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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. The color separations for Gems & Gemology are by Effective Graphics, Compton, CA. Printing is by Waverly Press, Easton, MD.

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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.
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

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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 Gubelin, 1980; Gubelin, 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 Vertecul method are still available on the market.
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.

CRYSTAL MORPHOLOGY

As a result of its unusual growth process, the Ramaura synthetic ruby exhibits several different crystal 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 \(R(0112)\) and \(r(1012)\) are generally predominant, and the basal \((0001)\) 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 \(r(0112)\), \(d(1012)\), and \(n(2243)\) 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-
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.
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 $n_1 = 1.762$ and $n_2 = 1.770$, while some of the material had values of $n_1 = 1.760$ and $n_2 = 1.768$ (this variation is also observed in natural ruby). These values give an optic character of uniaxial negative and a birefringence of 0.008.

Fluorescence. 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 t.t.d. | Pleochroism | Luminescencea | Absorption Spectrumb |
| $n_1 = 1.760$ | purple and pink | Variable: intensity ranges from weak to strong; nearly the same fluorescent colors as long wave reaction, with the addition of chalky, slightly blue to white zones observed in a few stones. No phosphorescence. | Absorption max. at 4750, 4765, 4905, 5005, 6590, and 6542 Å. Final鉴别 disen consistency between the violet and blue. Blocking out half of the waist and some of the blue, all of the green, and yellow, and a small area in the orange portion of the visible light spectrum. Not diagnostic. |
| $n_2 = 1.770$ | orangy red, and pinkish purple | Variable; the same range of intensity from weak to strong; nearly the same fluorescent colors as long wave reaction, with the addition of chalky, slightly blue to white zones observed in a few stones. No phosphorescence. | |
| $n_3 = 0.008$ | | Variable; some range in intensity from weak to weak; fluorescent colors range in intensity from extremely weak to wakle fluorescent colors; chalky red to orangy red, and pinkish purple | |

a Luminescence. Reactions listed are for faceted stones only and may change if the manufacturer changes the amount or 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.

This variation is also observed in natural ruby.
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 spectroscopy-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. 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 strong. 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 (3650 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 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 delimitation 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 crown fluorescence 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 synthetic 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 spectroscope 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
light absorption spectra of the seven faceted Ramaura synthetic rubies was conducted on a Pye Unicam, SP-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" distribution 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 H₂O 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 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 reported 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 > 0). 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 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 35x.

Figure 10. Flux-filled voids exhibiting portions that range from near colorless to white. Dark-field illumination, magnified 55x.

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 45x.

Figure 12. 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.

Figure 13. 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 were orange-yellow. These fingerprint patterns also 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 also exhibit a two-phase-like appearance, however, they are probably solid in nature (see figure 11).

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 were orange-yellow. These fingerprint patterns also
Figure 12. Healing fracture filled with white flux forming a flux "fingerprint" comprised of a combination of tiny, closely arranged droplets and more loosely arranged mesh-like patterns. Dark-field and oblique illumination, magnified 32x.

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 40x.

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 readily visible when viewed with the unaided eye. In some rubies, the growth features or color zoning were barely perceptible; in others they were easily seen throughout the entire stone.

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
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 undoubtedly 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
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 plazas 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 “phantoms” graining 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 Kashkan (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 appearance 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 found in natural rubies:...
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×.

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×.

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

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×.

Figure 23. Prominent color zoning is revealed in this Ramaura synthetic ruby by placing a diffuser over dark-field illumination. Magnified 15×.
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 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 (Hanni and Stern, 1982; Stern and Hanni, 1983) 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.

REFERENCES


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 so 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 low-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 Chiquinquira in the Muzo district. When the seller discovered that the stones would be taken to the
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
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 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.

Acid Remover. 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
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. 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 maría," 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 basis.
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. 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 continu-
The lightbulb of an ordinary table lamp provides heat for maintaining the oil at a constant high temperature.

used 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 x 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 reflective 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. This phenomenon is described 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 10X 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 Bogota 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 x.
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.

REFERENCES

Gemsological Institute of America, Santa Monica, CA.

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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 signs, 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 5/4-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.

Notes and New Techniques
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 crypto-crystalline response on the polariscope, a 9 is keyed in.

