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IN THIS ISSUE

Shedding Light On Ultraviolet

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Introduction

The intent of this article is to familiarize the reader with the following subjects:

I. Ultraviolet Light
II. Fluorescence and Phosphorescence
III. Ultraviolet Lamps
  A. Tubes
  B. Phosphors
  C. Filters
IV. Safety Precautions
V. Summary

I. Ultraviolet Light

The sun was the first source of ultraviolet radiation. Through thermonuclear reactions it emits a broad range of electromagnetic energy wavelengths including radio, infrared, visible light, ultraviolet, x-rays, and cosmic rays. The ultraviolet portion extends from x-rays at about 100Å to 4000Å where it merges with violet in the visible spectrum. Near or long ultraviolet wavelengths are those from 4000Å to 3200Å, medium waves are from 3200Å to 2800Å, and short waves are from 2800Å to 2000Å. Agreement is not universal as to the exact wavelength of these boundaries.

Wavelengths below 2000Å are absorbed strongly by air and none shorter than about 2950Å reach the earth's surface due to absorption by ozone in the atmosphere. Remaining solar ultraviolet rays up to about 3200Å may cause tanning or sunburn and vitamin D formation in the skin.

Early man-made sources of ultraviolet were usually powerful electric sparks produced between iron or carbon electrodes. Ultraviolet production was accompanied by much noise and visible light. Modern sources produce ultraviolet by an electric discharge through mercury vapor in argon gas or by discharges in xenon, hydrogen, or nitrogen gases. *Fig. 1* shows the range of wavelengths detected by the human eye and those reaching the earth's surface from the sun. Wavelengths are shown in microns, nanometers (nm), and angstroms (AU).

II. Fluorescence and Phosphorescence

Fluorescent response to ultraviolet light is recognized as a valuable test in the identification of many important gem materials. Small amounts of impurities such as chromium, manganese, and uranium, called activators, produce most of the fluorescence seen in minerals. In contrast, the presence of iron is known to reduce or prevent fluorescence.

Under the influence of radiation of the appropriate wavelength (appropriate energy), such as UV, some electrons in the activator atom will be raised to higher energy levels. These new levels, or orbitals, will accommodate the electron's higher energy state resulting from absorption of the UV rays. However, this condition is unstable and in most cases the displaced electrons return instantaneously to their original orbitals (the ground state).

Fluorescence, a visible emission of light, occurs as the returning electrons give up their excess energy. (Fluorescence can be an emission of any wavelength — x-ray, UV, or infrared, but it usually implies visible unless otherwise stated.) If the electrons returned directly, the light emitted would be of the same wavelength as the stimulating radiation absorbed and no fluorescence would result. Instead, the electron may return in steps, emitting, for example, infrared in the small step and visible light in the remaining step. The sum of the energies of the infrared and visible emissions will equal the energy of the ultraviolet absorbed. Synthetic ruby, activated by chromium, is a good example of this. See *Fig. 2*.

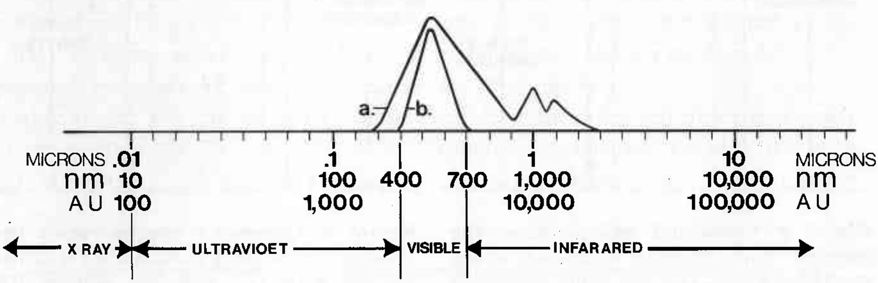

FIG.1

a. APPROXIMATE SOLAR RADIATION AT EARTHS SURFACE.
b. APPROXIMATE HUMAN EYE RESPONSE.

Figure 1.

Electrons may become temporarily trapped at an excited level in an "energy well." A small amount of additional energy is then needed to raise the electrons out of the "well" and allow them to return to the ground state. This additional energy may be supplied in the form of heat energy from the surrounding air. Electrons returning to their ground state may be delayed, as described above, for seconds, minutes, hours or even days. This delayed return causes a continued glow called phosphorescence. Synthetic ruby usually phosphoresces to x-rays while the natural does not, due to the presence of iron impurities. See *Fig. 3*.

III. Lamps

The lamps and tubes described below are of the "fluorescent" style and are representative of modern commercial equipment sold by companies such as Ultraviolet Products of San Gabriel.

There are three basic types of modern ultraviolet lamps: the "black light blue," the externally filtered long wave, and the externally filtered short wave.

BLACK LIGHT BLUE — This is the typical "black light" of psychedelic and theatrical fame. The filter is the purple glass from which the long wave tube is made, hence the name black light blue, which is abbreviated BLB on the tube. This is the most economical type but it is also the least efficient and emits considerable visible light. Maximum ultraviolet output is long wave at about 3660Å.

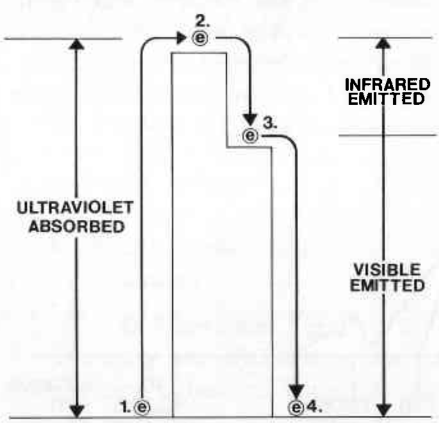

Figure 2. Ultraviolet energy raises the electron from the ground state (1) to the excited state (2). The first return step emits infrared (3), the second step emits visible light and returns the electron to the ground state (4). Longer steps (and shorter wavelengths) represent more energy. Thus, UV has more energy than visible light, which has more than infrared.

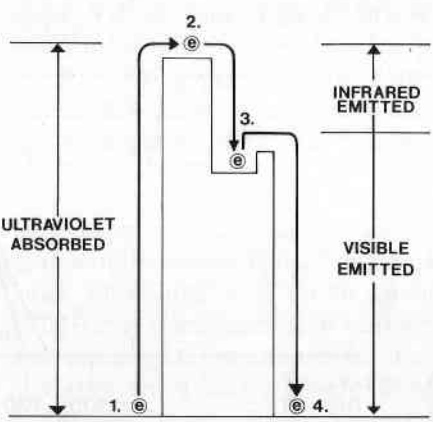

Figure 3. Ultraviolet energy raises the electron from the ground state (1) to the excited state (2). The first step of the return temporarily traps the electron in an "energy well" (3). The ambient air temperature supplies enough energy to raise the electron out of the "well" and make the final return step (4).

EXTERNALLY FILTERED LONG WAVE — This lamp uses a long wave tube and a separate filter which passes less visible light and is used in more critical applications. Maximum output is at approximately 3660Å.

EXTERNALLY FILTERED SHORT WAVE — This lamp uses a short wave tube and a separate filter which will pass short wave. A small amount of visible and very little long wave are also emitted. Maximum output is at approximately 2540Å.

COMBINATION LONG/SHORT WAVE — Some lamps are a source of both long and short wave. This may be accomplished in two slightly different ways. One is by using two separate tubes, one long wave and one short wave, in the same lamp with an external filter. The second is an interesting lamp containing one tube which is half long wave and half short wave. The external filter used in either case may be half long wave and half short wave or all short wave.

Long, short and combination wavelength lamps are available for AC and portable battery operation and in several powers, commonly 4, 6, and 8 watts total output. Units operated from an AC line contain a transformer which supplies the correct voltage to the tube. Portable units use 6 or 12 volt batteries and an inverter circuit to raise the voltage as necessary.

In most lamps the ultraviolet tubes have an approximate life of 5000 hours. Short wave filters have an estimated life of 500 hours and long wave filters last indefinitely.

