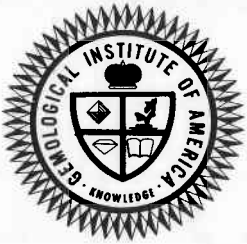
Gems & Gemology

WINTER 1980-1981



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IN THIS ISSUE

Carbon Dioxide As a Fluid Inclusion

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Abstract

Second only to water in abundance as a fluid inclusion filler, carbon dioxide in a liquefied form, because of its low critical temperature and extreme sensitivity to heating, is often and easily overlooked. Found in natural gem minerals, the explosive pressures CO_2 can generate in an inclusion chamber, even with only a slight rise in temperature, make it a type of fluid inclusion that all gemologists should be aware of.

Discovery and Identification

In the year 1823, while examining the interiors of several rough crystals of smoky quartz, topaz and sapphire under magnification, the Scottish physicist Sir David Brewster made note of and reported on a "remarkable new fluid found in the cavities of rocks." Under the microscope he noted the strange new liquid he had discovered was found quite often in the presence of water although the two did not mix. The refractive index of the new liquid was less than that of water and it had a coefficient of thermal expansion of approximately 30 times that of water. This new liquid was found to be of a non-wetting nature and would ball-up somewhat like mercury rather than spread and wet the walls of its negative crystal host. In general he found the liquid to be quite active.

Other researchers, interested by Brewster's discovery, followed his experiments. They verified his findings and also noted that the density of the new liquid varied greatly under slight changes of temperature. Some small bubbles of this liquid could be made to sink or float in otherwise water-filled negative crystals simply by altering the temperature.

It had been theorized that the new liquid might be carbon dioxide. But, it was not until 46 years later in 1869, with the discovery that CO_2 could in fact be liquefied, that the liquid first described by Sir David Brewster was found by spectral analysis to be carbon dioxide.

Gemological Observations

Since the time of Brewster and his colleagues the study of carbon dioxide inclusions has been continually carried out through the years. Utilizing infrared absorption spectrophotometry by passing an infrared beam through a thin parallel windowed plate of a gem, mineral researchers have identified five separate forms in which carbon dioxide may occur in

inclusions. Three of these forms are found in solution with water. They are CO_3^{-2}, HCO_3^{-1}, and H_2CO_3, the other two forms being gaseous and liquid CO_2.

It is these last two forms, the gaseous and liquid carbon dioxide, that are of primary interest to the gemologist.

Liquid carbon dioxide has a critical temperature of 31.2° C (88.2° F) minus two or three ° C if the CO_2 is not pure, as contaminants will depress the critical temperature.

The critical temperature is the highest temperature at which a gas can be pressure liquefied regardless of the amount of pressure applied to the system. The normal human body heat of 98.6° F is higher than carbon dioxide's critical temperature. In the course of routine gemological testing, if the standard technique of examination of the gem with the unaided eye is carried out, by the time the stone is examined under the microscope the temperature is usually above the critical temperature and the CO_2 liquid phase is now a gas.

Carbon dioxide also has a great sensitivity to infrared wavelengths that can produce localized heating and gasification of the liquid CO_2 in the inclusion even though the surface of the specimen remains below the critical temperature.

The amount of infrared present in normal incandescent illumination is quite adequate in locally gasifying the liquid CO_2 inclusions. So if a pen light or other such source is used in the unaided eye examination, the gemologist is almost sure to miss seeing the liquid phase.

This problem can be avoided by going directly from the stone paper to the microscope utilizing a pair of cool tweezers to handle the gem.

As the gem is gently warmed by the microscope illuminator the observer can watch as the critical temperature is slowly passed and the liquid CO_2 turns to a gas.

During the transformation of liquid to gas, the gas bubble might shrink and disappear, grow larger and then fade out, or the meniscus between the gas and liquid might appear to just fade out and sometimes flatten without changing size.

These changes are controlled by the degree of fill (critical density) of the fluid at the time of original formation of the inclusion in the crystal.

When the inclusion cavity is first filled during growth, it is under the influence of the temperature and pressure present at the time of filling and sealing of the cavity. These properties dictate a specific set of conditions for that inclusion.

As the inclusion cools from its temperature of formation it passes below the critical temperature and liquid CO_2 forms under the influence of the internal pressure. As the inclusion is reheated, during the last few degrees before the critical temperature is reached, gross changes in the density of the liquid and gas phases take place.

If the density of the CO_2 is greater than the true critical density (degree of fill), then the gas bubble will shrink and fade as the critical temperature is

CARBON DIOXIDE IN GEMSTONES

The following seven (7) pairs of photomicrographs illustrate liquid and gaseous carbon dioxide (CO_2) inclusions in (1) aquamarine, beryl, (2) smoky quartz, (3) sapphire, corundum, (4) topaz, (5) spodumene, (6) chrysoberyl and (7) tourmaline. Those photographs on the left were taken below the critical temperature of 31.2°C and those on the right were taken above the critical temperature after the disappearance of the CO_2 liquid phase. Water is a common accompanying immiscible liquid with the CO_2. Water is present with the CO_2 in the spodumene, chrysoberyl and tourmaline. Magnification range 25X to 70X.

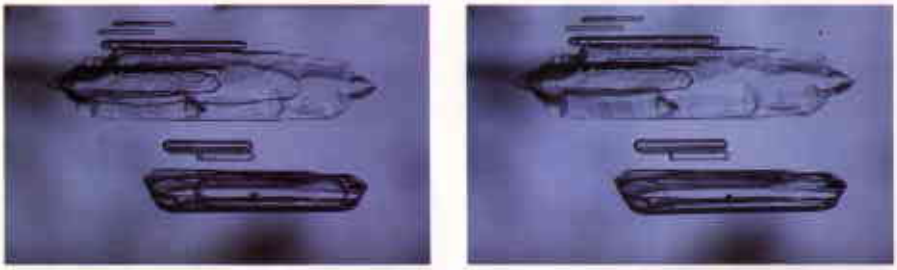

Figure 1. Beryl.

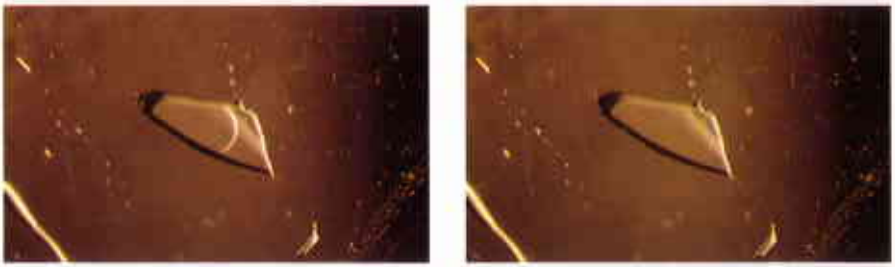

Figure 2. Quartz.

