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IN THIS ISSUE

The Three-Phase Inclusion — A Product of Environment

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

With the introduction of the synthetic emerald to gemology it became apparent that tests were needed to separate these laboratory products from their natural counterparts. Through the microscope obvious differences in natural and synthetic emeralds were evident. It was these early microscopic observations of natural emeralds that led to the gemological awareness of the three-phase inclusion. Today's gemologist, when examining an emerald, is delighted to see a well formed three-phase inclusion nested in the emerald's green depths, because he is assured by the inclusion's presence that the gem is natural.

It is this emphasis on three-phase inclusions in natural emeralds that has led many gemologists to believe that the three-phase inclusion is unique to natural emerald and is proof of emerald rather than just proof of natural origin. This idea is rooted so deeply that it is easy to overlook three-phase inclusions in other materials and just dismiss them as peculiar two-phase inclusions.

The three-phase inclusion is, however, commonly the product of growth from a hydrothermal or pegmatitic geologic environment and so is not confined to existence in natural emeralds alone, but can be expected to occur in a wide variety of natural materials.

As the volatile vapors and fluids associated with hydrothermal solutions and pegmatitic intrusives migrate through the host country rock, the mechanism for a three-phase inclusion is set. Through experimentation, it is known that as the temperature of a fluid increases, its ability to hold dissolved salts in solution increases. Therefore, as a hot, vapor-rich solution percolates through its host rock, it may dissolve variable quantities of salts from the surrounding rock and hold them in solution at elevated temperatures. As a solution rich in dissolved salts begins to cool, the salts will begin to crystallize. If some of this fluid has been trapped as a primary or secondary inclusion filler in a negative crystal, then the salts will crystallize in the inclusion cavity and form a solid phase. At the same time the solid phase is forming, the liquid is contracting as it cools. This contraction of the liquid in the closed environment of an inclusion cavity produces a vapor bubble. Now all three phases or states of matter are present and a three-phase inclusion is formed.

This sequence of geologic events resulting in the growth of three-phase inclusions is not limited to natural emeralds where it was first observed by gemologists. It is limited only by geological environment and in view of this fact we should expect many other gem materials to contain three-phase inclusions. Not all of the three-phase inclusions we encounter in other gem materials look like those found in emeralds from Colombia, South America. Many gemologists have a picture in their mind of a cube of halite (NaCl) and a vapor contraction bubble surrounded by a brine solution all contained in a somewhat flattened jagged-edged cavity. This is the classic picture of a Colombian emerald three-phase inclusion. It must be remembered, however, all that is necessary for a three-phase inclusion is the existence of three states of matter in a closed void of primary or secondary origin.

Since a number of significant colored stones have their origins in hydrothermal and/or pegmatitic environments, we might expect, and do find, three-phase inclusions in many of them. These three-phase inclusions do not necessarily look like natural emerald three-phase inclusions, but many of them, particularly those of hydrothermal origin, do have similarities. *Figure 1* illustrates a three-phase inclusion in a hydrothermal fluorite and *Figure 2* shows three-phase inclusions in hydrothermal quartz. Both of these photomicrographs illustrate notable similarities to their natural emerald counterpart.

Pegmatitic environments often produce three-phase inclusions with a somewhat different appearance. In *Figure 3,* a cavity in a pink beryl contains the liquid and gas phases as expected, but the solid phase consists of a group of nondescript crystals with a single acicular crystal extending into the cavity. A cavity in the topaz shown in *Figure 4* contains a quartz crystal. The quartz crystal solid phase is doubly refractive and is made clearly visible by the use of polarized light. Polarized light can be used to study other three-phase inclusions as well. *Figure 5* shows a three-phase inclusion in a colorless spodumene. Under polarized light the solid phase is easily visible as a bright spot against the much darker background of the host. In *Figure 6,* a fluid inclusion in a pink tourmaline shows two immiscible liquids, a vapor bubble and several doubly refractive solids under polarized light. A cavity in the spessartine garnet shown in *Figure 7* contains a solid phase that stands out from its background when using polarized light. The vapor bubble can be seen floating just above the solid. The negative crystal in the blue sapphire in *Figure 8* contains both liquid and gaseous carbon dioxide and a hematite crystal as the solid. Polarized light would not help in locating the hematite platelet as it is opaque.

The often complex nature of the three-phase inclusion is well demonstrated in the polarized light photo-

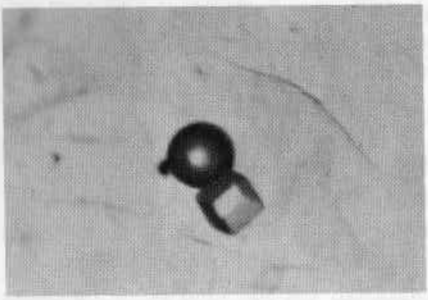
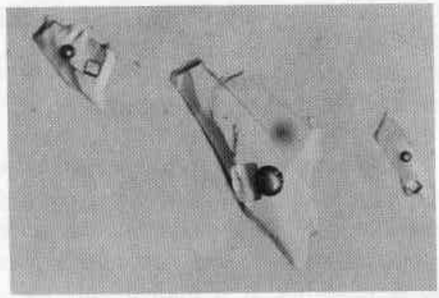


Figure 1.



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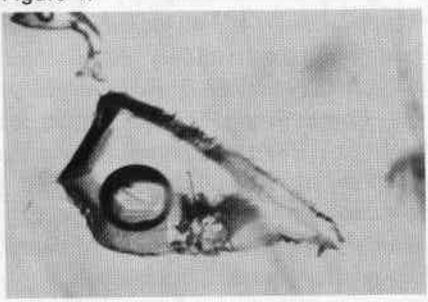

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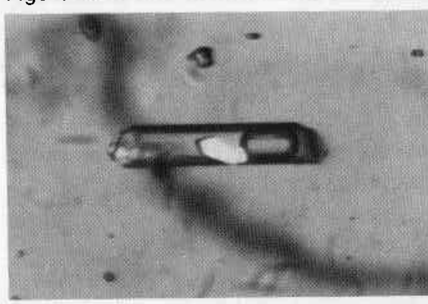

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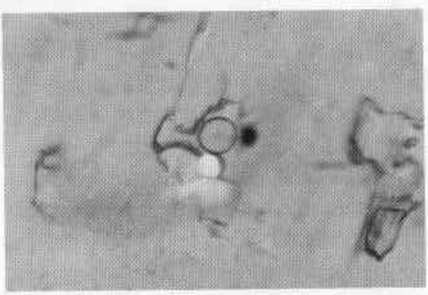

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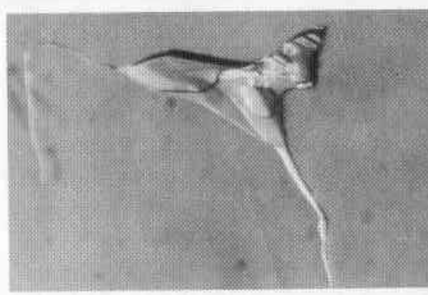

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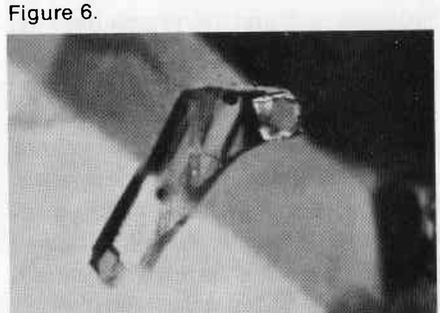

Figure 8.

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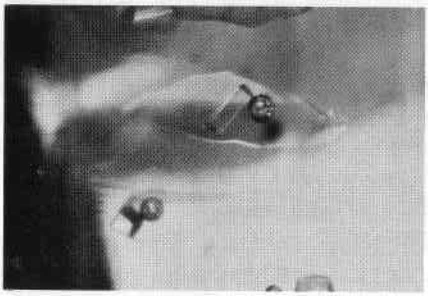
Figure 10.



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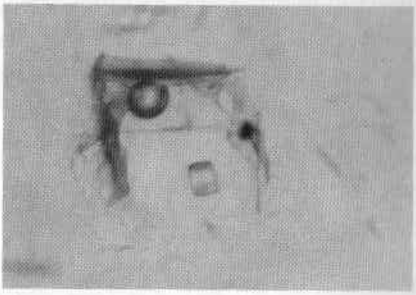

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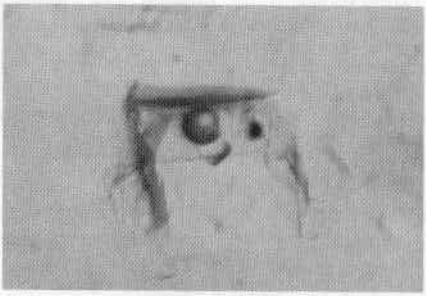

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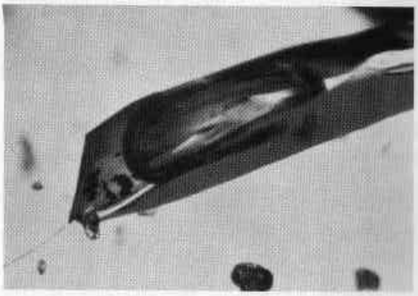

Figure 14.

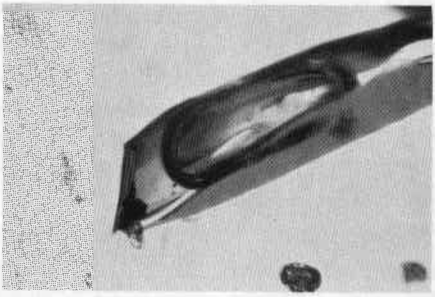

Figure 15.

micrograph in *Figure 9*. Within this single cavity in a Brazilian magnesite there is one vapor bubble, an obvious salt-rich solution and as many as ten separate solid phases, some of which are doubly refractive.

Mobile Solids

Gemologists who have studied fluid inclusions are familiar with the mobile gas bubbles that occur quite commonly in quartz gems, and to a lesser extent, in other gem minerals like beryl.

On the other hand, mobile solid phases in three-phase inclusions are for the most part not known. It is generally thought that the solid phase is permanently stuck to the inner walls of the cavity containing the three-phase inclusion.