A. Tubes

Short wave tubes must be made of quartz or a very pure silica glass to allow the transmission of short wavelengths. This is not necessary for long wave tubes and they can be made of ordinary glass. Both of these tubes are filled with argon gas at low pressure and contain a small amount of pure mercury which is present as small droplets in the tube. A wire heating filament at each end of the tube is used to vaporize the mercury which then conducts an electric current between the filaments. *See Fig. 4.* This electrical discharge stimulates the mercury vapor to emit certain characteristic wavelengths, the strongest of which is short wave ultraviolet at about 2540Å. This accounts for about 90% of all tube's output. The remainder consists of long wave UV, most at about 3660Å, and visible light concentrated at the wavelengths shown in *Fig. 5.*

B. Phosphors

The clear tube just described emits mostly short wave. To obtain a long wave source the clear tube is coated

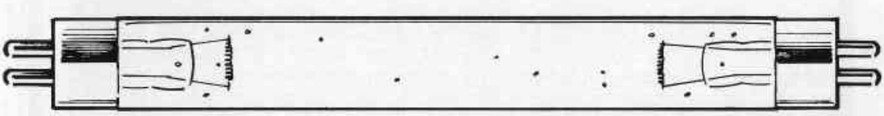

Figure 4.

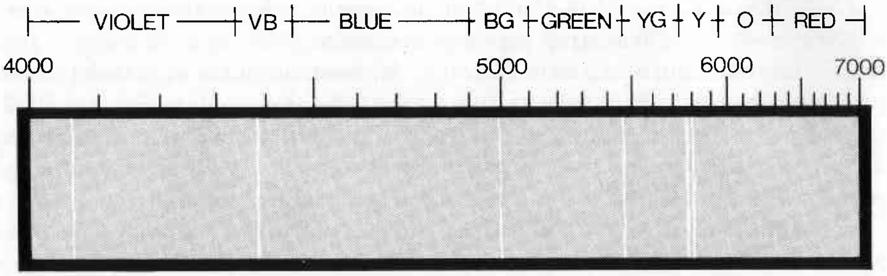

Figure 5.

inside with a special white phosphor. The phosphor absorbs the short wave (2540Å) energy given off by the mercury vapor and in return emits a longer wavelength (3660Å) ultraviolet. (You may recognize this as a type of fluorescence.) There are strong visible light emissions by the long wave (phosphor coated) tube concentrated at about the same wavelengths shown in *Fig. 5*.

A tube may be made half long wave and half short wave by coating only half of the tube. *See Fig. 7.*

An "ordinary" fluorescent light operates the same way except that the different phosphor coating used emits more visible light and far less long wave ultraviolet.

C. Filters

Ultraviolet filters are basically of three types: Long wave internal, long wave external, and short wave external.

The long wave internal filter is the tube itself which is made of a special cobalt filter glass. This tube absorbs much of the visible light emitted by the phosphor while passing the long wave through.

The long wave external filter is a special type of cobalt glass which transmits long wave while absorbing most of the visible light from the phosphor coated tube. Long wave filters will transmit ultraviolet in the range of about 3200Å to 4000Å and will last indefinitely.

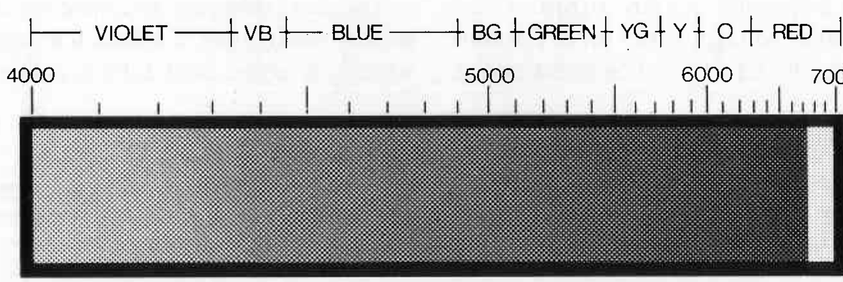

Figure 6.

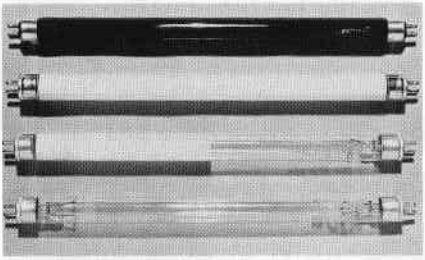

Figure 7.

The short wave external filter is used with an uncoated tube. It is an expensive cobalt mixture made with a glass-like texture and formulated to transmit short and long wave between approximately 2300Å and 4000Å. Short wave filters have a limited lifetime. Exposure to short wave affects the molecules in the filter causing it to become opaque to short wave. This process is called solarization. A solarized filter will still pass long wave and tends to pass more visible violet and blue.

The filter solarizes most quickly during the first 50 hours of use. The process then slows considerably and the filter has an estimated life of 500 hours. Short wave filters do not lose efficiency solely from age, but they may develop a white scaley coating with time. Thus a very old filter may be perfectly usable if it has not had too much use and does not have a heavy white coating. In his book *Ultraviolet Guide to Minerals*, Sterling Gleason claims some solarized short wave filters may be restored by a heating and annealing process.

Both long and short wave filters pass some red and violet visible light. A comparison of *Figs. 5 and 6* will show that the visible violet emitted by long and short wave tubes is passed by the filter while the other visible emission lines are absorbed. The heating filaments in the short wave tube may give off a visible red glow which is also passed by the filter.

IV. Precautions

For The Operator

"SUNBURN." Shortwave ultraviolet can injure unprotected skin and especially the eyes. NEVER allow short wave to reach unprotected eyes, even by reflection. Temporary or permanent eye damage can result. Eye glasses and most types of glass and plastic will stop short wave radiation.

ELECTRIC SHOCK. There are electrical hazards within the lamp due to the presence of high voltages. ALWAYS unplug the lamp before disassembling it.

For Stones

The color of some stones may fade with exposure to ultraviolet. Some zircon, heat treated yellow and pink topaz, kunzite spodumene, irradiated golden beryl, irradiated yellow sapphire corundum, and irradiated blue-green spodumene may react this way.

For The Lamp

To extend the life of the short wave filter, turn off the lamp when not in use. Do not turn on the lamp without a tube in place. This can cause damage to the electrical circuit, especially in battery operated lamps.

V. Summary

1. Short wave ultraviolet extends from 2000Å to 2800Å, medium wave from 2800Å to 3200Å, and long wave from 3200Å to 4000Å.

2. Many gem materials will absorb x-rays, ultraviolet, or visible light and emit visible light of a longer wavelength. This is fluorescence.

3. Mercury vapor, at low pressure and stimulated by an electric discharge, emits predominantly short wave ultraviolet at about 2540Å.

4. The white phosphor coating inside long wave tubes absorbs short wave and emits predominantly long wave ultraviolet at about 3660Å.

5. Short wave filters pass short and long wave ultraviolet from about 2300Å to 4000Å, plus some visible violet and red.

6. Long wave filters pass long wave ultraviolet from about 3200Å to 4000A, plus some visible violet and red.

7. Short wave lamps emit 2540Å ultraviolet, a small amount of long wave, plus some visible violet and red light.

8. Long wave lamps emit 3660Å ultraviolet and some visible violet.

9. Long wave ultraviolet is not harmful to the average normal human eye.

10. Short wave ultraviolet can burn the eyes and skin. It is absorbed by most common glass and plastic.

For non-critical applications or just for fun, try these:

11. Use an old (solarized) short wave filter as a long wave filter.

12. Use an ordinary fluorescent light, with any UV filter, as a source of long wave.

13. Use a "black light blue" long wave tube, or other tubes with appropriate filters, with an inexpensive battery operated fluorescent camping lantern.

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Developments and Highlights at GIA's Lab in Santa Monica

By RICHARD T. LIDDICOAT, JR.
and
CHUCK FRYER

Notes On Diamonds

Occasionally we encounter diamonds with the so called "sugar cube" inclusion. This type of inclusion, shown in *Fig. 1*, is seen in stones from Sierra Leone.

Fig. 2, taken at 12X magnification, shows an inclusion in a diamond that one of our staff gemologists, a former professor of oral pathology, says reminds him of a molar. *Fig. 3* shows the same inclusion at 63X. What appears to be doubling of the facet edges and the inclusion is actually the

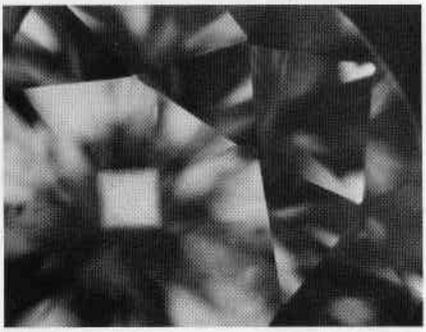

Figure 1.