If readings are input for both the highest and

*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.
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 Kruss KR602, which uses a strontium titanate prism, are available, 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

![Figure 3](image)

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.
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 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 SUBROUTINE statements to store the large number of gem constants required.

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.

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.

Notes and New Techniques
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.

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
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>
<thead>
<tr>
<th>INDEX no.</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Actinolite</td>
</tr>
<tr>
<td>2</td>
<td>Alabaster</td>
</tr>
<tr>
<td>3</td>
<td>Almandrite</td>
</tr>
<tr>
<td>4</td>
<td>Amber</td>
</tr>
<tr>
<td>5</td>
<td>Amethystite</td>
</tr>
<tr>
<td>6</td>
<td>Analcite</td>
</tr>
<tr>
<td>7</td>
<td>Anatase</td>
</tr>
<tr>
<td>8</td>
<td>Andalusite</td>
</tr>
<tr>
<td>9</td>
<td>Andradite</td>
</tr>
<tr>
<td>10</td>
<td>Anglesite</td>
</tr>
<tr>
<td>11</td>
<td>Apophyllite</td>
</tr>
<tr>
<td>12</td>
<td>Apatite</td>
</tr>
<tr>
<td>13</td>
<td>Aragonite</td>
</tr>
<tr>
<td>14</td>
<td>Aquamarine</td>
</tr>
<tr>
<td>15</td>
<td>Aragonite</td>
</tr>
<tr>
<td>16</td>
<td>Axinite</td>
</tr>
<tr>
<td>17</td>
<td>Azurite</td>
</tr>
<tr>
<td>18</td>
<td>Barite</td>
</tr>
<tr>
<td>19</td>
<td>Beryl</td>
</tr>
<tr>
<td>20</td>
<td>Beryl</td>
</tr>
<tr>
<td>21</td>
<td>Bluestone</td>
</tr>
<tr>
<td>22</td>
<td>Beryl</td>
</tr>
<tr>
<td>23</td>
<td>Beryl</td>
</tr>
</tbody>
</table>
```

Over 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.

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

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 achieved by keying in the appropriate index number (see Table 1).

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

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

REFERENCES


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, 1990, 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, 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

Mr. Lind and Dr. Schmetzer are research associates, and Dr. Bank is an honorary professor, at the Mineralogisch-Petrographisches Institut der Universität Heidelberg, D-6900 Heidelberg, Federal Republic of Germany.

Acknowledgments: The authors are grateful to Mr. F. Cullman of Lauer & Co., Idar-Oberstein, Federal Republic of Germany, for providing many of the natural and treated turquoise specimens used in this study, and for sharing information about turquoise treatment procedures.

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

*For further details, see Galla (1977) and Gahal (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 AlPO₄ (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 AlPO₄ 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 relics 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 AlPO₄ phase with cristobalite structure is formed, was observed. To clarify whether the AlPO₄ 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 AlPO₄ 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, Gubelin, 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. γ-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), the 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.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>X-ray powder diffraction pattern</th>
<th>Infrared spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turquoise, untreated</td>
<td>Turquoise</td>
<td>Turquoise</td>
</tr>
<tr>
<td>Turquoise, plastic impregnated</td>
<td>Turquoise or turquoise + berlinite</td>
<td>Turquoise or turquoise + absorption band at 1725 cm⁻¹</td>
</tr>
<tr>
<td>Turquoise, paraffin impregnated</td>
<td>Turquoise or turquoise + berlinite</td>
<td>Turquoise or turquoise + absorption band at 1725 cm⁻¹</td>
</tr>
<tr>
<td>Gilson “synthetic turquoise”</td>
<td>Turquoise or several diffraction lines of an unknown phase or turquoise + several diffraction lines of an unknown phase + berlinite</td>
<td>Gibbsite or turquoise + absorption band at 1725 cm⁻¹</td>
</tr>
<tr>
<td>Some “reconstructed turquoise” specimens from the trade</td>
<td>Gibbsite</td>
<td>Gibbsite + absorption band at 1725 cm⁻¹</td>
</tr>
<tr>
<td>Different imitation turquoises of the trade</td>
<td>Magnesite, calcite, or dolomite</td>
<td>Not investigated</td>
</tr>
</tbody>
</table>

* The 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 & Gemology. 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 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 statement 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

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

Editorial Forum

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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, South-west 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 352, 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 transmitted light and highlighted with the new GEM pinpoint 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 451, 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 clinohumite.
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.

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 under magnification (figure 3). We do not know if this is an isolated piece or if the material is destined for commercial use.

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

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

Mysterious Wear on a Diamond Ring
Figure 5 shows a gold pave 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...
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 diaspo-re. Diaspore is an aluminum hydroxide with the chemical formula $\text{Al}_6\text{Si}_2\text{O}_10\text{(OH)}_8$. 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.

**TABLE 1. Properties of gem-quality diaspore.**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimorphy with boehmite</td>
<td>Optic character: biaxial positive</td>