Upon close microscopic observation, however, solids in three-phase cavities can be seen, with some regularity, tumbling through their negative crystal prisons. Sometimes a gentle tap and the influence of gravity is all that is necessary to set them in motion. *Figures 10 and 11* show a cavity in a fluorite with a somewhat distorted rectangular solid phase that tumbles about like a log. In *Figures 12 and 13*, a cubic salt crystal is free to roll about in its quartz host like a microscopic die. Included in a pegmatitic topaz, the large primary negative crystal in *Figures 14 and 15* houses a vapor bubble and at the tip of the negative crystal, a flock of hematite plates float through the surrounding liquid like so many tiny black stars.

Conclusion

This article has illustrated three-phase inclusions in beryl other than emerald, together with tourmaline, garnet, topaz, spodumene, corundum, fluorite, quartz and the collectors gem, magnesite. But the list goes on to include many other gem materials in addition to those mentioned.

The three-phase inclusion is proof of natural emerald, proof of natural corundum, proof of natural quartz and so on.

The three-phase inclusion is the most complex of fluid inclusions. It can tell a great deal about the origins of its host gem, and it gives the jeweler-gemologist yet another weapon in separating natural gemstones from their synthetic and simulant counterparts.

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Irradiation-Induced Colors In Gemstones

By K. NASSAU, Ph.D.
Bernardsville, NJ 07924

Abstract

Both natural and irradiated gemstones may derive their color from color centers. Color centers vary with respect to the energy necessary to destroy the color center. As a result, some color centers are stable to light while others are not. Some color-center gemstone materials, such as brown topaz, may occur in both stable and unstable forms. If color centers in natural gemstones are destroyed by accidental heating, the color can usually be restored by irradiation. A summary is presented of current knowledge of irradiation sources used, stability of the color centers to light, and the characteristics by which the use of irradiation may be identified.

Introduction

In recent years there has been a drastic increase in the use of irradiation to induce or change the color of gemstones. This increase undoubtedly derives from the wider availability of facilities for performing such irradiation, particularly large and powerful gamma-ray sources.

Sometimes the first hint that irradiation had been used comes from the observation of fading of the color. In some instances, e.g., in Maxixe-type blue beryl, simple tests can establish the presence of an irradiation-produced color; in others, such as brown topaz, the fading in light itself is the best test; in yet others, such as blue topaz, no distinguishing test is known at present.

This article covers the irradiation and the properties of irradiated gemstone materials with the exception of diamond; full details on the latter can be found in the standard gem and gemology texts, e.g., in Webster's book[1].

Irradiation Sources

The term *irradiation* is a very broad one and covers the use of the full range of electromagnetic radiation as well as bombardment by energetic particles. Visible light itself can produce color changes in some materials; the energy of visible light ranges up to about 3 electron volts (abbreviated eV) at the violet end of the spectrum[2]. Slightly more energetic is ultraviolet radiation, particularly the 2537 Å short wave UV with energy of almost 5 eV.

More energetic than the ultraviolet rays in the electromagnetic spectrum are X-rays, which have energies ranging from hundreds to hundred thousands of eV. X-rays suffer from a lack of penetration; as a result the coloration will be produced only in a thin layer on the surface. In addition, X-ray generating tubes are expensive to buy as well as to operate, have a limited lifetime, and produce only a small area beam.

Even more energetic in the electromagnetic spectrum are gamma-rays, with energies ranging from the thousands into the millions of eV. These are produced by unstable elements obtained from nuclear reactors. The two most commonly used are the cesium isotope of weight 137 (compared with weight 133 for ordinary cesium) which emits gamma rays of energy 660,000 eV and the cobalt isotope weight 60 (compared with ordinary cobalt-59), which emits two gamma rays of 1.17 million eV (abbreviated MeV) and 1.33 MeV. Both cesium-137 and cobalt-60 decay as they undergo radioactive disintegration, with half-lives of 30 years and 5.3 years, respectively. As a result, a typical cobalt-60 cell slowly loses its activity, falling to one half after 5.3 years, one quarter after 10.6 years, one eighth after 15.9 years, and so on. When the cell needs recharging, the whole unit must be shipped back to the supplier.

Gamma cells are very simple in their construction, consisting of a large block of lead, weighing 3,800 kilograms (8500 pounds) in the unit of *Figure 1,* with a central cavity containing the radioactive element. The sample to be irradiated is loaded into the compartment seen open in *Figure*

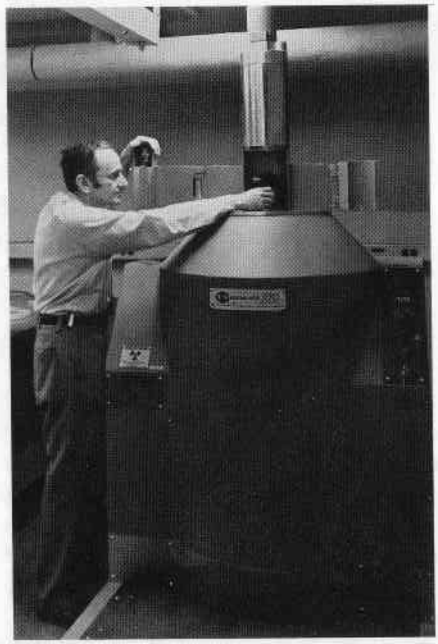

Figure 1. Sample being placed into a cobalt-60 gamma irradiation cell.

1 and is then closed and lowered into the cavity below. After the required dose has been reached, the compartment is raised and the sample removed. In the unit shown in *Figure 1* colorless quartz needs 20 to 30 minutes to reach a dark smoky color, but there are large powerful commercial sources in which specimens several feet across may need no more than a one-minute exposure. The magnificent large smoky quartz clusters from Hot Springs, Arkansas, are believed to be colored in this way. Gamma rays are strongly penetrating and will, therefore, produce uniform coloration. The cell does not consume power, nor is there any deterioration because of use—the rays are produced

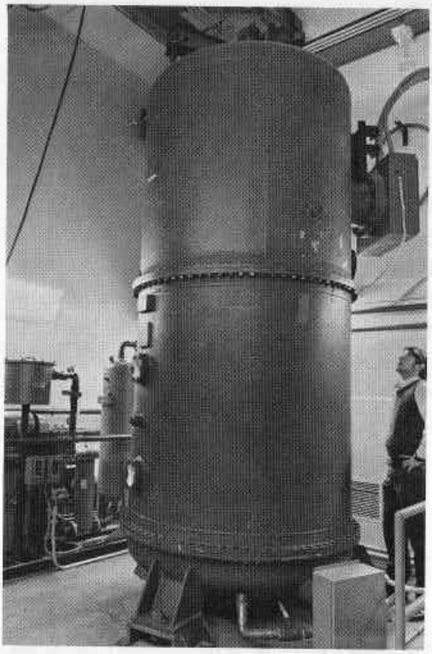

Figure 2. A Van de Graaff electron accelerator.

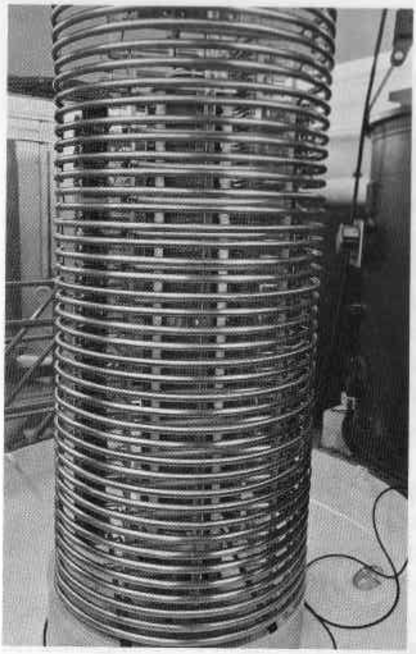

Figure 3. View of the interior of the Van de Graaff electron accelerator of Fig. 2.

continuously, merely slowly decaying in intensity over the years.

Turning from the electromagnetic spectrum to particles, there are three types used for irradiation: the negatively charged electrons, positively charged particles such as protons and alpha particles, and neutrons which have zero charge.

Electrons can be accelerated in linear accelerators, which may be powered by a Van de Graaff voltage generator, or in other machines such as betatrons. The terms beta-rays and cathode rays also have been used in the past for high-energy electrons. In linear accelerators the energy content of the electrons is simply expressed by the maximum voltage used, since one "electron volt" is defined as the energy of an electron when accelerated by a field of one volt. Thus, the electron accelerator of *Figures 2 and 3,* powered by one million volts, will produce 1 million electron-volt electrons, i.e., electrons of energy 1 MeV. Electrons in the billion electron volt (abbreviated GeV) range can be produced. Electrons are strongly absorbed and therefore do not penetrate deeply and produce only surface coloration. In addition, electrons produce strong localized heating and cracking can result. Electron accelerators are expensive, as well as expensive to operate.

A variety of positive particles can be accelerated in machines such as cyclotrons, synchrotons, and the like, to energies in the GeV range. There are protons (ionized hydrogens H^+), deuterons (ionized deuteriums or heavy hydrogens D^+), alpha particles (doubly ionized heliums He^{2+}), and so on. Alpha-particles are also produced by radium salts (energy about 5 MeV) and diamonds were at one time colored by being covered, for example, with radium sulphate. These positive ions do not penetrate well and also may induce radioactivity in the irradiated sample.

Neutrons are present in large quantities in nuclear reactors; samples are irradiated by merely insetting them into a reactor. Although neutron energies extend into the high MeV range, the average neutron energy may be less than 1 MeV. Because the neutron has no charge, there is no electrical repulsion when it approaches an atom, and a large energy is not necessary for significant effects. Neutrons thus can penetrate matter readily and produce uniform coloration. Their major drawback is that they have an effective ability to penetrate even into the atomic nucleus so that they can induce radioactivity in the irradiated material.

The various rays and particles used for producing color centers are summarized in Table 1. It will be noted that the low energy rays, such as X-rays, and the negative and positively charged particles do not penetrate well and thus color only the surface. Energetic gamma rays and the electrically neutral neutrons penetrate well and thus produce uniform coloration. Neutrons and positive particles can induce radioactivity.