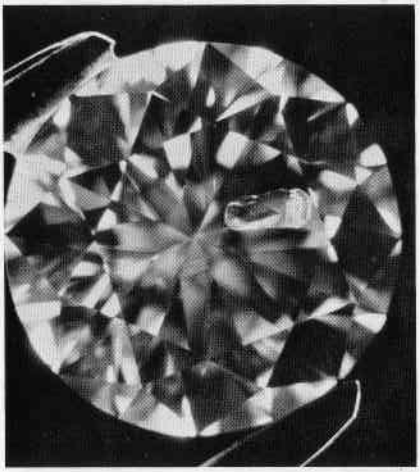

Figure 2.

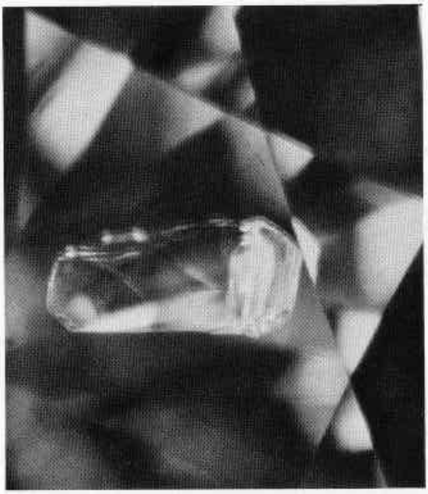

Figure 3.

result of inadvertent camera movement during the time exposure.

The table of the diamond pictured in *Figs. 4 and 5* shows a report number, the weight of 0.40 ct., a clarity grade of VS_1, Color G, finish good, sintered on the surface of the stone. We had seen this done by the Japanese before, but the markings were so small, a magnification of at least 200X was necessary to reveal them. The remarkable thing about this stone is that the writing can be seen at only 10X, as in *Fig. 4*.

A treated diamond was observed with a very unusual color that could only be described as grayish green and blue. Basically the color seemed to be a gray green but when viewed through the girdle a very distinct concentration of blue was observed at the girdle edge and the culet areas of the stone.

Colored Stones In The Laboratory

Every so often we get in a ruby or sapphire that has a surface looking like that shown in *Fig. 6*. This etching occurs when a jeweler performs some prong repair work or sizing on an item without removing the corundum from the setting. When the repair has been completed the item is then put into hot pickle solution to clean up the soldered joint. Corundum is soluble in borax and since most pickle solutions contain borax, the etched surface of the stone results. The moral of the story is to always remove a corundum from the mounting before repair or pickling.

Figure 4.

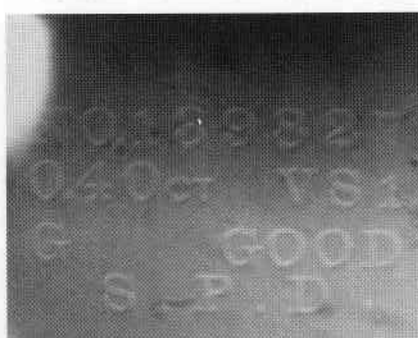

Figure 5.

Figure 6.

Another garnet with a strong color change, from greenish-blue to purplish red, recently came into the lab. The absorption spectrum revealed strong bands at 4150Å and 4350Å as well as a broad absorption from approximately 5100Å to 6300Å. The type of spectrum observed, along with the 1.76 R.I., would indicate the stone is a combination of the spessartite and pyrope end members in the garnet group. Our research department checked the chemistry on the energy dispersive unit of their SEM (Scanning Electron Microscope) and found Magnesium (Mg), Aluminum (Al), Silicon (Si), Manganese (Mn), Iron (Fe), Calcium (Ca) with traces of Vanadium (V) and Chromium (Cr). This would confirm our interpretation of the absorption spectrum and provide evidence that small amounts of grossularite and almandite were also present. The traces of vanadium and/or chromium are probably responsible for the color change of the stone.

We occasionally get in some large objects which present special problems in identification. *Fig. 7* shows one panel of a screen measuring 6 ft. high by 16 inches wide. The designs visible in the three sections of the panel are made up of bas-relief carvings applied to the background. Problem — identify the material of the carvings. Obviously specific gravity, refractive index, etc. the normal gemological tests could not be used. A minute amount of powder was scraped from the bottom of the

Figure 7.

gown on the carved oriental figure with flute on the right in the middle section. X-ray diffraction proved that at least this figure was carved from serpentine, not nephrite jade as represented to the client by the dealer in Hong Kong.

We received a 0.88-ct., near colorless round faceted stone from a student asking us to confirm the identity as Stibiotantalite. He had never seen nor heard of this material being as nearly colorless as was this stone. A hydrostatic density test was run, showing the S.G. to be approximately 7.33. Due to the inclusions, an optic figure could not be resolved. Some of the tubelike inclusions extending from the surface into the stone are shown in *Fig. 8*. The amount of doubling visible in the stone seemed to be consistent with the 0.83 birefringence of Stibiotantalite. An examination with the energy dispersive system of our SEM in the research department showed the presence of Antimony (Sb), Tantalum (Ta) and Niobium (Nb), confirming the identity.

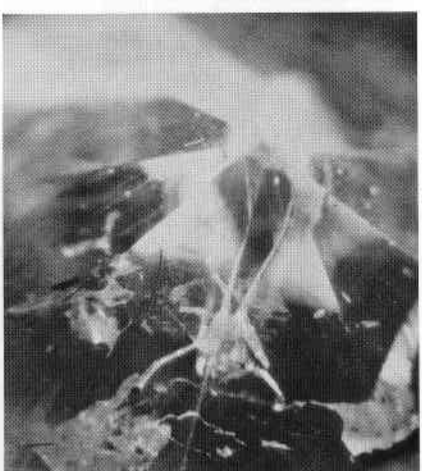

Figure 8.

The Rarest of the Rare

There are perhaps only 10 or 12 known Taaffeites in the world. All of these stones have been of the same lilac color. We have just encountered a very fine sapphire-blue stone of 3.34 cts. which has been confirmed by x-ray diffraction to be Taaffeite. The properties of this stone are: R.I. 1.718 - 1.722, birefringence of .004, uniaxial negative and a S.G. of 3.59. The absorption spectrum is shown in *Fig. 9*. The stone was found in a parcel of blue sapphires that were reputed to be heat treated, so there is a possibility that the color may be the result of heat treatment. Which of you Taaffeite owners will be the first to volunteer your stone for the great heat treatment experiment?

A 2.10-ct. oval mixed cut showed a slight color change from grayish-green in daylight to a very faint reddish overtone on the green color in incandescent light. In our opinion, the change was not strong enough to warrant calling the stone Alexandrite, had it been chrysoberyl. The stone showed strong twinning in the microscope (see *Fig. 10*), very similar to the twinning often seen in chrysoberyl. However, the R.I. was approximately 1.76 - 1.77 with a uniaxial reaction when the stone was rotated on the hemicylinder. Due to the twinning, no optic figure could be resolved in the polariscope. The absorption spectra showed a 4500Å,

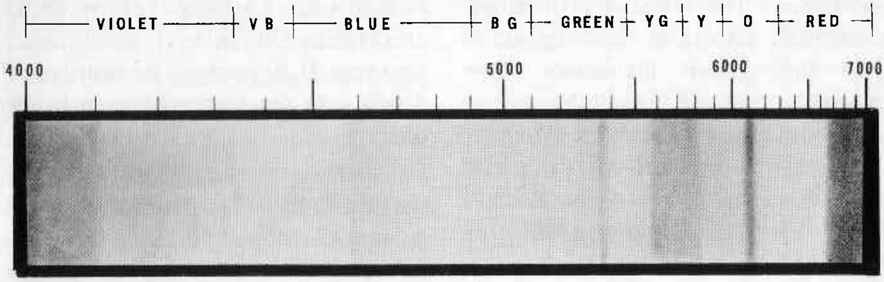

Figure 9.

4600Å, and weak 4700Å line, confirming the identity as natural sapphire. We do not recall seeing a sapphire of this color with such apparent twinning before.