Figure 3. Corundum.

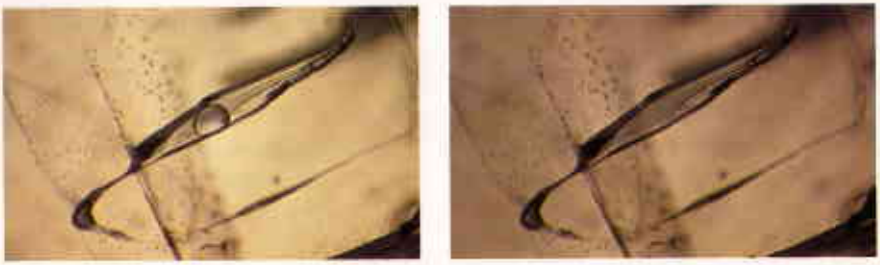

Figure 4. Topaz.

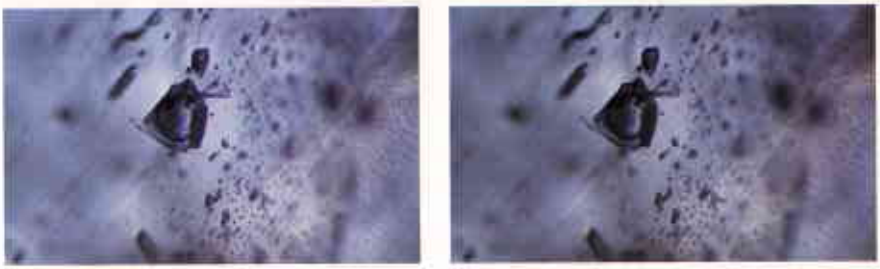

Figure 5. Spodumene.

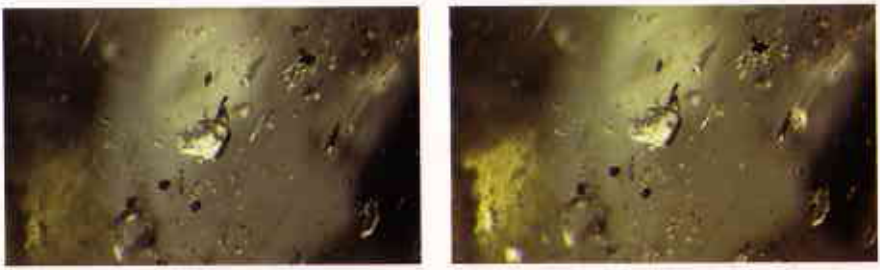

Figure 6. Chrysoberyl.

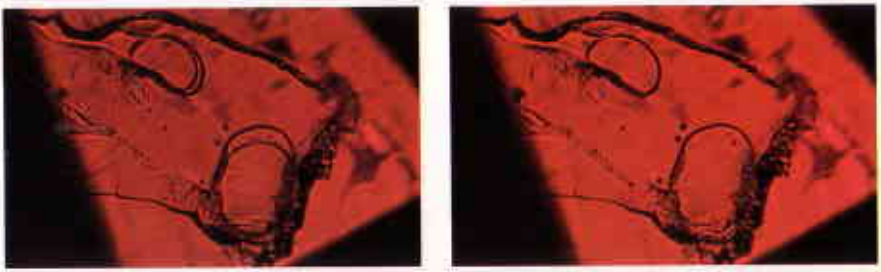

Figure 7. Tourmaline.

reached. If the density is less, then the gas bubble will expand to fill the negative crystal as the meniscus fades. If the true critical density and the density of the CO_2 inclusion at the critical temperature are essentially the same, then there will be no obvious change in the size of the gas bubble and the meniscus will fade out.

Carbon dioxide fluid inclusions are under extremely high pressure even at room temperature. At the critical temperature of 31.2° C, liquid and gaseous carbon dioxide fluid inclusions are exerting an outward pressure of over 1,000 pounds per square inch, and on heating above the critical temperature this pressure increases readily.

Without the aid of a compensating external pressure, CO_2 inclusions will commonly rupture long before the original filling temperature is reached.

CO_2 and The Jeweler

For many years now carbon dioxide fluid inclusions have intrigued countless numbers of gemologists. The gasification of the liquid phase as the critical temperature is passed has always been a source of fascination. In view of the internal pressures generated by carbon dioxide inclusions the manufacturing jeweler should be on guard as well. Carbon dioxide high pressure blowouts, the explosive mechanism behind many a fractured gem, may be one of the major microscopic features in detecting heat treated rubies and sapphires from Sri Lanka.

Another key to natural formation, liquid carbon dioxide inclusions are both interesting to observe and important to be aware of. In the microscopic examination of gemstones containing liquid inclusions a point should always be made to study the gems below 88° F because you never know what you're missing!

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Developments and Highlights at GIA's Lab in Los Angeles

By ROBERT E. KANE

Unexpected Absorption Spectrum in Natural Emeralds

A number of years ago Gilson introduced a new type of synthetic emerald, known to many gemologists as the Gilson type III. This type of synthetic emerald has since been reportedly discontinued; they are still, however, seen occasionally in GIA's Gem Trade Laboratories. Synthetic emeralds of this type have a bluish-green color and properties that are somewhat comparable to the properties of natural emeralds. The refractive indices are approximately 1.571 - 1.579, the S.G. from 2.68 to 2.69, and there is no ultraviolet fluorescence. The absence of fluorescence was accomplished by the addition of iron oxide, which in turn resulted in an absorption line at 4270 Å. Until recently it was believed that this absorption line or anything resembling it was not present in natural emeralds. We have seen, however, several emeralds of fine color (a few of them bluish-green) that have all exhibited absorption in the general area of 4270 Å. This absorption has been relatively faint and in some cases difficult to distinguish from the shaded absorption in the blue and violet regions of the visible spectrum. Detailed observation revealed a broad weak band from approximately 4250 Å extending to approximately 4305 Å, with suggestion of a slightly stronger absorption at 4305 Å. *Figure 1* shows this absorption spectrum.