The nature of the irradiation source does not matter as long as the

Table I — The Various Types of Radiations Used for Producing Color Centers

Radiation	Typical energy (electron Volts)	Penetration 2nd uniformity of coloration
Electromagnetic Spectrum:		
Light	2-3 eV	variable
Ultraviolet (SW)	5 eV	variable
X-rays	10,000 eV	poor, surface only
Gamma-rays	1,000,000 eV	good, very uniform
Particles:		
Electrons (negative)	1,000,000 eV	poor, surface only
Protons, deuterons, alpha-particles, etc. (positive)	1,000,000 eV	poor, surface only*
Neutrons (neutral)	1,000,000 eV	good, very uniform*

*Can induce radioactivity.

irradiation is energetic enough to produce the intended color change. Using excess energy usually does not alter the result, apparently with the single exception of diamond[1]. The only limiting factor is heat as with high energy electrons, which may produce cracking in heat-sensitive materials. The heating produced by such electrons in, say, a Maxixe-type beryl may be enough to fade the color as rapidly as it is being produced!

The *absorbed radiation dosage unit* usually used for irradiation treatments is the *rad;* a typical irradiation dose used for amethyst or smoky quartz is 1 million rads. Other units used in connection with irradiation are the *Curie* (amount of radioactivity in a material), the *Roentgen* (dose of ionizing radiation), and the *rem* (dose of ionizing radiation in man).

Color Centers

A change in color produced by irradiation is most often the result of the formation of a color center. This is usually a misplaced electron which can be an excess electron (an *electron color center*) which is *trapped* at a defect, or a deficit of an electron (a *hole color center*) located at a defect (with the missing electron trapped at another defect). The pre-existing defects without the hole or the extra electron are called *precursors*. When light exposure or heating permits the displaced electron to return to its original place, the color center is destroyed and the precursors are reformed in a process called *fading* or *bleaching*.

The *depth* of the trap is a measure of how much energy is needed to produce bleaching. The energy for bleaching of a color center can be supplied by light, by heat, or by a combination of both. When a color center has been bleached, it is usually possible to re-create it by another irradiation. This cannot be done if overheating occurred during the bleaching step. Thus, amethyst which has been gently heated to obtain a citrine color can be returned to its original color by irradiation, and the process can be repeated any number of times. If too high a temperature is used, however, the substitutional iron precursor changes to ferric oxide with the production of a deeper brown color, which cannot be altered by irradiation.

Details of color in general and some color centers in particular have been given by the author in several places [3,4,5] and will not be repeated here. A brief outline of color center theory is given in the Appendix.

The most important factors for a given color center are the stability to light exposure, i.e., the resistance to fading, and the characteristics which indicate that irradiation has been used. Based on the resistance to fading, three groups of irradiation-produced color effects can be distinguished. In a fourth grouping are discussed some irradiation-produced changes which do not involve color centers.

I. *Color Centers with Shallow Energy Traps*

In this group are included those irradiation-produced color effects which are not stable at room temperature even in the dark. Ordinary *fluorescence* can be viewed as an unstable color center, the effect being so fleeting that the red fluorescence of emerald, as one example, stops within a few thousands of a second after the ultraviolet irradiation is halted.

Lasting somewhat longer is the *phosphorescence* or *after-glow* of substances such as some fluorites, some calcites, and some diamonds; this behavior can be viewed as derived from transient color centers. This occurs when the color-center trap is relatively shallow, so that the energy of the thermal vibrations at room temperature is enough to permit slow escape from the trap. The color of the phosphorescence may be the same as that of the fluorescence, as in the brief red phosphorescence of particularly iron-free rubies (mostly synthetics) or it may be different as in those diamonds which have a blue fluorescence followed by a yellow after-glow.

If substances in this group are cooled to a low temperature and then irradiated, this will frequently stabilize the color center. On warming up, the color center again will become unstable and emit its energy over a specific temperature range, an effect which is then called *thermoluminescence*. Liquid nitrogen or even lower temperatures may have to be used to observe this effect.

II. *Color Centers with Medium Energy Traps*

There are some materials which are easily colored by low energy irradiation such as ultraviolet light and X-rays. One of these is the mineral hackmanite which can be colored red by UV radiation. This color is perfectly stable as long as the specimen is kept in the dark, but will fade on exposure to visible light (or more rapidly on heating). Such materials are sometimes called *photochromics*. Photochromic sunglasses are now manufactured which turn dark from the UV present in strong sunlight and fade rapidly in the UV-free indirect light in the shade.

These colors may be stable when cooled (arctic wear?) and thermoluminescence may occur during heat bleaching. Several gemstone materials, some naturally occurring, fall into this group.

There is some natural *topaz* which is brown as found but which fades rapidly when exposed to light. Similarly, almost any colorless or pale yellow topaz will color brown on being irradiated by X-rays, gamma-rays, etc. Two distinct component colors can occur, either separately or together: a pale yellow-brown and a dark cinnamon-brown; the former forms rapidly on irradiation and fades in a matter of hours in the sun; the latter forms more slowly and also fades more slowly in one or a few days in the sun. There are two additional radiation-related colors in topaz which are stable and are discussed in the next section. Details[6, 7] and color illustrations[7] have been published. Observation of the fading may be the only practical identification test for these transient brown colors in topaz.

Pink kunzite will turn a deep almost emerald-like green upon irradiation.

This coloration bleaches in an hour or so in sunlight and is quite distinct from the green of hiddenite. Color illustrations have been published[3,8]. Some pale tourmalines turn red on irradiation, some turn yellow and some blues turn purple; all of these may fade in days to weeks in the sun (but see also the next section). Details[9] and color illustrations[8] have been presented.

An important unstable color in beryl is a magnificent deep blue, approaching the blue of tanzanite or sapphire, seen in *Maxixe beryl* and *Maxixe-type beryl.* The former was found in 1917 in the Maxixe Mine in Minas Gerais, Brazil, while the latter has been produced in recent years by the irradiation of pale pink or other pale color beryls from certain localities in Brazil, Rhodesia, North Carolina, and probably elsewhere; UV, X-rays, gamma-rays, and neutrons have all been used for this irradiation. This deep blue beryl has been called "Halbanita" and "aquamarine," the latter being incorrect by customary gemological usage. A dark green color can result if the starting beryl was yellow. Full details[10,11], including color illustrations[11], have been published.

Maxixe and Maxixe-type beryls fade in a matter of days or weeks on exposure to sunlight. Identification and distinction from aquamarine is readily achieved[10,11] by the spectroscope (sharp lines near 7000 Å not present in aquamarine), by examination in polarized light (the blue color is carried by the ordinary ray, while in aquamarine it is carried by the extraordinary ray), or by observing the fading. Both are hole color centers, and the rather small difference in the spectrum between Maxixe and Maxixe-type beryls has been attributed to different precursors, being small amounts of nitrate NO_3^- and carbonate CO_3^{2-}, respectively [12]. Irradiation removes one electron from these, leaving the hole color centers NO_3 and CO_3^-, respectively. The displaced electron becomes trapped at a proton H^+ or a free carbon dioxide CO_2 in the channels, producing H and CO_2^-, respectively (see also the Appendix).

III. *Color Centers with Deep Energy Traps*

Materials in this group generally need higher energy irradiation (at least X-rays) and the resulting colors are stable to light at ordinary temperatures. The colors will fade if heat (or the combination of heat and light) is used. A report [13] stating that irradiated blue topaz faded under a mercury arc lamp omitted to mention that the sample reached over 300°F (149°C) under the fading conditions used[14]; undoubtedly, natural blue topaz also fades under such extreme conditions. Similarly, the investigation of reports of light-fading amethyst usually reveals that heat was also present. Thermoluminescence may occur during heat bleaching.

The color of most natural *brown topaz* is stable to light, but heating will destroy this color (if there is any chromium present, then pink or red "pinked" topaz results). Together with the two unstable brown colors discussed in the previous sections, this indicates the existence of at least three distinct brown colorations in topaz.

When *brown irradiated topaz* is heated or exposed to light, the brown color fades. Sometimes the fading does not return the material to the original colorless state, but instead produces a *blue topaz,* which can be even darker than the blue of naturally occurring blue topaz. The accidental observation of this phenomenon in a specimen thought to be quartz [6,7] explained the appearance on the gemstone market in the early 1970's of quantities of unusually deep blue topaz without the report of the discovery of a new mine. The author found that the irradiation of old collections of colorless topaz produced a significant quantity of blue, while more recently obtained colorless topaz did not. From this one could deduce that essentially all colorless topaz is now irradiated and then heated so as to locate all blue-producing material. There appear to be no gemological-testing differences between the natural and the irradiated blue topaz, and both appear to have the same stability toward light and heat.

Almost all colorless quartz, whether natural or synthetic, turns into smoky quartz[15] on being irradiated. This color is stable to light and bleaches over a wide temperature range on heating, just as does natural smoky quartz; the last trace of smoky color disappears anywhere from 140° to 400°C (284° to 752°F) depending on the specimen[16]. The color can vary from a yellowish or a reddish brown all the way to a pure black, depending on the type of material and the irradiation dose used. There appear to be no gemological testing differences between irradiated and naturally-occurring smoky quartz. The color center precursor consists of a few parts per million aluminum impurity (some alkali or hydrogen ions are also needed for charge compensating the Al^{3+} which substitutes for Si^{4+}).

If this heating to fade smoky quartz is carried out gradually in steps, much naturally occurring and irradiated smoky quartz will yield a greenish-yellow color, abbreviated *G-Y quartz.* This has been also called yellow quartz, honey quartz, citrine, and radiation-produced citrine; the latter two terms are undesirable because of the absence of iron, characteristic of naturally-occurring citrine. G-Y quartz forms from smoky quartz at 140° to 300°C (284° to 572°F); G-Y quartz loses its color at 140° to 380°C (284° to 716°F). There is some naturally-occurring G-Y quartz, and some rare colorless quartz irradiates directly to G-Y quartz without the formation of any smoky color. Full details of G-Y quartz[16], a reinterpretation of smoky quartz[15], and color illustrations[7,8] have been presented.