</tr>
<tr>
<td>Crystal system: orthorhombic</td>
<td>Refractive indices: $\alpha = 1.702$, $\beta = 1.722$, $\gamma = 1.750$</td>
</tr>
<tr>
<td>Fracture: conchoidal</td>
<td>Birefringence: 0.048</td>
</tr>
<tr>
<td>Cleavage: perfect one direction</td>
<td>Pleochroism: strong, yellowish green, brownish yellow, and violetish brown</td>
</tr>
<tr>
<td>Specific gravity: 3.3-3.5</td>
<td>Fluorescence: weak yellow</td>
</tr>
<tr>
<td>Hardness: 6-7</td>
<td>Spectrum: weak band at 4500 Å to 4600 Å</td>
</tr>
</tbody>
</table>

*Pleochroism for the stone tested, will vary depending on the color of the material.*

*One sample only tested.*

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.

**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.
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
8 x 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 x 5 mm in diameter. At the center on the flat side we noticed a quite unusual 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 concealed, 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 x 20.9 mm.

Figure 18. Rounded facet junctions on a faceted tanzanite.

**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 typical 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). Molds. 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 too 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 reresizing or re-pronging, without removing the stone.

**ACKNOWLEDGMENTS**

The photos in figures 1, 12, and 15 were taken by Mike Haskel. Andrew Quinn, from the New York laboratory, took figure 2-9. 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 Tony Hammond.

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COLORED STONES AND ORGANIC MATERIALS

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 fusion 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.


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 n = 1.586 and ε = 1.580, while the measured density is 2.794 g/m³. 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.

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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 pressures lower than 4 kilobars.

DIAMONDS


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 spectrometry 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 [Ca3(PO4)3(F,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.

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 raw 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.


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 Balfour, 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 34.5 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.


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 Cramer 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.


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 temperature and pressure at which they formed. Since these have been calibrated through laboratory experiments, it is now possible to use them to estimate the temperature 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.

GEM INSTRUMENTS AND TECHNIQUES


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 the degree of fractionation. Studies such as this provide a better understanding of the geologic history of kimberlite pipes.


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 decay 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 increase the brightness of the thermoluminescence peaks.

Differences in physical properties (i.e., refractive index, specific gravity) or types of inclusions have traditionally been used to distinguish natural emeralds from their synthetic counterparts. However, the property 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 manufacturer.

Chemical differences on the trace-element level reflect the different conditions of origin of natural and synthetic gem materials, and thus may be used to distinguish natural from synthetic stones. These compositional patterns among these several episodes of kimberlite intrusion.

Spinel in the root zone of a kimberlite can be used to determine whether a kimberlite formed within the diamond stability field.
The purpose of this article is to build up a photographic record of surface features on gem materials from Cerro del Mercedo. 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)], where much of the (OH) can be replaced by F. Since the hydronyl 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.


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 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 authors include photographs of typical surfaces of garnet, beryl, spinel, golden, 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.


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 spectral features in 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.

GEM LOCALITIES

Droushłoñi 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 approach the quality threshold for gemstone use. Other inclusions were seen, but they were either uncommon or too small to resolve at 10 x magnification.

The article is illustrated with photographs of the material and its inclusions at 10 x 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.


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 & Geology, 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 rubies. However, the glimpses into the Stone Tract’s history more than compensate for this.

The second part, entitled “The Nga Mauk Ruby,” is devoted to the legend behind the discovery of this 8.15 x 4.65 x 3.0 mm (5.1 x 1.2 x 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 a bribe and 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, they divided the stones into unequal pieces by the miners. Although this corundum-bearing amphibolite is exposed in the upper part of the valley, 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 x magnification.

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


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-schist 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 part 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.