We recently encountered a bright mottled green cabachon with dark green and brown inclusions. (See *Fig. 11.*) The R.I. of approximately 1.57 obtained by the spot method, a heavy liquid S.G. determination of approximately 2.75 and a reddish fluorescence to short wave ultra-violet light suggested a feldspar in spite of the color. Since we had not encountered feldspar of this color before, we scraped a little powder from the edge of the stone for x-ray diffraction analysis. The resulting pattern of the material almost exactly matched the pattern of anorthite. The SEM microprobe in our research lab was utilized to analyze the stone as well as the brown and green

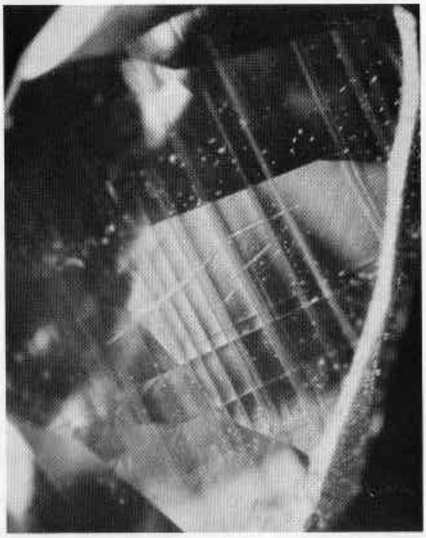

Figure 10.

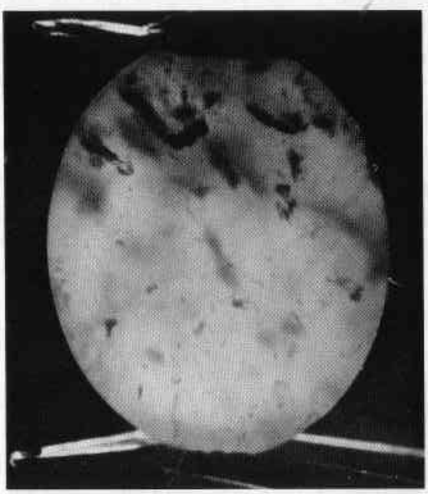

Figure 11.

inclusions. The chemistry obtained confirmed anorthite and suggested that the brown inclusions were probably titanite and the green inclusions uvarovite garnet. A scraping was made on one of the green inclusions that reached the surface and the diffraction pattern proved it to be uvarovite.

We wish to express our sincere thanks for the following gifts and courtesies:

To the *Asian Institute of Gemological Sciences,* Bangkok, Thailand, for 131 carats of heat treated synthetic blue sapphires to enrich our student test sets.

To *A. C. Bellanca*, Los Angeles, California, for a suite of East African tourmalines weighing 21.79 carats, to be used in displays and research projects.

To *Delano R. "Dee" Brister*, The Earth's Treasures, Sierra Vista, Arizona, for 112.17 carats of Bytownite (feldspar) that will be studied by our students and research staff.

To *Jerry Clark*, Fallbrook, California, for an assortment of 25 mineral specimens, including examples of Brazilian aquamarine and tourmaline, so that our students can learn to appreciate crystal forms.

To *David E. Cordoba*, Rancho Palos Verdes, California, whose gift of fourteen faceted gems includes a sphalerite (17.42 carats), all to enhance our display collection.

To *Diablo Gem Collections, Ltd.*, Walnut Creek, California, for an exceptional crystal of natural alexandrite chrysoberyl, weighing an amazing 51.81 carats, to beautify the displays in the Santa Monica headquarters.

To *Cheryl and Tom Fletcher*, Goleta, California, for 46.25 carats of green tourmaline exhibiting the cat's-eye effect, which will be used in our student study sets.

To *Pete Flusser*, Overland Gems, Culver City, California, who has donated 30.65 grams of rough garnet to be studied by our gem identification students.

To *Pete Flusser and Howard Gendler,* Overland Gems, Culver City, California, for 30.65 grams of rough Malaya garnet, a grossularite garnet of 1.59 carats, and 6.31 carats of African oilite, all to be used in the research and student study stone collections.

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To *David A. Gleason, III,* New Orleans, Louisiana, for his generous gift of a rubellite tourmaline (26.72 carats) and a golden beryl (9.94 carats) to beautify our gemstone displays.

To *Hulette P. Gleason,* New Orleans, Louisiana, for a selection of imperial topaz weighing 15.45 carats, 11.31 carats, and 7.19 carats, all to be displayed in the headquarters offices.

To *Garry W. Helm,* Darwin, Australia, for several samples of Zebra

Rock to be studied by our research department and students.

To *Mary and Daniel Henkin*, Elkhart, Indiana, who have enriched our display and research collections with complete color suites of corundum, garnet, and tourmaline; and for the diamonds used in the master set and study collection for the third team in the rapidly growing One-Week Gemology program.

To *Donald L. Herrick*, Dallas, Texas for a distinctive collection of faceted amethysts that weigh a total of 2286.81 carats, to be used in our displays and student identification sets.

To *Glenda S. King,* New Orleans, Louisiana, whose donation of a chrysoberyl (8.95 carats) and a pear shape brazilianite (5.30 carats) will be enjoyed as a part of our displays.

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To *John F. Meacham*, Long John Silver, Ltd., Victoria, British Columbia, Canada, for a copy of *Jade in Canada* to add to our library.

To *R. M. Mead*, Bisbee, Arizona, for a 3.07-carat cabochon of azurmalachite to become a part of our displays.

To *Dr. Michael Meftah,* Columbus, Ohio, for his kind donation of a superb faceted kunzite weighing 536 carats, which has attracted many visitors to our display cases.

To *Michael M. Menser,* Buchroeder's, Columbia, Missouri, whose gift of a variety of gems will be used in the student testing sets for the latest addition to the gemology program in residence.

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To *Fred Nakamura*, Long Beach, California, for a selection of fine gems including a 2.67-carat andalusite and a 10.07-carat chrysoberyl to augment our displays.

To *Pedro J. Obregon, M.D.*, Columbus, Ohio, for a 3.20-carat diamond surrounded by four 0.08-carat diamonds in a white gold setting, to be studied by the students in the Applied Gemology section of the Resident program.

To *Jose Guillermo Ortiz*, Colombian Emeralds Company, Bogota, Colombia, for an outstanding example of an emerald crystal in matrix so that our students can appreciate the crystal in its natural setting.

To *Ron Pingenot*, Tejon Gallery, Ltd., Denver, Colorado, for two quartz crystals that are half amethyst and half citrine in color, which will be exhibited to the students in our classes.

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To *W. B. Scholefield,* Los Angeles, California, for a 18.18-carat yellow scapolite, and 25.25 carats of tourmalines in assorted colors to supplement the display collection.

To *Mrs. O. L. Yeater,* Orange, California, for a selection of gems including a 1.30-carat mauve scapolite, a 1.15-carat sunstone, and a fiery opal of 20.65 carats, to be utilized in the study and display collections.

To *Judge Pearce Young,* Beverly Hills, California, for a spectacular array of twenty Mozambique tourmalines. These gems will form an important part of our display collection.

To *Clara T. Younger, M.D.*, Cypress, California, for two apatites (mauve, 2.33 carats, and yellow, 17.65 carats), a 1.61-carat idocrase, a 5.42-carat opal, a 2.73-carat tanzanite, and a 19.40-carat blue topaz, all to be appreciated in our displays.

FLUID INCLUSIONS

Hidden Trouble for the Jeweler and Lapidary

By JOHN I. KOIVULA
Mineralogist — Gemologist
Gemological Institute of America
Santa Monica, California

Jewelers using the torch near a gemstone mounted in a piece of jewelry and lapidaries in the process of dopping a gem have at times experienced the fracturing of a stone even though great care was taken in bringing the gemstone carefully and uniformly up to the working temperature. In a great many of these cases the culprit responsible for the destruction of the gem is a minute, almost invisible, fluid inclusion. A basic understanding of fluid inclusions and the way they react to heating, coupled with a quick examination under the microscope could save many gemstones from an untimely fate. In the process, the jeweler or lapidary could be saved from almost certain embarrassment, or worse.

With the probable exception of diamond, fluid inclusions can occur in virtually every crystalline gem mineral of natural origin that the jeweler or lapidary is likely to encounter. As a gem crystal grows at a specific temperature and pressure, a negative crystal may begin to form on its growing surface. As the negative crystal forms, it is filled with the growth fluid at the temperature and pressure of growth. As the gem crystal continues to grow, it may seal off the fluid filled negative crystal which would then become a closed system.