The detailed nature of the color of natural *amethyst* was not understood until the achievements of its duplication by man. When synthetic quartz is grown with the incorporation of iron, the resulting color is either yellow or green, depending on the growth conditions[3]. If growth has occurred in certain crystallographic directions and if the iron concentration is in the correct range, then irradiation will result in the hole color center of synthetic amethyst. Heating will restore the green or yellow color, just as happens with natural amethyst, which gives either a citrine color or the "greened amethyst." Irradiation will once again restore the amethyst color (as long as overheating was avoided, since this changes the nature of the iron impurity). Details[3] and color illustrations[3,7] have been presented.

A color center having a very similar color is the deep purple of "desert glass" seen in old glass bottles exposed to the sun's UV over several years in the Western desert states or to, say, gamma-rays for some minutes. A necessary precursor is the manganese which used to be added to glass to hide the green color of iron impurities.

The effects of irradiation on *tourmaline* can be quite complex. Some pale pink or other pale material turns deep pink to red, and some turns yellow; some blue tourmaline turns purple. These irradiation induced colors are stable to light in some specimens, but fade in others, as stated in the previous section. Details[9] and color illustrations have been presented[8].

IV. *Irradiation Effects not Involving Color Centers*

Although the production of color by irradiation and its destruction by heat or light is the touchstone of a color center, this in itself is not sufficient proof. One example of such a change not involving a color center occurs in aquamarine and golden beryl. As found, these natural materials have a color ranging from blue-green via green to yellow and are almost invariably immediately given a heat-treatment. The heating removes the yellow color component and is performed in the hope of producing a pure blue aquamarine. Often the result is a colorless beryl. Irradiation will return the material to the green or yellow state. The change here involves a change in the valence of the iron impurity causing the yellow color; the iron impurity causing the blue color is not affected by either the heating or the irradiation. These colors are stable to light and details[17] and color illustrations[3] have been published.

Lastly, irradiation has a charring-type effect on some organic substances such as paper, and this is used to darken some kinds of natural or cultured pearls; this does not work with all pearls. A color illustration has been presented[8].

Color Loss on Accidental Heating

In addition to the intentional heating of green and yellow beryls, accidental heating may at times destroy the color of some natural gemstones with stable color centers. If the heating was not excessive, then irradiation is usually able to return the gemstone to its original color. Such a step may be viewed merely as restoration rather than an irradiation-originated coloring. Restoration may be possible with accidentally heated blue or brown topaz, amethyst or smoky quartz, and red tourmaline, as well as with golden beryl.

Summary

Color centers can be produced by a

variety of irradiation treatments and can be destroyed by heating. Light bleaches some color centers, but not others, depending on the depth of the color center trap. There may be more than one type of color center which can produce a given color as in topaz, where one type of brown is stable to light, another bleaches slowly, and a third one bleaches rapidly. In some

Table II — Occurrence and Stability of Color Centers

Material	Color (& change on bleaching)	Colored form Naturally Occurring	Colored form Produced by Irradiation
I. Color centers with shallow energy traps (color unstable even in the dark*):			
Phosphorescents (fluorescents)	varied	—	Yes
II. Color centers with medium energy traps (color is bleached by light at room temperature or more rapidly by heating#):			
Hackmanite	red (to colorless)	Yes	Yes
Topaz	yellow or brown (to colorless)	Yes	Yes
Kunzite	green & lilac? (to pink or colorless)	?	Yes
Tourmaline	red (to pale or colorless)	?	Yes
Tourmaline	yellow (to pale or colorless)	?	Yes
Tourmaline	purple (to blue)	?	Yes
Maxixe beryl	blue (to colorless)	Yes	No
Maxixe-type beryl	blue (to pink or pale colors)	No	Yes
Maxixe-type beryl	green (to yellow or pale green)	No	Yes
Sapphire	yellow (to colorless)	No	Yes
III. Color centers with deep energy traps (color is stable to light at room temperature but is bleached on heating#):			
Topaz (Cr)	brown or orange (to pink or red)	Yes	?
Topaz	blue (to colorless)	Yes	Yes
Quartz	smoky (to greenish-yellow or colorless)	Yes	Yes
Amethyst	purple (to yellow, brown, or green)	Yes	Yes
Tourmaline	red (to pale colors or colorless)	?	Yes
Tourmaline	yellow (to pale colors or colorless)	?	Yes
Tourmaline	purple (to blue)	?	Yes
IV. Irradiation effects not involving color centers (change on heating shown):			
Beryl	yellow (to colorless)	Yes	Yes
Beryl	green (to blue)	Yes	Yes
Pearl	"blue" or "black" (permanent)	No	Yes

*Cooling may stabilize the color center, which will again become unstable or bleachable when returned to room temperature.

#Thermoluminescence may accompany destruction of the color center by heating.

instances the irradiated man-produced and the naturally occurring color appear to be identical (as in blue topaz, smoky quartz, and amethyst) and gemological distinguishing tests are not presently available. Table 2 summarizes the irradiation and bleaching behavior covered in this discussion.

Appendix

Two types of defects are needed for the formation of a stable irradiation-induced color. Consider a crystal containing two such defects as in *Figure 4a.* Defect A has no color absorption, but it has a pair of electrons from which one electron can be lost relatively easily, i.e., it can act as an electron donor. Defect B has no color absorption, but it has the capability of trapping an extra electron, i.e., it can act as an electron acceptor.

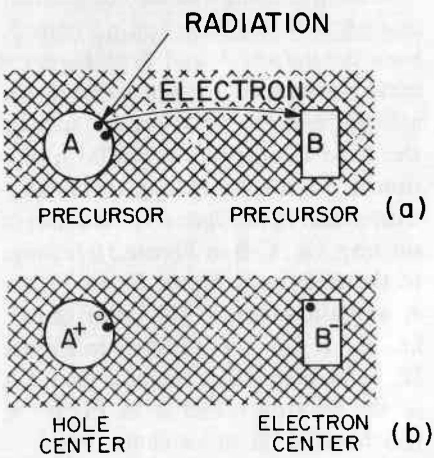

Figure 4. The transfer of one electron from precursor A to precursor B in (a) produces two centers, a hole center A+ and an electrom center B- as in (b); either of these can be a color center.

These defects are called *precursors.*

When radiation strikes defect A, one of the pair of electrons can be ejected as shown, and becomes *trapped* at defect B. As a result the arrangement is now as in *Figure 4b,* with both A+/B– each having an unpaired electron. The absorption of energy from light or from heating could now permit the extra electron on B– to return to A+, thus re-forming the original defects A and B as in *Figure 4a.*

In general, either defect A or defect B can become the color center; if it is A, then the result is the *hole color center* A^+; if it is B, then the result is the *electron color center* B^-.

In the case of Maxixe-type beryl, A is CO_3^{2-} and B can be H^+. The irradiation changes are:

Irradiation: CO_3^{2-} $CO_3^{-} + e^-$

. . . Equation (1)

Trapping: $e^- + H^+$ H

. . . Equation (2)

Here CO_3^{2-} is the color center precursor, e– is the freed electron, and CO_3^{-} the light-absorbing hole color center. The second defect H^+ which traps the electron by Equation (2) and becomes the electron center is also an essential part of the color center although it does not cause color in itself; without it the electron would immediately return to destroy the color center in the reverse of Equation (1). The second defect may be adjacent to the first, or it may be some distance away. Light or heat reverses Equation (2), and the liberated electron then reverses Equation (1).

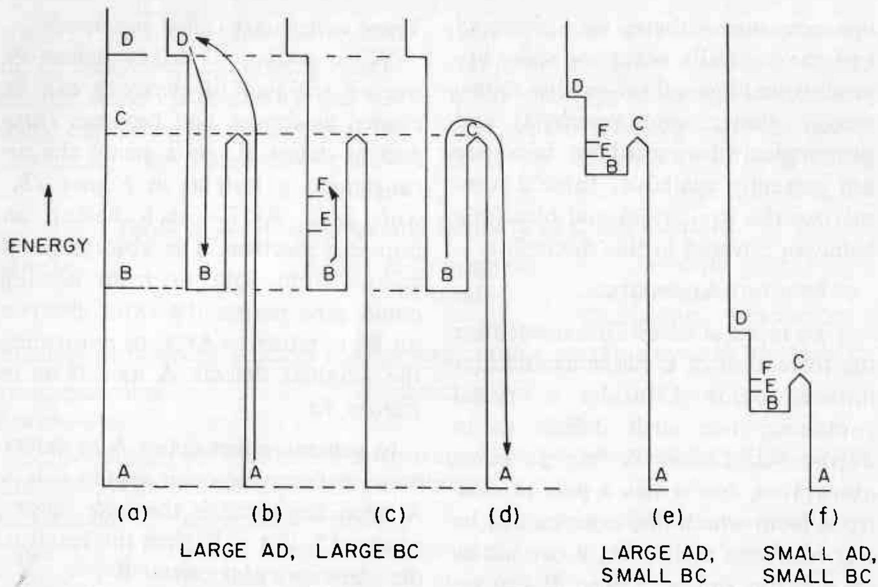

Figure 5. Energy level schemes showing color center traps involved in phosphorescence, fluorescence, and bleaching.

In an electron color center, e.g., in purple fluorite, B in *Figure 4* is the color center precursor and it is the electron color center B^- that absorbs light to produce the color. In this instance B^- is an electron trapped at a fluoride vacancy [3,4,5].

Details of the *energy level diagram* in *Figure 5* include: the *ground state* A corresponding to the precursor state; the formation of the *trap* by absorption of radiation from A up to level D and formation of the color center with relaxation down to its energy level B as at (b); the absorption of light within the *color center* by the B-E-F energy level system as at (c); and *bleaching* by escape of the electron from the trap over the energy barrier C as at (d) with re-formation of the precursor.

When the energy of the color center as a whole is considered as in *Figure 5,* both the defects A and B of *Figure 4* must be included: the energy levels for activation of the color center, such as the A to D energy absorption transition in *Figure 5b* belong to the electron donor A in *Figure 4;* the depth of the trap, i.e., C-B in *Figure 5b* belongs to the electron acceptor B^- in *Figure 4,* and the color of the color center, i.e., the B-E-F energy levels in *Figure 5c,* belongs to either the hole center A^+ or the electron center B^- in *Figure 4,* whichever is the color center itself.