The few emeralds that we have examined that exhibited this absorption have had refractive indices that have been rather high, ranging from approximately 1.583 -1.590 to 1.589 - 1.596, much higher than any known synthetic emeralds. The S.G. has been variable, but in the approximate area of 2.77. One of the stones examined was inert to both long and short-wave ultraviolet light and the others exhibited a very weak orangy-red fluorescence to long-wave ultraviolet light, as would be expected with natural emeralds of such fine color.

In comparison with most natural emeralds these stones have all been relatively free from inclusions. Of the inclusions that were seen nothing unexpected was noted; they contained inclusions such as two-phase, three-phase, biotite mica, fine needles, li-

quid inclusions, etc. Several of the emeralds that contained three-phase inclusions were reportedly of African origin. At the time this is being written further observation and a more detailed study is being undertaken in order to fully document this absorption spectrum and the properties of these natural emeralds.

Seldom Seen Absorption Spectra in Diamonds

In the determination of origin of color in most colored diamonds, the use of the spectroscope is invaluable. This determination is usually very routine and we rarely find any new or unexpected absorption. In the past year however, we have seen several yellow-brown diamonds of natural color that have all exhibited a faint absorption line at approximately 5601Å. When this absorption line was first seen it was somewhat unexpected; however, it now seems to be characteristic of natural color diamonds with a "dirty" yellow-brown color. All of these diamonds have exhibited an orange fluorescence.

Another unusual absorption pattern was seen in a fancy grey diamond of natural color weighing slightly over 4 carats. This diamond was the same stone that was seen a number of years ago in our New York Laboratory and was mentioned in the Fall, 1969, issue of *Gems and Gemology*. This diamond exhibited the unexpected absorption pattern seen in *Figure 2*. This stone had a moderate absorption line at approximately 5510Å. This absorption spectrum was so unique, that we felt it was worthy of mentioning again. Another unusual feature that this diamond exhibited was its reaction to long-wave ultraviolet light; a very strong blue color with zones of yellow. Under short-wave ultraviolet light, a similar but weaker reaction was seen. This zoned fluorescence is shown in *Figures 3 and 4*, photographed under long-wave ultraviolet light.

Mobile Bubble in A Three-Phase Emerald Inclusion

Gemologists are very familiar with three-phase inclusions in Colombian emeralds, the typical flattened void having a jagged outline containing a halite crystal and a gaseous bubble enclosed in a saline water solution *(Figure 5)*. A three-phase inclusion of a type that is less familiar to some gemologists is shown in *Figure 6*. In

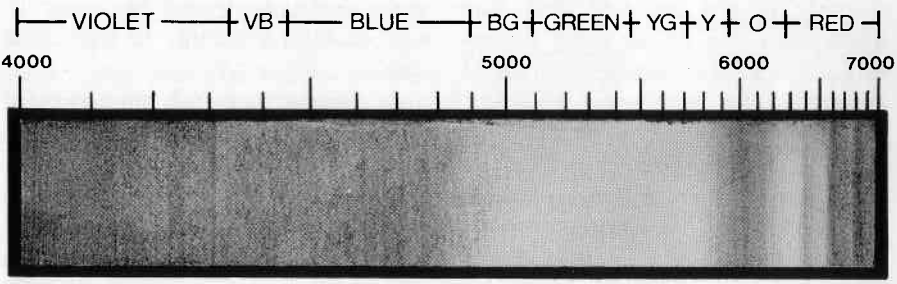

Figure 1.

this inclusion, instead of the typically flattened void there is a larger negative crystal with a very "three-dimensional" appearance. Mineralogists are familiar with mobile bubbles that often occur in quartz and fluorite crystals. These mobile inclusions are sometimes seen by gemologists in faceted quartz and fluorite, however, it is rare. An even less common occurrence is to see mobile bubbles in faceted emeralds.

Emeralds with mobile inclusions contain larger negative crystals, such as the one seen in *Figure 6*. These chambers are large enough to enable the bubble to move when subjected to slightly elevated temperatures. Seen in *Figures 6 and 7* is an excellent example of this type of three-phase inclusion. *Figure 6* shows the emerald at room temperature; the bubble is stationary and very close to the halite crystal. After several minutes in the microscope the heat generated from the light source has caused the bubble to move with moderate speed to the right of the chamber (*Figure 7*). The bubble remained in this position until the stone was allowed to cool at which point it returned to its original position *(Figure 6)*.

Mobile Three-Phase Inclusion in A Sapphire

Mobile bubbles are sometimes seen in natural blue sapphires. Also seen are mobile solids which in conjunction with the mobile liquid and gaseous bubbles create interesting mobile three-phase inclusions. These inclusions can easily be overlooked by a gemologist. In the microscopic examination of a gemstone's interior to determine the natural or synthetic origin of the stone, a negative crystal such as the one seen in *Figure 8* may be mistaken for an included crystal. If, during the crystal's formation, the walls of the negative crystal take on the external shape of the host crystal, as is often the case, it will resemble a solid crystal inclusion.

The knowledge that these negative crystals may be present gives the gemologist, with the correct illumination and viewing angle, the possibility of discovering fascinating and complex mobile inclusions. The 2 carat natural blue sapphire shown in *Figures 8 through 13* contains an excellent example of this type of inclusion. This stone has a large negative crystal which contains both liquid and gaseous carbon dioxide

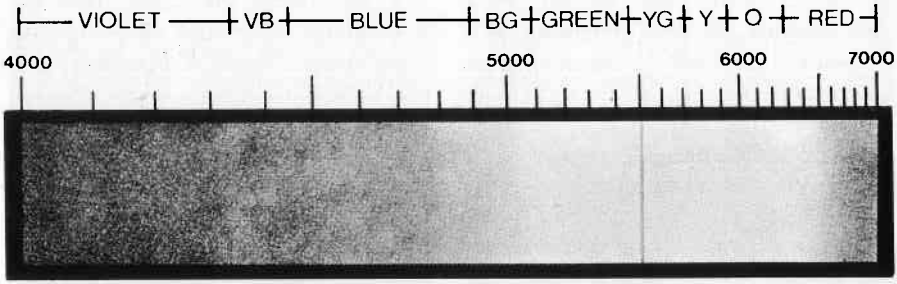

Figure 2.

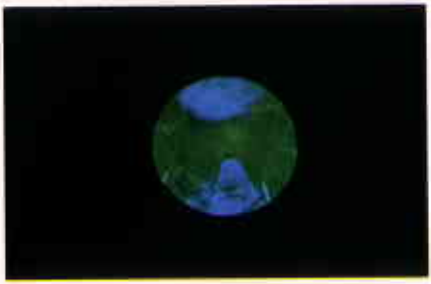

Figure 3.