As the crystal cools, the fluid that completely filled the negative crystal at the higher growth temperature begins to contract. As it contracts in the closed system of the negative crystal, it no longer fills the cavity, and a contraction bubble of vaporized liquid appears to fill the void. The bubble gets larger as the crystal gets cooler. We now have what gemologists refer to as a two-phase inclusion, as the negative crystal now contains two states or phases of matter, liquid and gas. In addition, if any salts have been dissolved in the liquid at a higher temperature (salts like sodium chloride [NaCl — common table salt] or potassium chloride [KCl] etc.), they may now crystallize out of solution at the lower temperature provided their concentration in the fluid is high enough. The result will be a solid crystal in the same void with the liquid and gas. We have added a third phase or state of matter and we now have a three-phase inclusion. Just as a drop in temperature caused the formation of the gas bubble, and if present, the solid crystal, a rise in temperature will cause the crystal to go back into solution and will cause the bubble to be resorbed back into the solution by virtue of the expansion of the liquid.

The disappearance of the vapor bubble is the critical step. We know from the physics of liquids that they are virtually incompressible. Therefore, once the bubble, which acts as a thermal shock absorber for the gemstone, disappears, a tremendous amount of pressure builds very rapidly. If the gemstone is subject to a further rise in temperature once the critical temperature at which the fluid fills the cavity has been reached, damage will be the unavoidable end result.

Many of us believe that gem crystals form at temperatures much higher than we would ever subject a stone to in the course of normal repair or lapidary work.

This, however, is not always the case. Some of the fluids filling these voids are very sensitive to heating, and have been known to fracture a gemstone when subjected to as little heat as is generated by the light bulb in a microscope stage.

The following paragraphs taken from a letter written in 1835 by the English Physicist, Sir David Brewster to Sir Walter Scott indicate the heat sensitive nature of some of these fluids.

"When the gem which contains the highly-expansive fluid is strong, and the cavity not near the surface, heat may be applied to it without danger, but in the course of my experiments on this subject, the mineral has often burst with a tremendous explosion, and in one case wounded me on the brow. An accident of the same kind occurred to a gentleman, who put a crystal into his mouth for the purpose of expanding the fluid. The specimen burst with great force and cut his mouth, and the fluid which was discharged from the cavity had a very disagreeable taste."

"In the gems which are peculiarly appropriated for female ornaments, cavities containing the expansible fluid frequently occur, and if these cavities should happen to be very near the surface or the edge of the stone, the fever heat of the body might be sufficient to burst them with an alarming and even dangerous explosion. I have never heard of any such accident having occurred; but if it has, or if it ever shall be heightened by any calamitous results, the phenomena here described will strip it of its wonder."

The following series of six photographs taken at 100X magnification illustrate in vivid detail the destruction of a quartz crystal caused by the heat induced expansion of its fluid inclusions. The fluid in this case is a highly viscous yellow colored oil (Petroleum) that stands out readily against the much lighter background of the quartz crystal host. The oil is somewhat sensitive to heating, but not nearly as sensitive as a fluid like liquid carbon dioxide, which is one of the more common fluid inclusion fillers.

In *Fig. 1*, we see the fluid chamber

at room temperature containing the oil and one large vapor bubble. The bubble appears to occupy approximately ten percent of the total volume of the inclusion at this temperature.

In *Fig. 2*, at room temperature there are now two smaller bubbles in the oil occupying the void. These were formed by slowly heating the inclusion until the oil completely filled the chamber. Then the inclusion was allowed to cool quickly. Due to the length to width ratio of the void (14 to 1) and the highly viscous nature of the oil, more than one gas bubble formed in the chamber as the volume of the oil quickly shrunk on rapid cooling.

Fig. 3 illustrates this same inclusion with three distinct bubbles present.

Fig. 4 shows the fluid chamber completely filled by the oil. Note that the background inclusions still contain gas bubbles.

Fig. 5 was taken only seconds later. Pressure and strain in the host quartz is building rapidly at this point and the inclusion is close to the critical state. Notice that the bubbles in the background inclusions have now disappeared.

Fig. 6 shows the host quartz after explosion of the main oil filled inclusion. Note the large fracture that has occurred. Although very small, this inclusion produced an easily audible cracking sound when it exploded. The approximate temper-

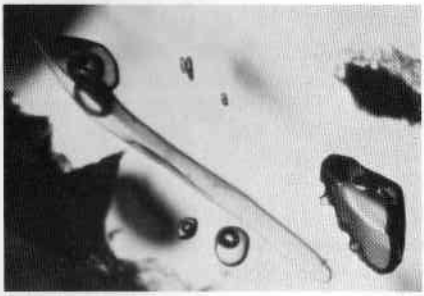
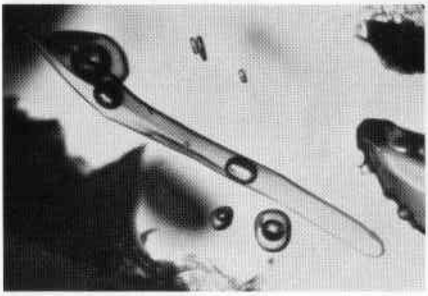


Figure 1.



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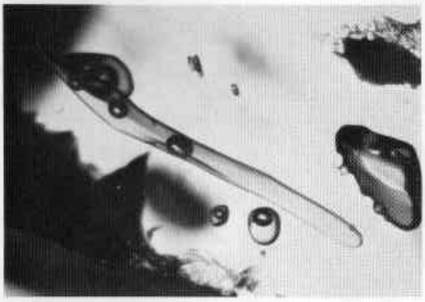

Figure 3.

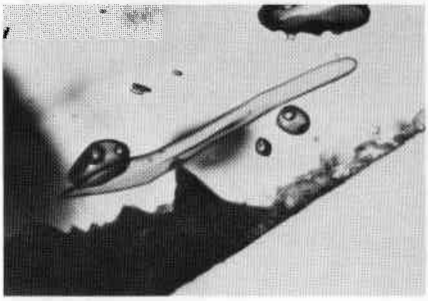

Figure 4.

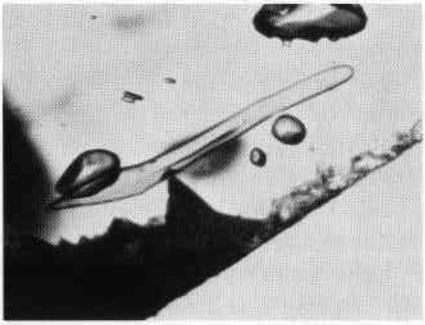

Figure 5.

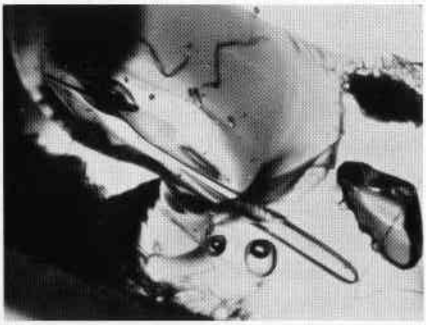

Figure 6.

ature at the time of explosion was 130° C (266° F) which is well within the temperature range of a jeweler's torch.

An inexpensive rock crystal quartz was used in the above experiment. It should be noted, however, that the same results could be obtained using much more costly gemstones like beryl, tourmaline, corundum and topaz.

Acknowledgement

I would like to thank D. Vincent Manson, Ph.D., Director of the Research Department at the Gemological Institute of America, for his critical review of this manuscript.

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Developments and Highlights at GIA's Lab in Los Angeles

By ROBERT E. KANE

During recent months at the Los Angeles laboratory we have encountered some very interesting inclusions in some of the diamonds submitted to us for grading. Some unusual crystals were seen in the round brilliant diamond shown in *Fig. 1.* This particular stone contained a large number of tetrahedral crystals in definite planes interspersed throughout most of the diamond. What cannot be accurately conveyed with a photograph is the three-dimensional nature of these odd inclusions. They were composed of three equal sides and a base.

The round brilliant shown in *Fig. 2* had an interesting feature. This diamond had numerous rounded crystals that resembled flux or elongated gas bubbles.