The scheme of *Figure 5(a) to (d)* corresponds to a large formation energy, needing X-rays or more energetic irradiation, and has a deep C-B trap that is stable to light at room temperature, as is smoky quartz or blue topaz. At (e) is shown a similar diagram with a much smaller C-B trap, where the energy present in light would enable escape from the trap and bleaching as in Maxixe-type beryl or green irradiated kunzite.

The scheme of *Figure 5(f)* would correspond to a photochromic material, such as Hackmanite, where UV radiation is enough to form the color center and light bleaches it again. If the trap C-B is a little smaller yet, then the energy present in the atomic vibrations at room temperature is enough to permit slow leakage out of the trap and phosphorescence can then occur as in some diamonds.

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GEMLURE

Born in the Depths: The Perfect Pearl

By CHERI LESH
Corte Madera, California

"Born in the depths of the seas, springing from living flesh, round and pure, the pearl detaches itself from the ephemeral creature that conceived it, and becomes immortal."

—Paul Claudel

"Full fathom five thy father lies of his bones are coral made: Those are pearls that were his eyes. Nothing of him that doth fade but doth suffer a sea-change into something rare and strange."

—Shakespeare, The Tempest, Act I, Sc. ii

Shakespeare's flight of fancy about the transmutation of human flesh into gems of the sea was not the only wild tale to circulate about the mysterious origins of pearls. The speculations on the birth of this gleaming gem rival the 'where do babies come from' theories circulating about storks and cabbage patches for sheer inventiveness and ingenuity. In India, it was believed until quite recently that pearls could be derived from eight sources: falling from the clouds with rain, in the head of a hog, the head of an elephant, from the bamboo plant, the cobra, the conch, the fish, and the oyster. Wisely enough, they believed that oysters were the most common pearl source, although the gem originating with the cobra was the most valuable. In a tract titled *Indian Gemmology* published as recently as 1967, Raj Roop Tank describes the cobra pearl in this manner:

"It has its source in the hood of King-Cobra, is very bright and of a blue tint. It is known as the 'Naga-Mani' or the 'Snake-Stone.' The Tantrics say that the King Cobra when it crosses its hundredth year, becomes 'Ichhadhari Naga,' then it acquires the power to transform itself into any form animate or inanimate. It also acquires 'Naga-Mani,' a magic Pearl Gem which it keeps in its mouth and takes out in dark nights to play with. The Gem emits brilliant light and can fulfill desires for material wealth if one is lucky enough to possess it. We do not know whether there is any truth in what the Tantrics say."

Lest the reader doubt that all eight varieties of pearl exist, however, author Raj Roop Tank assures us that "The writer has had an opportunity to see with his own eyes all the eight varieties of Pearls mentioned above at the place of Shri Dhanroop Mal the renowned Jeweller of Ajmer."

Layered like an onion, the pearl was often said to be the result of tears. In his epic, "The Bridal of Triermain," Sir Walter Scott makes mention of: "The pearls that long have slept/These were tears by Naids wept." Scott repeats the pearls/tears theme with the stanza:

"The liquid drops of tears that you have shed/Shall come again, transformed to Orient Pearls./Advantaging their loan with interest/Of ten times double gain of happiness."

In this passage, pearls signify grief transformed to beauty, wealth and happiness. The analogy of pearls and tears probably stemmed from the common notion that pearls were formed from dew drops ingested by oysters who rose to the ocean's surface to procure this beneficial liquid. Since dew was sometimes said to be the tears of Aphrodite, shed when she discovered the body of her mortal lover Adonis, the connection of pearls to tears to the Goddess of Love is apparent.

In Persia, pearls were used in religious worship from the earliest times, probably because of their obvious correlation with the moon, which they resemble. The 'little moons,' sometimes seen as tears of that great orb, must have been highly esteemed indeed at a period of history when time was measured by lunar reckonings and the Moon was worshipped as the mysterious ruler of tides and the fertile cycles of women.

Since pearls most often resemble the full moon, they were sacred to the Great Goddess in her full moon aspect as the cosmic lover, the Sea Mother who poured her love out on the earth, known as Isis, Ishtar, Aphrodite, and Venus. Statues of this aspect of the Goddess are traditionally adorned with pearl earrings. The mate to the earring that Cleopatra supposedly dissolved in wine was said to have been cut in half to make a pair which was offered up at the temple of Venus in Rome. An ancient statue of Isis on display in Alicante, Spain, was decorated by the richest of gems, including a diadem set with an 'unio'—a large round pearl whose name denotes its uniqueness and size—along with several smaller pearls, pearl and emerald earrings, necklaces and bracelets. The inscription on the base of the statue informs us that these gems had been offered by Fabia Fabiana who had been obliged by Isis herself to do this in honor of her grand daughter. Homer alludes to pearls as triple drops or beads in his description of Juno in the Illiad, XIV, 183:

> "In three bright drops
> Her glittering gems suspended from her ears."

He mentions this distinctive ornament again in the Odyssey, XVIII, 298:

> ". . . Earrings bright
> With triple drops that cast a trembling light."

Classical designs of Juno usually show three pear-shaped pearls pendant from her ears. The number three was sacred to the Goddess in her three-fold aspect, and also denoted fertility. The pear-shape may be meant to evoke the pregnant female form. No information remains as to why earrings were a more significant ornament than, say, a pearl choker or ring. Perhaps the ear, often described as 'shell-like' by poets, served as a creative simile to the oyster which had originated the lovely jewel and was therefore supposed to have a special affinity for them. Joan Dickinson theorizes that the custom of piercing the ears and adorning them with pearls may have originated with the cult of the shells, and the idea that the 'sound of the sea' one hears roaring in many shells was the voice of the Gods. By piercing the ear, as many natural shells are pierced (such as abalone), people may have hoped to maintain a constant connection to the voices of the Gods. The image of 'Venus on the Half-Shell' popularized by Botticelli's painting becomes more clear when Venus' symbolic relationship with pearls is kept in mind. In Rome, the interior of the temple of Venus was covered with pearls honoring She who was foam-born like them. Pliny reported that pearl-oysters lived in communities like swarms of bees, governed by one of great size and age which protected her subjects from danger. What seems at first to be an uneducated fantasy actually shows the mythic connections of pearls to matriarchal Goddess-worship. Bees were sacred in Crete, where the Mother Goddess and her earthly representation (known as The-Goddess-on-Earth) reigned supreme. Since pearls and pearl oysters were a part of the cult of the shells, with its worship of a supreme female deity, it was assumed that oysters had a social system similar to bees and early matriarchal communities.

Because of its association with the moon and the mysteries of creation, the pearl is the most expressly feminine of all gems. Most likely, the pearl was the first gemstone used for adornment. Probably discovered by the earliest humans as they pawed through edible shellfish, we can imagine the thrilling impression the initial discovery of pearls must have made upon the human mind. Unlike other gems, pearls require no faceting, polish or other human skill to make them cast forth their luminescent glow. The pearls' resemblance to the moon must have been immediately apparent, and this mystical connection caused them to be held in great awe. Gold, diamonds, iron and other precious stones and metals harvested from the earth were symbols of wealth, status and royalty only as civilization became sophisticated enough to mine and shape them for valued use. Before any of these substances were known, the burgeoning seashore civilizations worshipped the pearl and the cult of the shells. Along with the earth herself, the moon was the first deity honored by the old Nature religions. Queen of the night, fertility, tides and time waxed and waned beneath her omniscent gaze. The miniature moons known as pearls were her most valuable talisman, conveying divine power to their possessors. From earliest times through the customs of recent royalty, two bands of pearls set on a wide piece of ribbon and worn on the head symbolized descent from the Gods, conferring the divine rights of rulers. Joan Dickinson notes, "We can only guess that in the old nature religion this might have been a moon-inspired halo: by the time we see it in the head-wreaths of the kings of Persia its origins apparently were taken for granted."

The oldest surviving pearl jewelry extant is a pearl necklace once worn by Queen Achaemenid at around 2300 B.C., who ruled at Susa in Western Iran. The pearls of Persia were renowned throughout the civilizations of the ancient world. The dwellers of the fertile crescent knew the bodies of water surrounding the cradle of civilization—the Indian Ocean, Red Sea and Gulf of Persia—to be as rich in pearls as their fabled land was rich in soil. Divers gathered the pearls and sponges which grew in profusion in the Persian Gulf, and distributed them to a diverse host of traders and merchants who frequented Bombay. Another ancient use of pearl was discovered in the tomb of Queen Bhab of Sumer, where a gilded shell, gold spoon and carrying case, were found beside her. Apparently, all were used for the purpose of carrying and applying powdered pearl to the Queen's features. As Dickinson says in her work, *The Book of Pearls,* "Although male scholars refer to the find as a 'vanity' case, it is likely that just as poetry began as prayers, and jewelry as religious amulets, cosmetics began as symbols of religious devotion." She goes on to conclude that queens like Bhab wore powdered pearl on their faces to emulate the shining of the moon, and make clear their position as Her representative on earth. Dickinson points out that the Queen of Sheba is reported to have adorned her face with powdered pearl and gold dust, and that powdered pearl is one of the ingredients of kohl, the ancient cosmetic used by Egyptians as a spiritual statement as well as a beauty aid.

Ceylon was also a famous source of pearls for the ancient world, and pearls have a place in Indian mythology from the earliest writings which have come to us. Circa 3300 B.C., Brahmans of the Indus River basin mentioned pearls in the pages of their religious classic, the *Rig-Veda.* Singhalese historical records found in the *Mahavansa* and *Dipavansa* describe methods for gathering and evaluating pearls and note that King Weyaga gave his father-in-law a pearl worth 200,000 rupees. Two of India's most famous works, the *Ramayana* and the *Mahabharata* state that selected groups of individuals were trained both as warriors and pearl-divers. Were these aquatic warriors used as the first secret agent saboteurs of naval warfare? We shall never know.

In an Indian text known as the Kalpa Sutra, one of the sacred books of the Jains, principal rivals of the Buddhists, describes their beautiful Goddess as adorned with pearls:

"The pure cup-like pair of her breasts sparkled, encircled by a garland of Kunda flowers in which glittered a string of pearls. She wore strings of pearls made by clever and diligent artists, strung with wonderful strings, a necklace of jewels with a string of Dinaros, and a trembling pair of earrings touching her shoulders, diffused a brilliancy; but the united beauties and charms of these ornaments were only subservient to the loveliness of her face."