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 Lib-wo, 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 cargoes. "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 shipsload 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.


Mandawat describes the history of lapidary art in the city of Jaipur, India. Jaipur was founded in 1727 by the ruler of Jaipur, the great merchant city 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 mak- ers, 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.


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...
himself owned cigarette boxes designed by the Duke, one for each of his shows. Diana Vreeland owned 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 solitary diamonds "swimming pools." "Instructive and entertaining, this article teaches principles as well as history of good jewelry design.


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. Meer 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.

RETAILING

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.

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.

SYNTHETICS AND SIMULANTS

Although much of Gunawardene's article reiterates what has previously been reported on Knirschka 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 Knirschka rubies. It is interesting to note that when exposed to ultraviolet radiation some of the Knirschka rubies fluoresced red on the outer edges, but not in the center. According to Knirschka, this unusual pattern of fluorescence, first 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 Knirschka 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 most extensive than the citations given in any of the other articles in English.


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

The first four properties are briefly addressed. Gübelin notes that dark red Kashmir synthetic rubies often show a subordinate tint of brown to orange that is more intense than in the majority of Thai rubies. In addition, the dark red Kashmir material with a brownish or orange 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 spectroscopic expert 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 479 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.

TREATED STONES


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 Kase. Conspicuously absent from the chart, however, is information on the detection of many of the treatments.


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.

MISCELLANEOUS


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 those 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.
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 6.4% (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 Chugwater, 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
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 Bokwanga], 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 Glâsol 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 (new 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 Californian promise 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 11). 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-
A $20,000 reward has been offered for information leading to the return of the following collection of 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 (3⅞ x 1⅛")
2. Aquamarine crystal (sky blue) on quartz and feldspar (2" long)
3. Emerald (1⅝" high) on calcite
4. Emerald (1⅝" high) on calcite
5. Large green beryl (3⅞ x 1⅛")
6. Lime green beryl, two parallel crystals (2⅝ x 1¼")
7. Green Russian beryl, two parallel crystals (3 x 1"), 16 vertical faces and 17 termination faces, very rare crystallography
8. Yellowish green heliodor beryl (2⅝ x 1¼")
9. Sea green yellow beryl, pinacoid termination (4½ x ⅛")
10. Diamond crystal, 20.23 ct octahedron
11. Olive green chrysoberyl, V-shaped (2¼"")
12. Tanzanite (1¼" high)
13. Tanzanite (1¼" high)
14. Silver crystals on calcite (approximately 3" x 2")
15. Diaspore on calcite (4½ x 4¼")
16. Pink gem rose tourmaline crystals with green tips on pink koikiite matrix (two crystals, longest is 3½")
17. Rubellite (2¾ x 1¼")
18. Emerald green tourmaline, two parallel crystals (3 x ½")
19. Biotite (blue and green) tourmaline (3⅛ x ¼")
20. Gold crystals on 2" square piece of quartz
21. Imperial topaz crystal (approximately 5½" long)
22. Gold in limonite (1½"")
23. Twisted quartz crystal on plastic stand (2½" x 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 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 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) 579-7117. Applications for the design contest are available from Alex Bahlarian, Chairman, AGTA Spectrum Award Committee, P.O. Box 32086, Phoenix, AZ 85064.

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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 Schroeder 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 23, 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.


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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 Arc0 Publish- ing, 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 physi-
cal-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 clearance for synthetic spinel, among others. He also confuses birefringence with pleochroism, graininess with polish-
ing lines, and the value of a hardness test with that of the highly import-
ant refractometer in gem testing.

Several of Mr. Greenbaum's key separations are gemologically un-
sound. For example, he suggests that fluorescence will separate jadeite and nephrite. He misidenti-
ifies 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-
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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 clearance for synthetic spinel, among others. He also confuses birefringence with pleochroism, graininess with polishing lines, and the value of a hardness test with that of the highly important refractometer in gem testing.

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MINERALS OF BROKEN HILL
Edited by Dr. H. R. 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 Miners Sequence and about the minerals of the Consols Mine and the Hill. From here, there are three 

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