Another diamond that had an unusual inclusion is shown in *Fig. 3.*

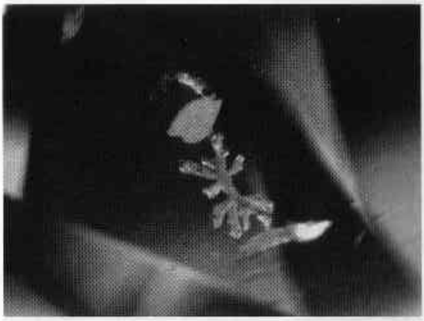
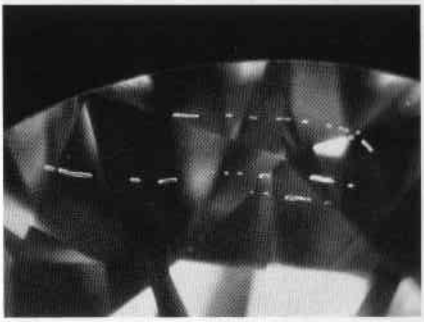


Figure 3.

Figure 1.



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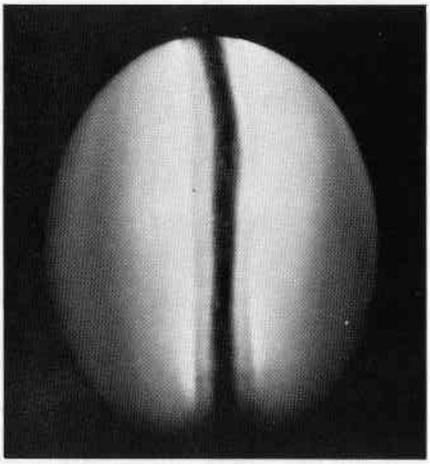


Figure 4.

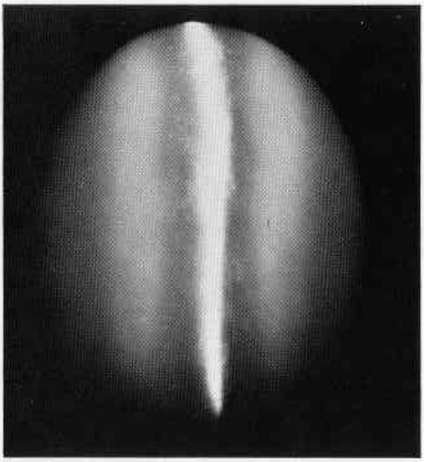


Figure 5.

This inclusion had a dendritic appearance which is somewhat rare in diamond.

Imitation Cat's-Eye

Recently we had the opportunity to examine a rather fine glass and fiber optic cat's-eye imitation. This material had a refractive index over the limits of the refractometer. The specific gravity was 4.20. The stone was inert to short wave and long wave ultraviolet light. To the unaided eye this semi-translucent brownish-yellow stone had a silky appearance and exhibited an extraordinarily sharp eye, almost too sharp. This stone's appearance had a remarkable likeness to the "milk and honey" effect seen in a fine-quality cat's-eye.

When this material was revolved under two overhead light sources, the opening and closing of the eye was exhibited very well *(Figs. 4 and 5)*. When viewed from the side over a light source, the stone was transparent and near colorless as is exhibited by *Fig. 6*. When it was examined under magnification a "honeycomb-like" hexagonal structure was shown *(Fig. 7)*. Each larger hexagonal area contained hundreds of small hexagonal fibers *(Fig. 8)*. These fibers are the cause of the chatoyancy. The darker colored areas in *Fig. 8* are the fibers that cause the color in the stone.

Fish Shape Brilliant

Quite recently a client requested an Origin of Color on his very unusually cut fish shape brilliant diamond *(Fig. 9)*. This stone had 17 pavilion facets and 22 crown facets. It was a rather pleasing color, fancy pinkish-violet of natural origin.

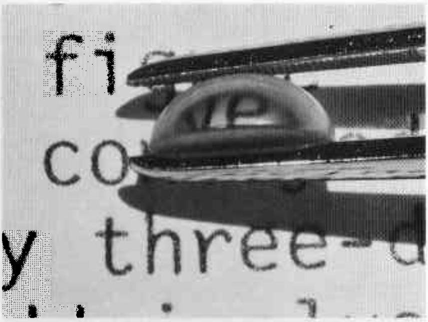
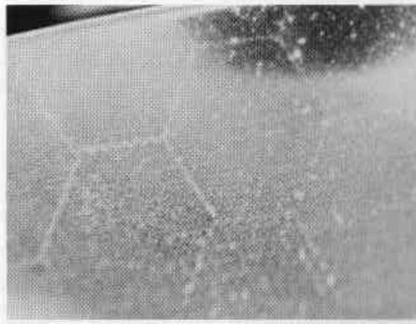


Figure 6.



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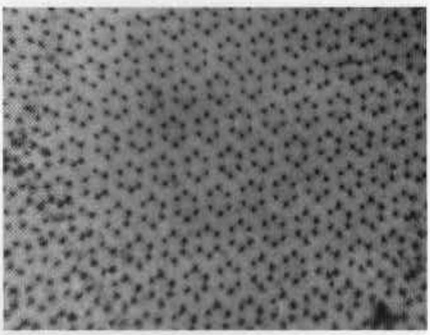

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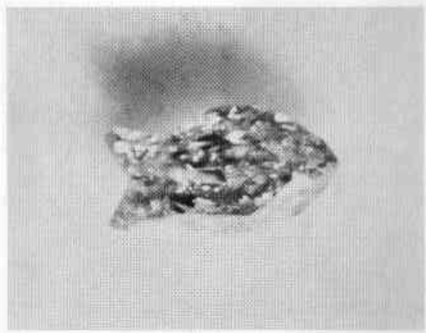

Figure 9.

Rutile in Emerald

Recently the Los Angeles laboratory received for identification a transparent green rectangular step cut. This stone was identified as emerald by its refractive indices and rich chromium spectrum. When examined under magnification the interior of this gemstone proved it to be of natural origin. The interesting feature of this natural emerald was that it contained numerous randomly oriented yellowish-brown needles, presumably rutile, rare in emerald *(Fig. 10)*.

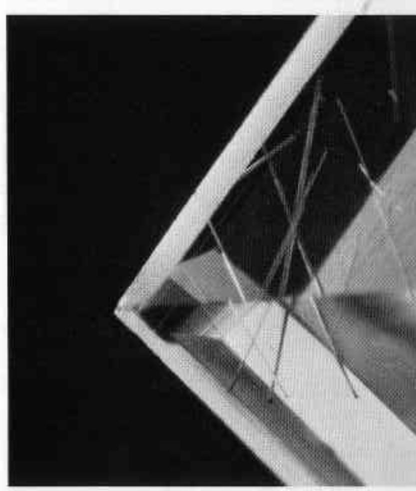

Figure 10.

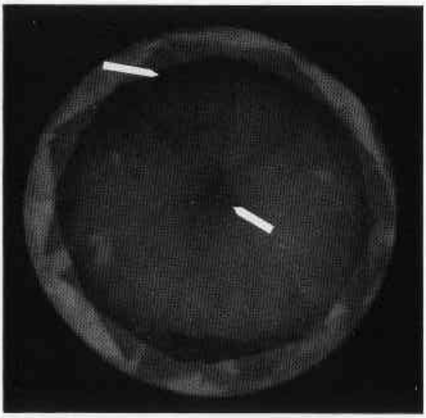

Figure 11.

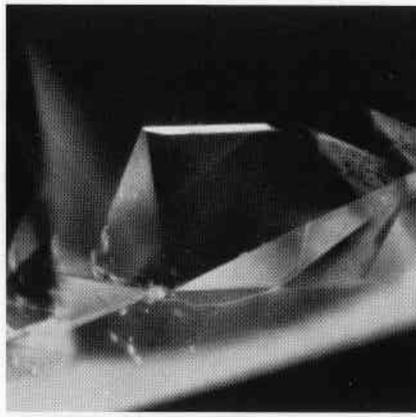

Figure 12.

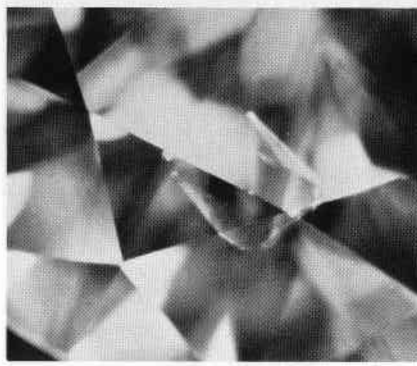

Figure 13.