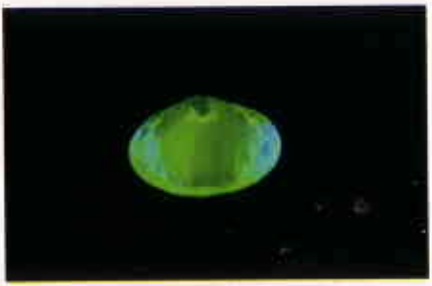

Figure 4.

Figure 5.

Figure 6.

Figure 7.

and a hematite platelet. At room temperature the almost spherical liquid carbon dioxide bubble occupies an area which is approximately 0.4 mm. long in the negative void which is approximately 1.2 mm. in length. *Figure 9* shows the bubble in the center right portion of the negative crystal. The very slightest movement sends the bubble lightly bouncing off the walls of the void. Within just a few seconds, the heat generated by a 30 watt light bulb in the dark-field microscope stage causes the extremely sensitive liquid carbon dioxide bubble to violently boil and vaporize at a rapid rate. *Figure 10* shows the bubble as it rapidly shrinks. Within a time lapse of less than ten seconds, the bubble has completely vaporized and disappeared from view *(Figure 11).* Removing the stone from the microscope stage and allowing it to cool, enables the liquid carbon dioxide bubble to return to its original position seen in *Figure 9.*

Tilting the stone slightly causes the hematite platelet to move from the opposite side of the void. The hematite platelet is the dark material in the center of the void seen in *Figure 12. Figure 13* shows the hematite resting

Figure 8.

Figure 9.

Figure 10.

Figure 11.

Figure 12.

Figure 13.

on top of the liquid carbon dioxide bubble. After several seconds in the microscope stage, the bubble starts to boil. The movement of the bubble causes the hematite platelet to bounce up and down until the bubble has completely vaporized, at which point the hematite falls to the other side of the void.

Fluids in two and three-phase inclusions, such as the one described here and illustrated in *Figures 8 through 13*, can be extremely sensitive to heat. Gemstones that contain inclusions of this type may be severely damaged when exposed to heat, whether it be the low temperature that is generated by the light bulb in a

Figure 14.

Figure 15.

Figure 16.

Figure 17.

Figure 18.

Figure 19.

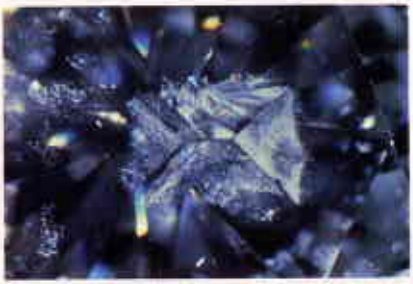

Figure 20.

Figure 21.

microscope stage, the heat that a stone may encounter during the cutting and polishing processes, or the heat from a jeweler's torch. For more information on this subject, refer to "FLUID INCLUSIONS; Hidden Trouble for the Jeweler and Lapidary" by John I. Koivula, published in the Spring, 1980 issue of *Gem and Gemology*.

Epigenetic Stains in Diamonds

During the lengthy transportation of diamond crystals from tremendous depths within the earth, a diamond crystal often undergoes excessive temperature and pressure changes. Therefore the crystal has not always reached its full development at the same time the crystal stops growing. Cleavages and fractures may occur during the transportation of the crystal. Cleavages and fractures that reach the surface of a faceted diamond are often weak and sometimes dangerous areas. These cleavages and fractures, however, do not always remain free from foreign substances. They will sometimes be filled with xeno-physical liquids in which mineral substances enter the crystal and a type of healing often takes place upon the crystallization of these mineral substances. This epigenetic (taking place after the crystal stops growing) pseudo-healing often times produces interesting and artistic patterns in the form of inclusions. Occasionally the diamonds we see in the laboratory contain inclusions of this type. These "healed fractures" do not usually threaten the durability of the diamond, but they often lower the clarity grade because of the undesirable discoloration. The discoloration may in some situations impart more body color to the diamond which lowers the color grade also. Not only do these inclusions typically exhibit a brownish, reddish, or orange discoloration, but they also often have an opaque and dull whitish appearance. *Figures 14 through 19* show examples of this type of inclusion. In all of these diamonds the inclusions originate at the surface of the stone.

Figure 14 shows a diamond macle complete with trigons, included in a round brilliant diamond. The darker area in the upper left of the inclusion is a feather that breaks the surface of the pavilion. It was at this point that a liquid was allowed to enter the interior of the diamond.

Figure 15 shows the typical dull whitish appearance that these inclusions often exhibit. Discoloration took place only in a few areas at the edge of the inclusion. Also at the edges are needles that radiate outward at various angles. *Figures 16 through 19* show four inclusions that contain not only discoloration and a dull whitish appearance in some areas but also exhibit the typical crystallization of mineral substances that take on a somewhat dendritic appearance.

Reference: Gübelin E., INTERNAL WORLD OF GEMSTONES 1974, page 67

Clouds in Diamonds

Occasionally we see very symmetrical "envelope" clouds in diamonds *(Figure 20)*. These clouds are usually composed of four extremely thin sides and always originate at the table of the diamond. The areas inside of

Figure 22.

Figure 23.

Figure 24.

Figure 25.

Figure 26.

Figure 27.

Figure 28.

Figure 29.

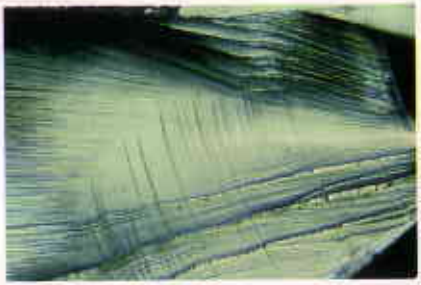

Figure 30.

Figure 31.

Figure 32.

these clouds are usually free from visible inclusions. Clouds of this type are presumably one half of an eight sided cloud; the remaining half being in another faceted diamond cut from the same crystal. When a diamond containing a cloud of this type is examined from the pavilion it is readily apparent that "voids" have created different patterns on each of the four sides of the cloud. These areas are devoid of a dense concentration of visible inclusions and can be arranged either in a very symmetrical or in an irregular pattern. *Figure 21* shows the pavilion view of one side of an "envelope" cloud. This pattern is somewhat reminescent of the Maltese-cross clouds that we occasionally see such as the one shown in *Figure 22*. This cloud is the same one mentioned in the fall, 1979, issue of *Gems & Gemology*. The difference between these two types of clouds is that the pattern in *Figure 21* is formed by six areas that are relatively devoid of inclusions except for a fine line intersecting each "void." The Maltese-cross clouds always have four sides and are composed of a very thin cloud.