At Mutan, one of the great Indian cities of antiquity, there was a Hindu temple containing an idol whose eyes were two large matching pearls, making Shakespeare's conceit, 'those are pearls that were his eyes,' a reality. Hindu literature associates pearls with Krishna, the eighth avatar or incarnation of Vishnu, one of the most popular Gods of Hindu worship. Another Indian myth recounts offerings made by the elements as gifts worthy of a deity; the air offered a rainbow which formed a halo over the God, the fire a falling star which served as a lamp, the earth a ruby which decorated the forehead, and the sea a pearl which was worn over the God's heart.

In the dramas of Kalidasa, the Hindu Shakespeare of 3rd Century A.D., pearls were called mukta, the pure. And the Atharvaveda, a 2,400-year-old manuscript, makes allusion to the use of an amulet of pearl shell and pearls among the Hindus as a means of bestowing long life and protection upon young Brahman disciples. An excerpt from the ritual recites:

"The bone of the Gods turned into pearl; that, animated, dwells in the waters. That I do fasten upon thee unto life, luster, strength, longevity unto a life lasting a hundred autumns. May the amulet of pearl protect thee!"

The five gems known to the Hindus as the maharatnani or 'great gems' were the diamond, pearl, ruby, sapphire and emerald which were correlated, respectively to the sun, moon, Venus, Mercury and Saturn. Together with four lesser gems they formed a talisman known as the naoratna which theoretically combined the favorable influences of all the celestial bodies which brought their astrological power to bear on the fate of an individual life. The pearl was always deemed second or third in importance due to its association with the powerful tide-changing moon.

Pearls were also sacred in the Orient. The Chinese mention pearl gifts in the *Scripture of Documents* (Shu Ching) compiled in about 2,200 B.C. Later references of the Chou period (1122-256 B.C.) list pearls as one of the most highly regarded gems. Some writers credited pearls as having originated in the brains of dragons (similar to the cobra-pearl myth of India). They were used as charms against fires and other disasters (the relation of pearls to the water element may have accounted for their sympathetic magic capabilities to defeat fire). Other Chinese writers describe pearls so brilliant they were visible at a distance of a thousand yards, swearing that rice could be cooked by the light from them. The Book of the Later Han regards the pearl as the hidden soul of the oyster. It is said by various Oriental sages that "Whisper the right word and a spirit will appear from the pearl, like a genie from a lamp to grant the speaker all happiness on earth."

The pearl was the sigil of kings in the Americas as well. The Aztec kings possessed pearls of great value; in Mexico, the palaces of Montezuma were studded with pearls and emeralds. Pearl necklaces dating from 500 B.C. were found in Monte Alban in Mexico and many other types of pearl jewelry were found in ancient Inca temples and burial grounds in Peru.

As we mentioned before, the ancient Greeks and Romans were especially partial to pearls. Pliny notes that a portrait of Pompey, conqueror of Pontus and Syria, was encrusted with pearls, and that it portrayed him wearing a crown featuring 33 fine specimens. The noblewomen of Rome were reputed to wear their pearls to bed with them at night so that the lunar globes would light their dreams with visions of beauty and abundance. The demand for pearls grew so great that sumptuary edicts were issued by several Caesars forbidding women under fifty-five and all women who were unmarried or childless from adorning themselves with the popular gems. It is generally admitted, however, that the Roman ladies turned a deaf ear to these attempts to regulate their pleasures. For all their sternness, the emperors themselves were not immune to the lure of Venus' baubles; Constantine's crown and helmet, Caligula's boots and Nero's scepter and the masks of his retainers were all heavy with pearls.

Since Cleopatra was known to her people as Isis-Incarnate, a living love Goddess, it is not surprising that dramatic legends concerning pearls are associated with her reign. Her desire for the aquatic gems was rumored to be insatiable, and there is no telling how much her lavish use of pearls as personal ornamentation added to the fatal attraction cast by her beauty and power. It is said that she impressed the already infatuated Mark Anthony with her indifference to wealth by dissolving a magnificent pearl earring in her wine and quaffing the mixture with elan. In actual practice, this feat would be impossible unless the pearl was pulverized and the wine was near vinegar. But perhaps the chroniclers of the time were too dazzled by the magic of the Isis-Incarnate to note such petty details as the grinding of the pearl to powder or the quality of the wine imbibed. If stories of Cleopatra's predilection for dramatic enchantments are true, it might not be beyond her to use a goblet with a false bottom and recover the pearl intact for later use! The symbolism of the tale is more significant than its historical reality. By partaking of pearl, Cleopatra was indicating that while pearl was a rich and costly substance, that no nectar was too dear for the palate of a Goddess. In the Egypt of her day, rulers were still believed to be physical incarnations of the Gods, so Cleopatra's apparent hubris becomes understandable given the assumptions of her culture.

Pearls have traditionally been talismans of mental as well as physical creation. While usually associated with Goddesses of love and procreation, pearls were also especially sacred to the Nine Muses, the deities who inspired humans to create poetry, drama and song. Pliny the Elder, Roman historian who lived from A.D. 23-79 mentioned that caskets of pearls, most of them war trophies, decorated a famous altar to the Muses. It is easy to see the metaphorical relationship between the pearl and spiritual sources of inspiration. Many artists have written of the link between suffering and creation and empathized with the homely oyster which covers the source of its pain with layers of glistening nacre, much the way the artist takes the pain in his or her life and covers it with layers of paint, clay or adjectives to create a thing of lasting beauty. One tribute to the oyster's creative powers follows:

Know you, perchance, how that poor formless wretch
The Oyster, gems his shallow moonlight chalice?
Where the shell irks him, or the sea sand frets,
He sheds this lovely lustre on his grief.

—Sir Edwin Arnold (1832-1904)
"The Oyster"

In the centuries which bridge the ancient past with our present, the pearl continued to be a source of wonder, speculation, wealth, metaphor and even healing. In the Bible, sacred to Judeo-Christians, St. John's conception of the heavenly city includes gates of pearl (Rev. XXI,21). As the moon was once regarded as a door to spiritual illumination, so we see her emblem, the pearl, on the gates to a new heaven. The Biblical heaven was a heaven of the Father, but the symbols of the Mother Goddess guarded the gates therein with a mixture of old and new symbology. The third of the Mohammedan's seven heavens was entirely composed of pearl. The Bible refers to pearls many times as symbols of purity, chastity, great worth, and wisdom. One of the most famous Biblical references is 'Pearls before swine,' which is a metaphor for knowledge wasted on the ignorant or profane. Wisdom, like pearls, is formed by the slow accumulation of layers of knowledge. The pearl provides a lesson upon the uses of pain and adversity by converting affliction into a precious gem symbolic of all that is pure and beautiful. As the great Persian poet Hafiz says:

"Learn from yon orient shell to love thy foe / And store with pearls the wound that brings the woe."

In many cultures, pearls were thought to have magical and curative powers. The Romans believed that yellow pearls brought wealth, brown pearls wisdom, white pearls freedom, and green pearls, happiness. The Chinese believed that pearls increased sexual vigor, improved eyesight and cured ailments of the ear. Since pearls contain a lot of calcium, it is possible that in a calcium deficient body they might stimulate healing. Eastern cultures such as Japan and China consumed little milk or dairy products, so perhaps pearls—an expensive alternative!—provided some of the necessary nutrients. As to sexual vigor, the much touted story of Cleopatra suavely dissolving a large pearl in wine and sipping it before the bedazzled Mark Anthony certainly would seem to indicate that the ingestion of pearls makes one *feel* sexy. The Taoists considered pearls a vital ingredient in elixers of immortality. According to an old Taoist authority, one must take a long pearl worn for many years, and steep it in a combination of serpent's gall, honeycomb and pumice stone (the snake, bee and volcano represent the Goddess of life, destruction and rebirth). When the pearl becomes malleable it is drawn out to a length of two or three feet and cut into pill shapes which will prolong life indefinitely without need for further nourishment.

Indian Gemmologist Raj Roop Tank describes the medicinal properties of the pearl in his book, *Indian Gemmology:* "Pearl is specifically prescribed for diseases caused by the deficiency of calcium in human body and for the diseases of the heart. It is also indicated in diabetes, micturition, insanity and other mental diseases. Unbored pearls of good quality are crushed finely for eleven days in rose or Keora water. When reduced to a very fine powder and no granule remains, the paste is allowed to dry in shade and the powder is then taken as medicine with a suitable vehicle according to the directions contained in the well-known books of Ayurvedic and Unani systems of medicine."

The thirteenth century German monk Albertus Magnus listed pearls as being beneficial for "mental diseases, affections of the heart (also known as love-sickness) and in hemorrhage and dysentery."

The famous 'aqua perlata' was regarded as a sovereign remedy for almost everything (but especially melancholy and the dread love-sickness) from the middle ages to Victorian times. Writer Anselmus de Boot and scientist Francis Bacon both believed in the efficacy of aqua perlata, which was described as a mixture of fresh lemon and pearl powder, sometimes mixed with sugar, rosewater, tincture of strawberries, borage flowers, balm and cinnamon water. If nothing else, it sounds like a refreshing beverage for a sunny day at the beach, and the combination of calcium from the pearls and vitamin C from the fresh lemon probably had an invigorating effect. Other common pearl recipes from the Middle Ages include pearl milk or elixers of jacinth and pearl remedies which were applied for high fever or great weakness. These and other pearl concoctions probably had more magical than nutritional effect, but the placebo principle is as valid a medical concept today as it was to the healers and shamans of ages gone by.