Unusual Fluorescence

When we were checking the long-wave ultraviolet fluorescence of a round brilliant diamond, an unusual occurrence was noted. When this diamond was viewed table-down, it exhibited a very strong blue fluorescence overall, with a very strong yellow fluorescence outlining the inside of the table and around the culet. This is indicated by the arrows marking the darker areas of the diamond shown in *Fig. 11*.

Large Well-Formed Knot in Diamond

Recently we examined a rather large knot in a 1.50-carat round brilliant diamond. The staff at the Los Angeles laboratory has seen many large knots in diamonds before. This, however, was one of the few occasions where we have seen such a prominent and well-formed octahedral knot. When this diamond was viewed from the pavilion, we observed that approximately one half of an octahedron had become "captured" in this round brilliant diamond *(Fig. 12). Fig. 13* shows how this inclusion appeared when viewed from the crown.

Large Natural

In *Figs. 14 and 15* an extremely large and deep indented natural is shown. Note the almost perfectly shaped trigon in *Fig. 15*. Except for this large natural it was a rather clean diamond. As the price of diamonds

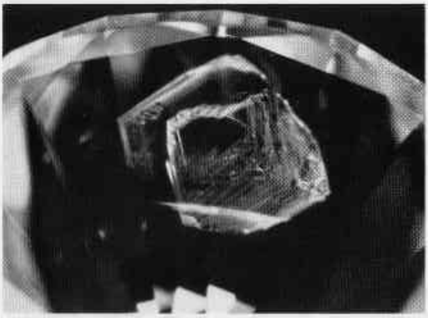

Figure 14.

Figure 15.

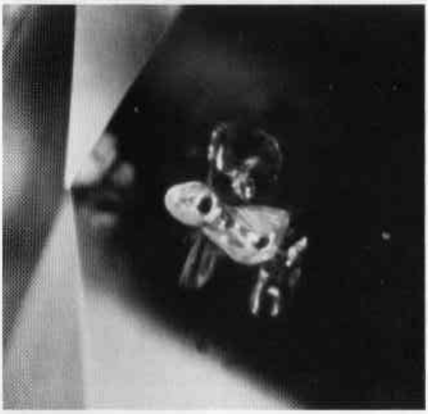

Figure 16.

Figure 17.

continues to increase, we will probably see more examples of extreme weight retention from the rough.

Nature's Art in Diamonds

Seen in *Fig. 16* are two included diamond crystals with feathers that make up an inclusion that looks very much like a honeybee in flight. When this round brilliant diamond was viewed at certain angles, the included diamond crystals had an intense yellow color. The inclusion shown in

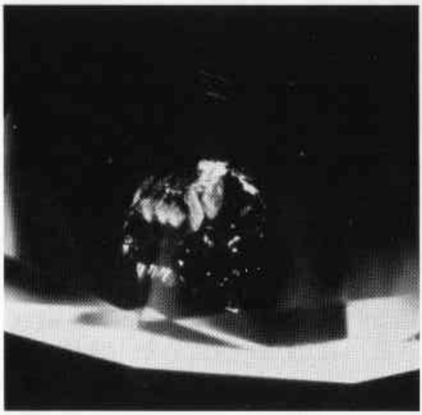

Figure 18.

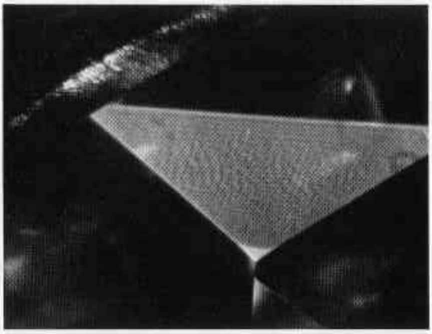

Figure 19.

Fig. 17 is reminiscent of a fly fisherman's lure. *Fig. 18* shows a group of inclusions that form an arrangement resembling a strawberry.

"Lizard Skin" Polish

Fig. 19 is a photomicrograph of "lizard skin" polish viewed under reflected light. This type of polish is also referred to as "steplike polish" by some diamond cutters. This effect occurs when a particular facet is parallel to or almost on an octahedral face, and is caused by the extreme hardness of the octahedral face.

Acknowledgements

We wish to express our sincere thanks to GIA student *Max Cohen* for the gift of a Lechleitner "overgrowth" emerald. This stone will make a fine addition to our reference file.

We would also like to thank *Michael R. Havstad* of Gem Media for the excellent photographs seen in *Figs. 4, 5, and 6.*

All other photographs by Robert E. Kane and Shane F. McClure.

GEMLURE
Opal: Smolder of Fortune?

By CHERI LESH

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". . . he flirted on her beautiful forehead a drop or two of the moisture which remained on his own hand. The opal, on which one of these drops had lighted, shot out a brilliant spark like a falling star, and became the instant afterwards lightless and colourless as a common pebble, while the beautiful Baroness sunk on the floor of the chapel with a deep sigh of pain. All crowded around her in dismay. The unfortunate Hermione was raised from the ground, and conveyed to her chamber; and so much did her countenance and pulse alter, within the short time necessary to do this, that those who looked upon her pronounced her a dying woman."[1]

It seems hard to believe that the fantastic passage quoted above could cast a shadow of suspicion over the opal's sparkling fires. Yet this unwarranted reputation as a gem of ill-luck has dogged the opal for more than a century, and the myth seems to have derived largely from Sir Walter Scott's novel, *Anne of Geierstein: or The Maiden of the Mist,* published in 1831. In this book, the mysterious damsel Hermione, "a doctor of theology in the dress of an Eastern dancing girl,"[2] appears before the Baron of Arnheim under extraordinary circumstances. Scott describes this apparition in minute detail, paying particular attention to her headdress; "she wore no turban or headdress of any kind, saving a blue riband drawn through her auburn hair, and secured by a gold clasp, the outer side of which was ornamented by a superb opal, which, amid the changing lights peculiar to that gem,

[1]Scott, Sir Walter, *Anne of Geierstein: or The Maiden of the Mist,* Boston, Bazon & Ellsworth, 1831.

[2]Ibid.

displayed internally a slight tinge of red like a spark of fire."[3]

However, in context, it is quite obvious that this opal is no ordinary opal, just as Hermione is no ordinary Persian woman. This is a tale of bewitchment, and Hermione's opal, which glowed with its own rather than with reflected light, bears no more relation to actual opals than a unicorn does to a Shetland pony.

Some believe that Scott modeled the opal in *Anne of Geierstein* after a magnificent, large opal which Napoleon presented to Josephine. The play of color in this jewel was so intense that Napoleon called it, "The Burning of Troy." Perhaps Scott did deliberately make an evocative analog to that gem, playing on the British dislike of anything French — particularly anything related to a French Emperor who had sworn to master the world!

Regardless of Sir Walter's feelings toward the French, there is no evidence to suggest that he meant to slander opals. While Sir Walter Scott was, in the style of his day, a bit didactically moral, he had a great love of beauty. He would not have wanted to impugn such a beautiful stone as the opal, and such was certainly not his intent. Writers deal in metaphor the way jewelers deal in actual gems; it is their livelihood. Only a very literal reading of *Anne of Geierstein* could produce an aversion to opals. Scott wanted a talisman which would symbolize the inner fires and changeable passions of his elfish and elemental anti-heroine.

[3]Ibid.

Since mood rings had not yet been invented, his artistic quest for an appropriate symbol fell upon the opal. It was a logical choice; several varieties of opals are indigenous to Scotland, so it was undoubtedly a stone he was familiar with. However, the occult image conjured by the Baroness Hermione and her ever-changeable gem were supposed to be due to a peculiar circumstance of enchantment, not to any inherent quality of the opal itself.

Once this superstition regarding opals has been demystified and explained, few consumers will retain any uneasy feeling towards them. The tradition which honors the beauty and good fortune of opals encompasses at least 3,000 years and many different cultures. The Aztecs and Incas introduced their variety of opal to the Spaniards, who noted that the peoples of these ancient civilizations held the opal in higher regard than any other gem except for jade. In Indonesia, opal is known as "The Royal Gem of Java" and also as "The Queen" and is considered a sign of royal blood. The ancient Greeks and Romans revered the opal above all other gems except the emerald. According to Orpheus: "On Olympus the opal was the delight of the Immortals, so fair to view that it charmed the strong eye and strengthened the weak."[4] The Greeks held the opal to be sacred to Aphrodite, the Goddess of Love, and the Romans also valued it as the

[4]Leechman, Frank, *The Opal Book*, Sydney, Australia, Ure Smith, 1961.

badge of Venus and her cherubic child Cupid.