Another type of cloud occasionally seen in the laboratory is one half of a well-formed and symmetrical octahedral cloud. These clouds are similar to the "envelope" clouds in the fact that they are also composed of extremely thin walls and often have different patterns on each of the four sides. These clouds always originate at the table of the diamond. *Figure 23* shows one half of an octahedral cloud being viewed from the table of a round brilliant diamond. In this photomicrograph the facet reflections make it difficult to see the composition of the cloud. *Figure 24* is a pavilion view and shows the composition more clearly. In a few of these diamonds octahedral graining (often referred to as "cubic" graining and frequently seen in a square outline in the crown of a four-point round

brilliant) was present and was parallel to the walls of the octahedral clouds. This graining and the orientation of the clouds indicate that the sides of the clouds were parallel to octahedral faces and that their host diamonds are four point brilliants. *Figure 24* shows the distinctive formation of triangular patterns so typical of diamond octahedra.

Figure 25 shows a partial crown view of another half-octahedral cloud. On one of the sides of this cloud a very distinctive triangular formation of "voids" was seen. *Figure 26* is a pavilion view of this formation. *Figure 27* is a pavilion view of another half-octahedral cloud and shows how dramatically these patterns can differ from one cloud to another.

A Surprised Jeweler

The fact that diamond is the hardest substance known to man and among the toughest of gemstones, often leads a jeweler to overlook the reality that in certain situations diamonds can and do break very easily because of diamond's easy cleavage. The diamond weighing approximately 1.00 carat, shown in *Figures 28 through 31,* is an excellent example of this. As a jeweler was working on a piece of jewelry an unfortunate event took place. Not knowing the exact circumstances it is difficult to state the precise cause. A very probable explanation would be that there was an inherent feather present in the area indicated by the arrow in *Figure 28,* so that a sharp blow or prolonged pressure at that location caused the diamond to break in half. A more complete understanding of diamond's properties and a quick examination with a loupe or microscope might have saved this jeweler from considerable expense and embarrassment.

Variety in Tourmaline

Tourmaline crystals are found in a wide variety of colors and when more than one color occurs in the same crystal, attractive bi-color or tri-color (also referred to as parti-color) stones can be fashioned . We recently had an opportunity to view an exceptional 11 carat tri-color tourmaline. We felt this particular stone, shown in *Figure 32,* was worthy of mention since it was remarkably free of inclusions and it illustrates a good depth of color as well as good distribution of its three color divisions: pink, colorless and greenish-blue. The color combinations in parti-colored tourmalines can vary and the divisions of color zones may be sharply defined or may gradually blend as in the one described here.

Acknowledgements

I would like to thank the following people for their excellent photographs: Michael R. Havstad of GIA's Gem Media for Figure 32; John I. Koivula for Figure 16; Shane F. McClure for Figure 19. All other photographs are by the author.

Inclusions in Andalusite — A Comparison of Localities

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Through the microscope the pleochroic world of andalusite is a symphony of color. The facets mirror hues of olive green, orange and reddish brown while a myriad of unknown inclusions appear suspended in their reflective rays.

When studying the interiors of gem andalusites the mysteries of its inclusion world begin to unfold and we learn that andalusite like other gem materials reflects its birth and life through its internal paragenesis.

Born in the heat and pressure of contact metamorphism, andalusite is the product of interaction between granitic or pegmatitic intrusives as they penetrate argillaceous or mica schists, clay slates, or gneisses. Alumina and silica are abundant in this environment and when the proper temperature and pressure for growth are present andalusite crystallizes.

During the process of crystallization small guest crystals of foreign minerals may contaminate the otherwise orderly formation of andalusite. In addition, droplets of liquid, some of which are pressure liquefied gases, may adhere to the growing surface and be included. These guest minerals and primary liquid droplets make up the initial phase of andalusite's inner world.

As with other gem minerals, the growth of andalusite is not always a calm and orderly process. Crystals can become cracked during growth or at any time after they have ceased to grow. These fractures will be filled with whatever is surrounding the crystal at the time of breakage. If a healing solution enters the break and the environment is one of growth then the fracture will start to repair itself. If however the break is invaded

Inclusions In Brazilian Andalusite

1. Limonite lining in an epigenetic fracture. 35X.

2. Euhedral apatite crystals. 30X.

3. A ball-like cluster of rutile needles. 25X.

4. A booklet of biotite mica. 30X.

by a foreign solution and regrowth is not possible then an epigenetic dry crack lined with other mineral compounds is formed as the solution evaporates.

Solids Found in Andalusite

Brazilian andalusites are noted for their stalks of rutile and euhedral crystals of apatite. Rutile formed syngenetically with the andalusite may take the form of ultra-fine curving needles, stiff straight log-like randomly oriented yellow crystals, and more rarely dense thick radial crystal masses. Apatite crystals, also of syngenetic origin, are often found in close proximity to the rutile. It is not uncommon to find apatities that have grown around acicular crystals of rutile giving the effect of having been pierced or punctured. The apatite crystals commonly show sharp, well defined faces, but the overall shapes of the crystals are often distorted.

Indicating growth in a mica schist, protogenetic booklets of brown biotite are also occasionally found with the rutile and apatite.

Sri Lankan andalusites will often contain growth tubes that run parallel to the C axis of the host. These

5. Quartz crystals. 50X.

6. Secondary healing fracture. 35X.

7. Andalusite in andalusite under polarized light. 30X.

8. Limonite stained growth tubes. 50X.

hollow tubes will regularly contain yellow to orange epigenetic fillings of iron stained foreign matter. In addition to growth tubes these gems may play host to protogenetic crystals of quartz. These quartz guests are very tiny colorless blebs showing traces of their crystal form. They appear to be somewhat resorbed or corroded.

Andalusites from all localities can contain limonite as an epigenetic fracture filling. The hydrous ferruginous oxides transported by xenophysical solutions invade the open fractures decorating them with natural art in tones of yellow and orange.

Fluid Inclusions

Whether they are of primary or secondary origin, the first thing the gemologist notices about andalusite's fluid inclusions are their curious lack of discernible gas bubbles. The fluids that fill the negative crystals are immiscible mixtures of an aqueous brine (H_2O + salts), liquid carbon dioxide (CO_2) and occasionally nitrogen (N_2).

The fluid inclusions in andalusite are commonly two-phase in nature. They consist of two or three immiscible liquids often together with various solids that have crystallized from the fluids as they cooled.

