong. For example, he states that a gem's luster is related only to refraction and transparency, and not to hardness. Mr. Greenbaum apparently does not consider that hardness directly relates to the quality of polish a gem will take (a major factor of luster) and that transparency has little or nothing to do with the quality and quantity of light reflected from a gem's surface. He lists cleavage for synthetic spinel, among others. He also confuses birefringence with pleochroism, graining with polishing lines, and the value of a hardness test with that of the highly important refractometer in gem testing.

Several of Mr. Greenbaum's key separations are gemologically unsound. For example, he suggests that fluorescence will separate jadeite and nephrite. He misidentifies the components of garnet and glass doublets—there is no cement layer. And, to separate lapis lazuli from sodalite, he recommends heating the specimen to see if it loses color!

Mr. Greenbaum's color plates of gemstones are good; the black-and-white photos and line diagrams, however, could be improved. His section on assembled stones also needs clarification, as does his reasoning for including a chapter on gem investment in a book on gem identification.

Considering factors such as readability, organization, production quality, and price, it would be wrong to assume that Mr. Greenbaum's work does not achieve something for its intended audience. It is not, however, a book that would illuminate the gemology library of the average jeweler or gem enthusiast.

BILL BOYAJIAN
Resident Colored Stones/Gem
Identification Supervisor, GIA

*This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404.

MINERALS OF BROKEN HILL

*Edited by Dr. H. K. Worner and R. W. Mitchell, 259 pp., illus., published by Australian Mining & Smelting Ltd., Melbourne, Australia, 1982. US\$42.50**

Once in a great while, the gem and mineral community is blessed with a book that sets new standards of excellence. Such is the case with *Minerals of Broken Hill*, which deals with the classic mineral deposit in far western New South Wales, Australia. The book was commissioned by Australian Mining & Smelting Ltd. to celebrate the 100th anniversary of Broken Hill's discovery. It is dedicated to Sir Maurice Mawby, one of Broken Hill's best-known mining engineers.

Minerals of Broken Hill is a rare combination of superbly researched technical information and stunning photography. There are 170 excellent color illustrations. More than a dozen experts on Broken Hill contributed to the volume, and the well-known scientist Dr. Howard Worner planned and edited it.

The first chapter discusses the discovery and history of Broken Hill. From here, there are three chapters dealing mostly with the complex geology of the deposit. With the history and geology as background, we read first about the minerals of the primary ore, then about those of the secondary ore. There are two chapters on the minerals of the Consols Mine and the Mine Sequence and about the minerals of the area in general. The main focus of the book is the detailed alphabetical description of approximately 300 mineral species and varieties found at Broken Hill. These descriptions are supplemented with photography that rivals that of any mineral book I've ever seen. Some of the mineral specimens pictured are the finest of their kind. The book concludes with useful tables of mineral data,

including important references for each mineral found in the deposit.

In the introduction, Dr. Worner states that the objectives of Australian Mining & Smelting Ltd. in sponsoring the book were to establish an authoritative and comprehensive record of Broken Hill's mineralogy and to stimulate the interest of both amateur and professional mineralogists. The company and Dr. Worner are to be congratulated for more than meeting this objective, and thanked for providing the mineralogical community with one of its finest books. Perhaps this work will stimulate other mining companies to sponsor similar books on their deposits. We can certainly hope so.

PETER C. KELLER
Director of Education, GIA

DIAMONDS AND DIAMOND GRADING

*By Godehard Lenzen (transl. by Patricia B. Lapworth), 258 pp., illus., published by Butterworths, London, England, 1983; originally published in German as Diamantenkunde, by Verlagsbuchhandlung Elisabeth Lenzen, Kirschweiler, 1979. US\$59.95**

Originally written as a textbook for German training institutions, this book was to have been broadened in its appeal by the translator to achieve a progress report on diamond grading and international accord on grading systems. The text begins with a review of basics such as diamond chemistry, structure, mining, and distribution, before digressing strangely into the areas of diamond synthesis and simulants. The largest sections concern the grading of a diamond for color, clarity, and cutting. Further digression follows in the form of a breezy description of recutting and irradiation. A lengthy and narrowly defined (in Western terms) section on certificates, "expert opinions," and evaluations brings the reader to the

final chapter, which is concerned with the levels of German law.

The organization of the material certainly leaves something to be desired, and a few chapters, as noted above, do not fit the book's theme at all. Lenzen's protracted prose is difficult to read, and one doubts that this is merely a problem of translation. The author seems obsessed with the rulings and caveats of various European gem committees and documents—which are of little importance to the American market. The book contains only black-and-white photographs, in harmony with the colorless writing style and often gray explanations.

For all of these deficiencies, there are some redeeming qualities. The author does a creditable job of explaining the functions of the diamond bourses. And he does the reader a real service in exploding the myth of "eliminating the middleman" to save money in diamond purchases. This is accomplished by explaining the (vital) functions of these middlemen—functions that cost money and that will inevitably become part of the price, regardless of who performs them. Also to his credit is an accurate description of the theory of corrected weight used in diamond evaluation, a system "which emanated from the United States" (GIA). Since the proportion deductions suggested by GIA have been liberally altered in this book, the reader should be forewarned that the pricing outcome could well be different. Also, Lenzen's understanding of the GIA clarity term *internally flawless* (IF), presented on page 104, misses the mark by a country kilometer.

In summary, it appears to this reviewer that very few people who can read English will want to try it with this book. The major objection is not to what is said, but to the ponderous, Teutonic style of the work. The paper is smooth and the cover photo is pretty, however.

JAMES R. LUCEY
GIA instructor, Santa Monica