It is true that the opal presents an irresistible allure as a lover's token. It has already been mentioned that Napoleon chose an opal as a bond of affection between himself and his Empress Josephine, and he considered that stone so inherently romantic that he nicknamed it "The Burning of Troy," evoking memories of Helen and Paris, those star-crossed lovers of the past. History tells us that Mark Anthony coveted a ring belonging to Senator Nonius, which contained an opal the size of a hazelnut. Mark Anthony wanted the ring to give to Cleopatra, as a token of his ardent passion. When Nonius refused to sell him the ring, Anthony flew into a rage, and retaliated by ordering Nonius' death and the confiscation of all his property. Nonius had to flee from Rome so abruptly that he could take only the clothes he wore — and the opal he valued so highly. Nonius apparently lived happily ever after in exile, while Mark Anthony met defeat on the sands of Egypt to the forces of Octavian. Various historians have confirmed their culture's belief in the luck and virtue of these gems. Pliny, who related the story of Nonius, called opal a gem of incomparable beauty and elegance. B. de Boodt (1647) acknowledged it as the most beautiful of gems, and Dutens (1779) shared that opinion and said that in his time, opals were valued as high as diamonds. Ure (1853) confirmed this evaluation, saying, "In modern times fine opals of moderate bulk have been frequently sold at the price of diamonds of equal size: the Turks being particularly fond of them."[5]

The mass hysteria accompanying the Black Plague in Europe caused the opal to fall into temporary disrepute. Many in the Middle Ages sought to appease an angry God by destroying all the "devil's vanities" such as statues, pictures, jewels, fine clothing, anything they possessed of artistic and aesthetic value. The 'bad luck' of the opal, then, was simply linked to the fact that it was an object of great beauty! Since theology of the time dictated that the glories of the earth were a snare and a delusion, Satan's web spun to trap unwary mortals, a gem of incomparable beauty like the opal attracted much suspicion. To the medieval mind, the world was a horrific place populated by unseen demons and strange hosts of evil: demonic possession was nine-tenths of the lawless. Even the Victorians shared the medieval distrust of earthly pleasure. The faddish superstition which arose in connection with the publication of *Anne of Geierstein* was probably the result of a prudish Victorian sensibility which eyed the sensual glories of the world with doubtful qualms. Queen Victoria herself considered the opal's inner fires an aesthetic virtue, devoid of more sulphurous connotations. She stoutly defended the opal's reputation, and instituted a royal custom of giving the sparkling gems to her daughters on the

[5]Ure, *Dictionary of Arts, Manufacturing and Mines*, New York, 1853.

occasion of each of their marriages in an attempt to allay the public's empty fears.

For those souls brave and rational who dismiss the whisperings of the timid, the rewards of opal are many. For those who want a gem which is as individualistic as they are, opal is ideal. Opal comes in many varieties, enough to suit every personality and preference. There is the pin fire, a needlepoint rainbow; the harlequin opal with its jester's patchwork of color; the flash opal with its moving bands of light; the abanderado opal with its ribbons of fire. From Mexico, there is the unique water opal which they term "illusivisnando" which is as transparent as a raindrop but with the full spectrum of the rainbow glinting within like a crystallized tear of the sun.

The basic body hue of opals also covers the full range of the rainbow, from the milk opal with its creamy white background to the mysterious black opal which sometimes shimmers with rare tints of indigo and violet. Orange, peach, salmon, honey, cherry, beige, turquoise, peacock or cloudy blue, the opal shows a thousand faces, with plays of color ranging from volcanic fires to the northern lights. Whatever the customer's desire, an opal can be found which will suit almost any requirements for shade or style.

The opal is a stone of incomparable warmth and loveliness, rife with lover's symbolism. The diamond's chaste white flame may be forever, but the pulsing hearthfires of the opal speak more eloquently of passion. It is an ideal love token for trysts and engagements.

Another favorable aspect of opals is that each one is unique. A handful of one-carat diamonds may each have a distinctive 'fingerprint' revealed by a gemprint machine, or may be distinguished by a trained gemologist with a microscope, but they are dazzlingly alike to the prospective buyer. The opal's individuality can be easily detected by the layperson wanting a distinctive gem, and this uniqueness makes it even more valuable. It is a substance ancient beyond human lore; opal was 60 million years old before humans made the first arrowhead. Fossilized shells and bones of prehistoric animals have been found entirely replaced by the silica gel known as opal.

The ancient earth processes which create opal are unique to that stone; no other gem is like it. It is a child of the volcano, whose Goddess, Pele, is known as "the fire in the night." It is a fortuitous composition of the four elements of earth, fire, water and light. Formed by deep fires in the earth, it owes its brilliant reflection of the light to the water trapped by an intricate lattice of silica within. The "fire" of the opal is created by Nature's brush alone, not the faceting skill of a patient human hand. The 'only Nature can make an opal' factor may appeal to those involved in the back to nature movement.

Of course there are those who claim that opals are unlucky because they are fragile. Well, so are butterfly wings and soap bubbles. Iridescence in nature is a transient phenomenon. Rainbows, halos around the moon, and the sunset playing over the sea are fleeting. Opal is the most durable form of shimmer and shine in Nature's jewelbox. The Aztecs called opal "vitzitziltecpatl," "the hummingbird-stone." The pleasures of owning a ruby-throated rainbow cannot be measured in days and years alone. The fragility of modern opal is greatly overestimated. Even the vibrant but delicate Virgin Valley opals of Nevada can now be stabilized by a process formulated by Bill Kelly in 1962. The process contains no foreign additives and does not alter the physical or chemical properties of opal. There are several different techniques for preserving opals from losing their moisture and cracking or crazing. Fine gem quality opals from every source are now generally well-regulated to ensure their long-lasting qualities. There are opals in European museums whose fire has remained undiminished over periods of hundreds of years. So there is no longer any reason for the exaggerated fear of opal's impermanence to tarnish the name of this lovely stone.

Speaking of opal's "good name," an examination of the word's origin reveals still further the veneration in which this stone was held, as far back as the dawn of language. It has often been said that the opal derives its name from the Sanskrit, "Upala," meaning "Precious Gem." In Greek this became "Opallus," which became transformed to "opal" in modern day English. While there is no disputing opal's designation as a "precious gem," Barrie O'Leary states that this derivation is incorrect. He traces the term opal to two ancient Greek words, one of which is the root for such words as "optical," "opaque" and "optometrist" and means "to see." The other Greek root word gives us "alter" and "alias" and translates as "to change." Thus opal literally means, "to see change." Curiously, the word "Witch" also derives from a term meaning "the bender or changer." Magic has long been known as the art of change, so it would seem that the potential mystical properties of the opal were discovered early on. Coincidentally enough, the Indonesian word for opal is "Kalimaya." Kali means "river," and also the Goddess of birth, death and transition. Maya means "illusion." So for the Indonesians, the opal was "a river of illusion," with "the Goddess of illusion" as another possible interpretation. Opal is also known as "The Queen" and has a long association with royalty.

The persistent beliefs that opal is a harbinger of fortune, good or bad, probably stem from the deep effect viewing the stone can have on the human spirit. The flickering fires which shift and change like the Northern lights under the opal's glossy skin are profoundly moving. They thrill the senses and titillate the soul. The early Australian Aborigines held them in awe, believing that the glistening, mysterious glows within were evil spirits beckoning and enticing them with their beauty.

However, it is a cross-cultural trait among aboriginal peoples to hold the powers of the world in a reverence approaching dread, and to refuse to touch them, believing that only a Shaman, a tribal mystic leader, could harness those powers and shape them to his/her purpose. Now that we no longer fear such earthly spirits, the fact that the opal's lights seem so alive as to possess their own soul can be seen as a tribute to their powerful beauty.

In a modern psychological context, how one feels about opals may well reflect how comfortable one is with one's own inner fires and mysteries. An uneasiness with the hidden, arcane side of human personality may translate into a fear of the gem which causes those dark currents to stir and flutter within. People at peace with their spirituality can relax and appreciate the glory of opal. As an old Australian opal miner once put it, "The only unlucky thing about opals is not having any."

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