These two-phase inclusions in andalusite are commonly found filling the individual negative crystal healing islands that together make up the intricate secondary syngenetic partially healed fractures intrinsic to andalusites from all localities. More rarely they can be found filling much larger primary cavities.

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An Examination of Red Beryl

By FRANK MILEY
Graduate Gemologist
Los Alamos, New Mexico

Introduction

Red beryl is a gem that has recently been coming into prominence. Where does it come from? How much is available? What does it look like? How can it be identified? Recent acquisition of a faceted gem prompted these questions. After researching available literature and finding very little gemological information, it became obvious that some personal research was to be done on as much red beryl as could be examined.

Sources

Red beryl is only found in three locations in the United States. No other sources have been reported. It occurs in the Thomas and Wah-Wah Mountain ranges in Utah [1] and in the Black Range in New Mexico [2]. All crystals are small; the largest crystals are found in Utah. The Utah material provides faceted gemstones that are generally less than .5 ct.; common sizes usually range from .1 ct. to .4 ct. Nearly all faceted gems exhibit a high degree of internal fractures and inclusions. The largest faceted red beryl that has been reported [3] is 2.93 ct. The author has not had the opportunity to see or examine this rare gemstone.

In some literature red beryl is listed as bixbite. If you should do a literature survey, you should be aware of both names. In this article it is referred to as red beryl.

Properties

Several faceted specimens of the Utah material were examined for this report. New Mexico material was on display[4] as crystal specimens; it was much too small to be faceted. This material was not available for microscopic examination. It was noted however, that the tone and hue were very close to that of the Thomas Mountain material. The Utah material exhibited differences in transparency, tone, hue, and intensity. They are listed as "T" Thomas Mountains, and "W" Wah-Wah Mountains. The information obtained from examining the Utah materials is listed as follows:

Description:	"T" Translucent, dark orangy-red of medium intensity. "W" Semitransparent, medium red of high intensity, see *Figure 1.*
Crystal character:	Hexagonal.
Fracture:	Conchoidal.
Specific gravity (a):	2.65
Characteristic inclusions (b):	Fingerprint pattern.
Transparency:	Semitransparent to translucent.
Luster:	Polish is vitreous. Fracture is vitreous.
Refractive index (c):	1.561(±.001) — 1.569(±.001)
Birefringence:	.008
Optic character (d):	Uniaxial.
Pleochroism:	Purplish-red and orangy-red.
Ultraviolet fluorescence:	Inert to both wavelengths.
Color filter:	No reaction.
Absorption spectra (e):	No diagnostic spectra.

(a) The value of 2.65 was determined by using heavy liquids. The gemstone tested floated in a liquid of 2.67 specific gravity and sank in a liquid of 2.62 specific gravity. The heavy liquid method was used because there is a possibility for a great variation in determining the specific gravity on small specimens. The examined specimens were all small, consequently, as a secondary method of determination, three faceted gems were used simultaneously to determine the specific gravity by the immersion method. The combined weight of the three faceted gems was .52 ct., and the specific gravity as determined by this method was 2.67. The published value[5] for red and violet beryl lists the specific gravity range to be 2.77 to 2.87.

(b) Red beryl was highly included with secondary inclusions consisting of single phase, gas filled, fingerprint patterns, see *Figure 2.* It also contains bizarre shaped healing voids. Both of these types of inclusions were in planes or curved surfaces. There were more fingerprint patterns present than the planes of healing voids. The fingerprint patterns in red beryl have been characteristic. At 20X, straight sided and round inclusions were intermixed. At 60X, the straight sided inclusions were pointed and the round inclusions appeared to have short straight sides. At 125X, much smaller inclusions began to appear in between the inclusions described at 60X.

When magnified, all faceted gemstones had one or more internal fractures that extended to the girdle.

No other inclusions were noted in all specimens examined up to 125X.

(c) A Duplex II Refractometer

Figure 1. A .20 ct. red beryl from Wah-Wah mountains.

Figure 2. Fingerprint inclusions at 36X, dark field.

was used with Monochromatic Yellow Light to determine the refractive index of each gemstone. The published value[5] for red and violet beryl lists the refractive index range at 1.585 (±.006) — 1.594(±.006). Since there was a difference between published and experimental data, high and low standards were used to check the instrument. The reading obtained for sapphire was 1.762 — 1.770 and the reading for quartz was 1.544.

A series of readings were obtained by rotating each gemstone on the hemisphere of the refractometer. Readings were obtained at 0, 45, 90, and 135 degree positions and each was plotted on a chart. This was done to determine the birefringence.

(d) The uniaxial interference figure was obtained using the Illuminator Polariscope set in the cross polaroids position. The magnifier from the refractometer was inverted and placed on top of the analyzer and a small glass sphere was in contact with the specimens. This arrangement showed the gems to have a sharp uniaxial interference figure.

The published value[5] for beryl is uniaxial negative.

(e) The number 808 Spectroscope Unit was used to check the gemstones for the spectroscopic analysis. No diagnostic data was obtained from the use of this instrument. The red color was reported[2] to be caused from the presence of manganese (Mn^{+2}); this has been determined by microprobe analysis. The absorption spectra tests performed on the red beryl specimens that were examined did not indicate any diagnostic absorption.

Photographs

Figure 1 is a photograph of a 4.78 x 3.05 mm emerald cut, .20 ct. red beryl from the Wah-Wah Mountains. *Figure 2* is a photograph of the same .20 ct. red beryl, using dark field lighting at 36X.

Conclusion

If faceting grade red beryl becomes more plentiful it should become a popular gemstone. The red hue of the Wah-Wah Mountain material resembles ruby and ruby red spinel. The red hue of the Thomas Mountain and Black Range material is slightly darker and resembles cuprite. Red beryl is highly included and contains internal fractures, consequently, the durability should be comparable to highly included emerald and should be used in protective type mountings.

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(3) Barlow, F. John, *Lapidary Journal,* P. 2540, 1979, Red Beryl Of The Wah-Wahs.

(4) New Mexico Minerals Symposium, UNM Campus, Albuquerque, N.M., September 29, 1979.

(5) Gem Identification Course of the Gemological Institute of America.

GEMOLOGICAL NOTES

Gübelin Identifies Apatite in Taaffeite

During his recent research on the rare gem mineral taaffeite, Dr. Edward Gübelin made note of a very slightly rounded but euhedral prismatic crystal included in one of the Taaffeites he was studying. The crystal was identified as apatite and recorded on film by Dr. Gübelin who gave permission to publish the photograph *(Figure 1)*.