Of course, pearls were not always regarded as beneficial in their effects. Johann Wolff seriously considered whether the mysterious illness and death of popes Leo IV and Paul II could have been caused by the large numbers of pearls and stones they wore, the coldness of such objects causing a fatal chill to their owners. It's lonely at the top . . . Like the opal, the pearl also suffered from the rumor that they lost their luster with the death of their owner. When the moon began to be regarded as a herald of baneful influences (e.g., *lunacy*) rather than a source of beneficient inspiration, pearls also assumed a questionably occult reputation. George Frederick Kunz casts the cold water of reason against this legend in his authoritative work *The Magic of Jewels and Charms* saying: "The invariable experience of the writer has been that whenever pearls have been said to have suffered in this way, the true explanation has been that they were old and poor at the time of their purchase, and that this romance was started on its travels as an excuse to cover up the defect of such pearls and to arouse the belief that they had been remarkably beautiful and valuable when they were originally acquired."

In Europe of the Middle Ages, pearl powder was in vogue with the apothecaries of the time, but the jewels themselves were frowned on for the same reason that they were once honored: their connection with the powers of the moon. It was an age where woman's power—the power of lunar cycles and everyday miracles of seasons and birth—was being crushed. As a moon talisman, pearls were tied in to the previously dominant Nature religions and therefore contrary to the creed of transcendant divinity. Many sumptuary laws were passed, restricting women from wearing pearls except under very limited conditions, such as the first ten or fifteen years after their first marriage. In 1609, all importation and dealing in pearls was forbidden in Venice, Italy. And in that same time range in Germany, the Bishop Tudertines excommunicated all the women of his diocese who wore pearls. In the American colonies, the Puritans banned pearls as "Pagan symbols."

Aceticism gave way to decadence by the dawning of the Renaissance. Queen Elizabeth I was known for her partiality to pearls as well as her reign of religious freedom and tolerance. By assuming the habit of a Goddess, she made her commitment to wordly pleasures clear. There were no sumptuary edicts issued in Elizabeth's time to deny the use of the earth's wonders to enhance personal beauty. She wore increasingly grand numbers of gems as her age advanced, in the apparent hope that, dazzled by the radiance of her pearls, her subjects and suitors would be blinded to the fading of her youth.

Joan Dickinson evaluates the historical and mythical significance of pearls in this summary: "As Nature herself became viewed simply as utilitarian to man, the pearl became viewed either as ornament or utility." Pearls have changed from moon symbols and objects of pantheistic worship, to occult or worldly temptations, and to ornaments signifying wealth and power. In our agnostic age, they are objects of material value only. But the soft lunar glow of the pearl still captures our hearts, as the moon still shifts the tides in our blood. A woman clasps a strand of pearls around her neck . . . and Aphrodite weaves her magic once again.

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Where Have All Our Answers Gone? . . . Or . . . Let Me Introduce You to Gill's Index

By JOSEPH O. GILL, C.G., F.G.A.
Sotheby, Parke Bernet, Inc.
Los Angeles, California

What is a *Gill's Index? Gill's Index* is the guidebook to all English language literature on the subject of gems and jewelry . . . the bringing together and the mapping out of that vast body of published knowledge on this specialized subject. This is the first time an effort of this kind has been made . . . and effort it was!

Over a period of 12 years I have been collecting a library of all books, papers and journals in the English language on gems and jewelry. For the first five years I sent out want-lists to over 300 fine book dealers all over the world and wrote a minimum of 20 letters each day. It was a "blitzkrieg attack" to create a complete resource library as rapidly as possible. It was my intention to find every rare and old book available on the market having reference to gems. Since I only read English and I wanted a usable research library, the only limitation I placed on my collecting was that all publications had to be in the English language. I searched the bibliography of each new acquisition for other related publications on gems and later found most of those references.

Journal collecting proved to be the most challenging. It was like assembling a puzzle—trying to piece together the hundreds of odd issues needed to complete each set of journals. Through the courtesy of several gem institutes, my needs were made known through their publications. This was done as a kindness and I deeply appreciate all their efforts. Ultimately, full sets of all the major and many of the minor journals were collected. The articles in the journals were amazing in that they covered in depth so many rare and unique subjects. One concentrated on lapidary, another on locations, and yet another on technical gemology or jewelry styles. Of the journals I collected, the earliest commenced publication in 1882 and several continue to the present day, so it is possible to witness on the spot the development of the science of gemology.

These journals together were like an immense volume of knowledge but with no index or table of contents. I had accomplished my goal of collecting a comprehensive research library only to find that it was of little use without easy access to the facts within. Recognizing the need for access to this knowledge I decided to create a complete subject index for each publication within my library.

Organizing the layout of such an index for quick information retrieval was not a small task. I decided that Part One should cover each gem individually, and over 180 gem materials are included. Part Two embraces world localities, country by country (93 countries in total), and the United States is further subdivided by state. Part Three consists of all the many technical aspects of gemology and includes a section on the growth of the various gem associations and institutes over the world. Part Four comprises antique jewelry, fashion, museum collections, lapidary and jewelry making.

The following journals are indexed individually in chronological order under each subject title within the four parts of the index:

1) Minerals Yearbook (chapters on gemstones)	
2) Mineral Resources	1882-1921
Mineral Industry	1905-1932
Minerals Yearbook	1932-1975
2) The Gemmologist	Aug., 1931-Dec., 1962
3) Gems & Gemology	Jan., 1934-Fall, 1977
4) The Journal of Gemmology	Jan., 1947-Jan., 1978
5) Lapidary Journal	Apr., 1947-Apr., 1978
6) The Australian Gemmologist	July, 1958-Nov., 1977

The journals have been listed separately under each subject for the benefit of most readers who possess only one or two sets of journals. The researcher will also find this beneficial in keeping his references well organized. The journals appear in the order in which they were first published and are listed that way throughout the text.

Following the journals, under each subject within the four parts, under the title of "Gem Library Bibliography," is a chronological listing of relevant books and articles. These additional references are as complete as possible—from the first book on gems in the English language published in 1652 to the most modern studies. In addition to books I include in this section specialized geological survey publications from many countries, college theses, various museum publications, and articles from other journals not fully indexed. All articles related to gems and jewelry are included from such journals as: "The American Mineralogist," "Nature," "Scientific Monthly," "Science," "The Mineral Digest," "Economic Geology," "The Mineralogical Record," "Journal of the Mineralogical Society of America," "Life," "Harpers," "Jewelers' Circular-Keystone," "Engineering and Mining Journal," "Rock and Gem," "The Canadian Mineralogist," "Rocks and Minerals," "The Mineralogist," "American Journal of Science," "Journal of the American Chemical Society," "Mineralogical Magazine," "Nicholson's

Journal," plus many more.

Many weekends I would start work at six o'clock in the morning and work straight through, with at most an hour's break, till two o'clock the next morning. In the beginning I had no intention of publishing the index but meant only to use it for my own research. However, I showed my notes to several people from the Gemological Institute of America and they saw the index as a worthwhile contribution to the study of gemology. They strongly urged me to finish my notes and prepare a manuscript as they would be pleased to publish the finished index. It took over 18 months of typing several hours a day just to copy my original handwritten notes.

At last the research is done, the manuscript has been published, and "Gill's Index to Journals, Articles and Books Relating To Gems and Jewelry" is available to all. In this 420 pages of index one can see how journals have attempted not to overlap each other in their special report studies, and they avoid repetition wherever possible. One is also able to see where the weaknesses occur in research. The text will be helpful in eliminating the reiteration of past reports and highlighting the potential for future original studies. The index is best used with some review of the introduction and especially the table of contents.

This book will be used by mineralogists, geologists, museums, libraries, students of gemology, writers, jewelers, amateurs or professionals planning gem field trips anywhere in the world, and by the more knowledgeable gemological associations.

After these 12 exciting and productive years of collecting, my research library now includes every major publication written in English on the subject of gems and jewelry and is one of the finest in the world.

It's a great pleasure to present *Gill's Index* through the Gemological Institute of America which has continually brought us the latest developments in gemology. I feel this effort was much needed and will be most appreciated by all gemstone and jewelry enthusiasts.

BOOK REVIEWS

GILL'S INDEX TO JOURNALS, ARTICLES, AND BOOKS RELATING TO GEMS & JEWELRY

A Review By Edward J. Gübelin, Ph.D., C.G., F.G.A., Lucerne, Switzerland

A precious technical book among the gem-literature.

The newly published Gill's Index is a helpful and time-saving instrument for all lovers of gems and jewelry who are not satisfied with merely owning or looking at these jewels but are also curious and interested about the origin, composition, formation - in short: all the knowledge that distinguishes the amateur from the expert. What is Gill's Index?

Joseph O. Gill, F.G.A., C.G., G.G., has created a reference-book that gives multi-dimensional information of the entire literature about gems and jewelry in the English language. Gill's Index mainly brings the publications of the eighteen leading technical journals (like The Gemmologist, Gems and Gemology, The Journal of Gemmology, The Australian Gemmologist, The Lapidary Journal etc.,) in a suitably structured summary.

The book consists of four parts.

The most extensive is the first part, which gives information about the general nature of natural gems and synthetic stones. Following are expert articles about more than 180 kinds of gems and decorative stones in alphabetical order from Actinolite to Zoisite.

The second part of the index puts the gemological literature in order of the geographical origin. Here, the scientific essays have been arranged under more than 140 places of discovery.

In the third part there are works about the gemological science, and the fourth part brings order into all the publications worth knowing about antique gems and jewelry. In all instances, under each of the already-mentioned sections, the title of each work is listed as in the technical journal and in chronological order, whereby the page number and also the names of all authors of importance are given.

Those who own Gill's Index never have to fear questions like: What is a Hambergite? Where does Ekanite come from? What are the characteristic properties of black coral? Which gems do you find in Kenya? etc. Everyone can immediately find the pertinent source in Gill's Index to be able to answer all questions. Even just reading the titles to the articles often gives answers to such questions and transmits much knowledge, so that one can see Gill's Index being used for revision purposes by scientists and students. No wonder the publisher of Gill's Index, the G.I.A., is proud of this work, and has therefore promised to renew it every few years. This welcome decision removes all doubts about whether or not to buy the book. (G.I.A. Bookstore, 1735 Stewart Street, Santa Monica, California 90404).

The idea and concept of Gill's Index should be taken up by other scientific branches of knowledge. After all, the motto for the expert stands: Not the not-knowing is shameful, but the not-knowing where you could look it up!