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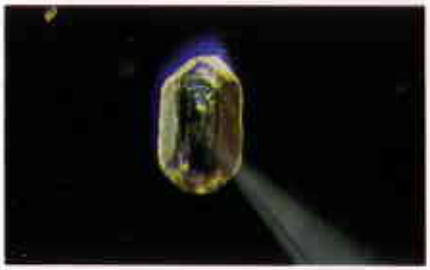


Figure 1.

More News On Citrine-Amethyst Quartz

By JOHN I. KOIVULA

In the Summer 1980 issue of *Gems and Gemology* an article by this writer was printed entitled "Citrine-Amethyst Quartz—A Gemologically New Material." In that article the following paragraph appeared:

> "It should be noted that although the low level natural radiation in the earth could surely produce the amethyst coloration over a period of years, the same result could be achieved by artificial sources of irradiation, and at the present time there would be no way to tell the difference."

Since that time Kurt Nassau, Ph.D., of Bell Laboratories, has taken the project under his wing. With Brazilian material supplied by this writer and the GIA, he has been able to produce sectorally color zoned citrine-amethyst quartz from color zoned amethyst. A detailed report on the theory, method and results of Dr. Nassau's experimentation will appear, illustrated in color, in the premier issue of the new *Gems and Gemology* in Spring, 1981.

This writer has also just recently examined several other color zoned amethyst cross sections from Mexico, Canada, Brazil and the United States. Most of these were rather small, but two large, half-inch thick slabs several inches in diameter from a locality in the state of Arizona were sent to GIA for examination by Mr. Donald Campbell of Campbell Lapidary in Lakewood, Colorado. In view of Dr. Nassau's findings it seems that even large pieces like Mr. Campbell's might be potential subjects for treatment.

Observations on an Imperfect (?) I_1 Diamond

By JOHN I. KOIVULA

A large round brilliant cut diamond that was recently graded by the Santa Monica Gem Trade Laboratory was assigned an I_1 clarity. By all diamond grading rules the imperfect grade was justified, and yet the laboratory gemologists that graded this gem thought that it was both rare and beautiful. The inclusion that set the grade was a perfectly shaped and centered octhedral cloud (see *Figure 2).* To call this type of natural perfection imperfect seems almost cruel. The laboratory gemologist sees far more internally flawless diamond than he does gems like the one captured in *Figure 2.*

It seems difficult to imagine that two diamonds could be considered equal in clarity if one contained numerous cleavages and fractures that seriously affected its structural integrity and durability, while the other played host to a bit of natural perfection like an octahedral phantom cloud. Both gems appear the same on paper, but through the microscope they are worlds apart.

Brief Notes On Chatham Flux Sapphires

By JOHN I. KOIVULA

For several years Chatham Industries has been experimenting with the growth of flux melt blue sapphires. Their early products were very heavily included and not useful for faceted gems. Just recently, five oval faceted synthetic blue flux sapphires in the two carat range were examined. These sapphires were a dark blue color and strong color zoning was viewed in two of the five stones. The zoning went from near colorless to deep blue and was confined to definite straight-sided angular patches that reflected the growth and structure of the original crystal (see *Figure 3).* Platinum flakes and splinters looking like submetallic to metallic included crystals were also observed (see *Figure 4).* The commonest inclusions noted were residual flux. All five of the gems examined exhibited flux inclusions that took the form of white colored, thick veined, fingerprint patterned curving layers *(Figure 5),* whitish curving and flowing smoke-like clouds *(Figure 6)* or a combination of both forms as in *Figure 7.*

The values obtained for the specific gravity of these synthetics ranged from 3.98 to 4.06. The presence of platinum as an inclusion will surely affect the specific gravity on the high end.

The refractive index of the five stones seemed to be quite steady at 1.763-1.772 with a corresponding birefringence of 0.009.

Spectroscopic examination of the five sapphires showed a very vague band centered at 451.5 nm. in the blue. This absorption band was quite vague and could not be considered as diagnostic. The absorption spectrum was confirmed by Stephen C. Hofer of GIA's Research Department who

Figure 2.

Figure 3.

Figure 4.

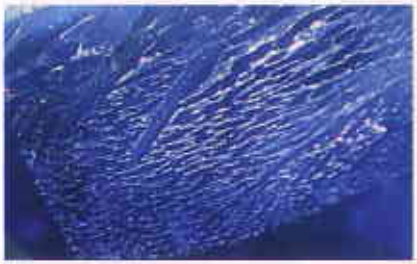


Figure 5.

Figure 6.

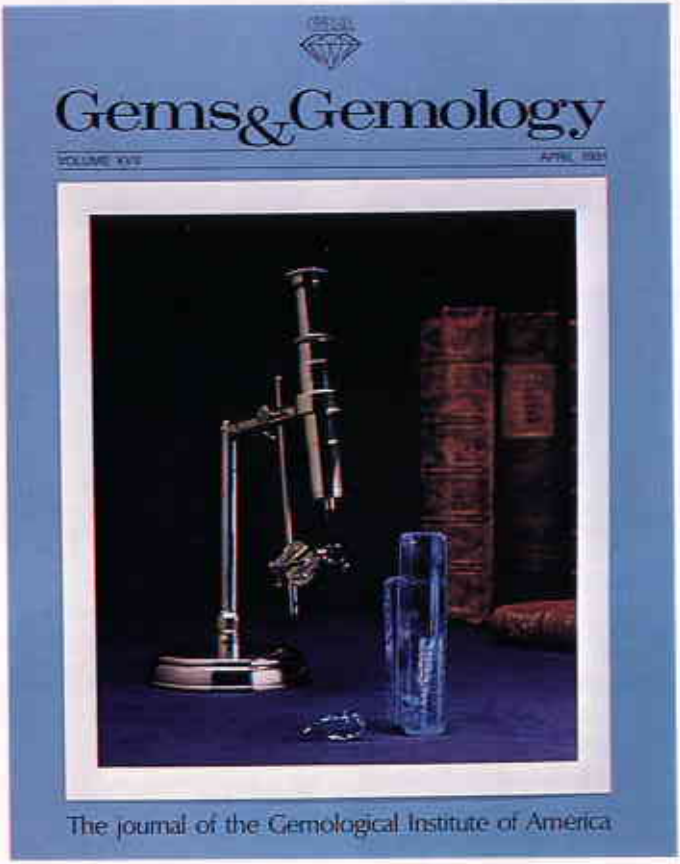
Figure 7.

ran one of the gems on GIA's Carl Zeiss PMQ3 Spectrophotometer.

The X-ray fluorescence of the five Chatham flux sapphires tested ranged from a pale white through a faint bluish-white to a yellowish-white. There was no phosphorescence observed after X-ray excitation.

Under the short wave ultraviolet lamp a dull brownish white fluorescence was observed while exposure to long wave ultraviolet light produced a moderate whitish yellow glow. During exposure to both long and short wave illumination two of the synthetic sapphires showed distinct patches of bright yellow fluorescence. Under the microscope no inclusion centers for the fluorescence were observed, and the areas that fluoresced bright yellow were not bordered by any optically detectable irregularities.

The new Gems & Gemology Is Coming This Spring



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The following guidelines were prepared both to introduce you to the new GEMS & GEMOLOGY and to let you know how we would like a manuscript submitted for publication to look. No manuscript will be rejected because it does not follow these guidelines precisely, but a well-prepared manuscript helps reviewer, editor, and reader appreciate the article that much more. Please feel free to contact the Editorial Office for assistance at any stage in the development of your paper, whether to confirm the appropriateness of a topic, to help organize the presentation, or to augment the text with photographs from the extensive files at GIA. We look forward to hearing from you.

Introduction

GEMS & GEMOLOGY is an international publication of original contributions concerning the study of gemstones and research in gemology and related fields. Topics covered include (but are not limited to) colored stones, diamonds, gem instruments, gem localities, gem substitutes (synthetics), gemstones for the collector, and jewelry arts. Manuscripts may be submitted as:

Original Contributions — full-length articles describing previously unpublished studies and laboratory or field research. Such articles should be no longer than 6,000 words (24 double-space, typewritten pages) plus tables and illustrations.

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Notes & New Techniques — brief preliminary communications of recent discoveries or developments in gemology and related fields (e.g., new instruments and instrumentation techniques, gem minerals for the collector, and lapidary techniques or new uses for old techniques). Articles for this section should be approximately 1,000-3,000 words (4-12 double-spaced, typewritten pages).

GEMS & GEMOLOGY also includes the following regular sections: *Lab Notes* (reports of interesting or unusual gemstones, inclusions, or jewelry encountered in the Gem Trade Laboratories), *Book Reviews* (as solicited by the Book Review Editor; publishers should send one copy of

each book they wish to have reviewed to the Editorial Office), *Gemological Abstracts* (summaries of important articles published recently in the gemology literature), and *Gem News* (current events and upcoming activities in the field; please keep our readers informed of meetings and other activities in your area of the country or the world by sending notices to the Editorial Office at least three months before the desired publication date).

Manuscript Preparation

All material, including tables, legends, and references, should be typed double spaced on 8½ x 11" (21 x 28cm) sheets with 1½" (3.8 cm) margins. Please identify the authors on the title page only, not in the body of the manuscript or the figures, so that author anonymity may be maintained with reviewers (the title page is removed before the manuscript is sent out for review). The various components of the manuscript should be prepared and arranged as follows:

Title page. Page 1 should provide: (a) the article title; (b) the full name of each author (first name, middle initial, surname), with his or her highest degree and affiliation (the institution, city, and state or country where he/she was working when the article was prepared); (c) acknowledgments of persons who helped prepare the report, where appropriate; and (d) five key words that we can use to index the article at the end of the year.

Abstract. Page 2 should repeat the title of the article followed by an abstract. The abstract (no more than 150 words for a feature article, 75 words for a note) should state the purpose of the article, what was done, and the main conclusions.

Text. Papers should follow a clear outline with appropriate heads. For example, for a research paper the headings might be: Introduction, Previous Studies, Methods, Results, Discussion, Conclusion, and Implications. Other heads and subheads should be used as the subject matter warrants. Also, when writing your article, please try to avoid jargon, to spell out all nonstandard abbreviations the first time they are mentioned, and present your material as clearly and concisely as possible.

For general style (grammar, etc.) and additional information on preparing a manuscript for publication, *A Manual of Style* (The University of Chicago Press, Chicago) and *The Elements of Style* (by Strunk and White, MacMillan Publishing Co., New York) are recommended.

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list only those references actually cited in the text (or tables or figures).

Include the following information, in the order given here, for each reference: (a) all author names (surnames followed by initials); (b) the year of publication, in parentheses; (c) for a *journal,* the full title of the article or, for a *book,* the full title of the book cited; and (d) for a *journal,* the full title of the journal plus volume number and inclusive page numbers of the article cited or, for a *book,* the publisher of the book and the city of publication. Sample references are as follows:

Darragh PJ, Sanders JV (1976) Opals. *Scientific American,* 234:84-95.

Heinrich KFJ (1968) Common Sources of error in electron probe microanalysis. In J Newkirk et al., Eds., *Advances in X-ray Analysis,* pp. 40-45. Plenum Press, New York.

Liddicoat RTL Jr., Copeland LL (1967) *The Jewelers' Manual,* 2nd ed. Gemological Institute of America, Santa Monica, CA.

Tables. Tables can be very useful in presenting a large amount of detail in a relatively small space, and should be considered whenever the bulk of information to be conveyed in a section threatens to overwhelm the text.

Type each table double spaced on a separate sheet. If the table must exceed one typewritten page, please duplicate all headings on the second sheet. Number tables in the order in which they are cited in the text. Every table should have a title; every column (including the left-hand column) should have a heading. Please make sure terms and figures used in the table are consistent with those used in the body of the text.

Figures. Please have line figures (graphs, charts, etc.) professionally drawn and photographed. High-contrast, glossy, black-and-white prints are preferred.

Submit black-and-white photographs and photomicrographs in the final desired size if possible. Where appropriate, please use a bar or other scale marker *on* the photo, not outside it, rather than a magnification factor in the legend.

Use a label on the back of each figure to indicate the article's title (or a shortened version thereof) and the top of the figure. Do not trim, mount (unless one figure is composed of two or more separate photos), clip, or staple illustrations.

Color photographs will be considered for publication. Please include three sets of color prints or slides with the manuscript package submitted for publication consideration.

All figure legends should be typed double spaced on a separate page. Clearly explain any symbols, arrows, numbers, or abbreviations used in the illustration.

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New Price Structure for Gems & Gemology

Effective November 1, 1980, the Gemological Institute of America is changing the price structure for its quarterly Journal, *Gems & Gemology,* as follows:

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These increases are being made to reflect the major redesign of the Journal—expansion to an 8½ x 11" format, approximately 64 pages, with the regular use of color and the addition of several special sections. These changes will appear in the Spring 1981 issue.

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