GEMOLOGICAL NOTES

The Optical Constants of GGG

By K. NASSAU, Ph.D.
Bernardsville, N.J. 07924

Since it was first used as a diamond imitation in the early 1970s, the optical constants of Gadolinium Gallium Garnet (GGG) have usually been given as RI 2.02 or 2.03 and DISP 0.038. I myself have used these values and am sometimes quoted as the source, but have merely repeated data current in the field.

Recent precision measurements by Dr. D. L. Wood of the Bell Telephone Laboratories gave the following values (rounded to five significant figures):

Refractive Index	(sodium light)	1.9698
	(G, 4308Å)	2.0043
	(B, 6870Å)	1.9597
Dispersion (G - B)		0.0446

Rounded off, the gemological values that should be used are: RI 1.970, DISP 0.045. There could be a small variability derived from compositional variations.

I am grateful to Dr. Wood for permission to use his data.

Remodeling the Ivory Tower

By CHERI LESH
Corte Madera, California

The House of Representatives has passed a bill which would restrict ivory imports in an ecological move to help save the world's remaining 1.3 million elephants from extinction. If passed by the Senate, this bill would place a six-month ban on the transport of all elephant products in and out of the U.S. After the initial six-month ban, imports would be allowed only with permits from the Department of the Interior. Such permits would be issued only if the nation exporting elephant products had U.S. approved regulations to protect their dwindling elephant populations from dangerous exploitation.

Jewelers are as concerned as anyone with preserving these magnificent animals, yet they may have mixed feelings about the loss of the beautiful substance of ivory from the jeweler's repertoire. Fortunately, many substitutes for ivory exist, including bone, antlers, antique or fossilized ivory, plastic substances, fictile ivories, and vegetable ivory.

Bone is, of course, the closest to ivory in its structure and composition. Though of a similar composition, it is somewhat less dense and does not show the graining usually seen in ivory. The bone most commonly used to simulate ivory is prepared from the long-bones of mammals, especially the bones of cattle, which are a by-product of the meat trade. There is no shortage of supply, so despite the necessary preparation of the material, called degreasing, it is a cheap and plentiful substitute.

Antlers are a less commonly used substitute, but this natural animal product has great potential for more widespread use. Many deer shed their antlers every year and grow new ones, so the species need not be threatened by extinction because of the value of their horns. For instance, in Jackson Hole, Wyoming, the Boy Scouts make an annual collection of fine elk antlers which the elk shed seasonally. These antlers are then put up for sale, and are especially popular with Oriental buyers who purchase them for detailed carvings such as the Japanese netsukes and occasionally for their alleged aphrodisiac qualities. Deer horns are also commonly used for knife handles and inlay work. Deer horn is generally more brownish-yellow in hue than bone or antique ivory, and has its own unique and distinctive beauty.

It is sometimes possible to obtain antique elephant or whale ivory which is already in this country. Since whales are even more endangered than elephants, no one would question the ethics of abstaining from purchasing whale materials from recent kills even if the law permitted it. But there is still some antique material from the days of the huge New England whaling industry which is generally used for scrimshaw. Curiously enough, one can occasionally obtain fossilized ivory from an animal already extinct, the woolly mammoth. Fossilized ivory from these ancestral elephants has been found in Northern Europe, Asia, Russia and the North American continent, preserved in the natural refrigerator of glacial ice. This ancient ivory tends to have a mellow tan or yellowish tint and, aside from a slight brittleness due to age, is identical to modern ivory.

The plastic ivory imitations are probably the most widespread and cheapest form of ivory substitute available. Types used for the production of artificial ivory substances include cellulose acetate, ethyl cellulose, bakelite and other thermoplastics, as well as casein, which is a milk by-product. Plastic substitutes usually exhibit a noticeably lighter weight and specific gravity than bone or ivory. The plastics usually exhibit little or no graining but can appear quite convincing, particularly when the pieces are small or used in conjunction with other jewelry materials. Ivory-like plastics may be dyed to obtain an 'antique' look, and sometimes these 'aged' hues are the most convincing in appearance.

Other prepared imitations are

known as Fictile ivories; these are copies or reproductions of artistic ivories made of plaster of paris (gypsum) tinted with yellow ochre. The glossy surface appearance of such imitations is a result of treating the surface with a mixture of wax, spermaceti or stearine. These artificial ivories are the easiest to distinguish from genuine ivory, and thus the least useful to the jeweler.

Perhaps the most unexpected and fascinating of the ivory substitutes is vegetable ivory. There are two sources for vegetable ivory, the 'ivory-nut palm' which is native to South America, the fruit of which is known as Corazo Nuts, and the nuts of the Doum Palm which grows in North Africa, especially Egypt. The 'ivory' of the Corozo nuts has traditionally been used in the manufacture of chess pieces, small ornamental objects and buttons. While the size of the nuts is too small to fashion very large objects, larger pieces may be constructed by interlocking pieces or with a mosaic technique. An example of this artistic approach is the model temple in vegetable ivory exhibited at the Royal Botanical Gardens at Kew. Both species of vegetable ivory have a lower density than dentine ivory, but with their attractive appearance and high polish they are easily mistaken for the more valuable animal product. Vegetable ivory may be easily dyed to resemble antique ivory or horn, and in some cases has even passed for coral. The structure of both palm nuts is pure cellulose, and their cellular structure often creates a grain appearance similar to animal ivory.

Jewelers can take heart, then, that the beauty of ivory jewelry need not pass into extinction. Even customers who initially insist on 'genuine' ivory can probably be mollified by appealing to their natural desire to preserve the intelligent and fascinating elephants for the enjoyment of future generations. Ivory substitutes enable the customer to enjoy the beauty of ivory while feeling a sense of satisfaction that they are contributing to the protection of a vanishing species.

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Gemology As a Profitable Sales Tool

By STUART J. MALKIN, B.Sc., G.G.

Our firm has, through experience and intuition, developed a series of operating concepts which we have found to be not only ethical but highly profitable. They are presented here as they specifically relate to the sale of gemstones and jewelry.

We use gemology as a basis for sales. Most customers are very interested in the gemstone(s) they are considering purchasing. We "instruct" our customers in the gemological aspects of the stone they are purchasing; where such stones are found, how they are mined, why they are rare or exist in limited supply. These concepts make every gemstone a "conversation piece" for the customer.

We first try to establish the customer's preference in gemstones, then in the mounting. We like the GIA concept that the jewelry should be purchased before the clothes. Our customers like to build a coordinated outfit around and based on the gemstone!

It is important that the negative aspects of a gemstone be completely revealed to the customer. This not only builds his appreciation for stones of better color and clarity, but reinforces his judgement of you as a trained, ethical gemologist. Further, inclusions in gemstones can be a valuable sales aid. For one thing, they are frequently "proof" of a "natural" stone - a good concept for a customer to understand and appreciate. Inclusions are also a good point of interest for the customer when he is proudly displaying his acquisition. They open the door to the sale of other gemstones as the customer's appreciation builds. We teach our customers to use a loupe, and for larger gemstone sales we present the customer with a loupe and pair of tweezers.

Any appraisals or "calls" the gemologist makes should be conservative. Color gradings, split clarity calls, quality judgements of colored stones, etc., should all be made on the low side. We believe this operates to the customer's great advantage - you should do it, and tell the customer you are doing it! Most everything you do should be in writing. Certainly stones or jewelry submitted for repair, remount or appraisal should be examined in the customer's presence and descriptions recorded. Flaws, suspicion of synthetics, etc., should be dutifully recorded as this can only increase the customer's awareness of your professionalism.

You should maintain and publicize a gemological laboratory with the best instruments available. We give our customers a list of all our equipment, as they appreciate knowing that their gemstones were thoroughly examined scientifically and professionally. We conduct a gemological examination of every stone sold by us or submitted to us. "Sight calls" are out of place in our concept. Normally, we do not allow customers to observe testing procedures, but we are glad to discuss them in detail should a customer be interested.

Master sets should be constructed for the gem being graded. CZ color masters are fine for grading Cubic Zirconia but not for grading diamonds. There is a tendency, due to the relative ease of assembling a CZ Master Set, to eliminate the need for diamond master grading stones. We feel this would be a professional failing. So we use the very fact of a GIA master diamond grading set as a sales point.

We encourage questions and future customer contact. We want customers to think of us when they have questions about gemstones—as we will take the time to increase their understanding, notwithstanding the absence of an imminent sale.

It is no accident that "natural," "real" and "honest" continue to survive as concepts which most people truly hold as highly desirable life criteria. That such concepts are not operative in many segments of the business community is a source of great disappointment. Our language itself has added a new term, "rip off," to characterize the popular view of the business world, sometimes with considerable justification.

Happily, there is an alternative and it has total applicability to the gemologist/jeweler: "*Always* operate in your customer's best interests." Think about that! To construct your business philosophy around a concept that says "every decision I will make today about this job, this ring, this gemstone, this sales presentation - or whatever - will be *from the customer's vantage* and in their best interests." You will discover that such a business posture is the most profitable operating concept ever conceived. Patently, customers will return to you for sale after sale; you and your employees will be happier with yourselves and radiate this happiness to customers. It is to your advantage that many businesses do not operate this way and would never think of doing so, therefore, YOU and YOUR company can emerge as the trained and ethical gemologist/jeweler.

Aschentrekker

By BETSY BARKER, G.G.
Gemological Institute of America
Santa Monica, California

Aschentrekker — the ash-drawer — tourmaline; the mysterious bit of stòne that pulls ashes out of the bowl of a long clay pipe. During the 1700's in Holland, this was a favorite toy for the wealthy traders and a question for the scientists of the European world. For the Dutch, it was magic brought back from the fantasyland of the distant colonies in Asia. Like a magnet, the aschentrekker seized the minds of the western world with its magical power to attract ashes.

Holland, (now the Netherlands) was immensely powerful in the 1700's. Her navy controlled the seas of Europe, and traded with the almost mythical lands of Asia. When tourmaline first arrived from Sri Lanka in 1703, Holland was a paradise for the middle classes. Bankers, skilled shipwrights, and textile barons provided a ready market for the skills of painters such as Rembrandt, Van Dyck, and Vermeer. One of the paintings by an English artist, Hogarth, shows a young man viewing the sun through a transparent, gemmy crystal of tourmaline.

But without tobacco, a recent import from the Americas, the odd properties of tourmaline would have been unknown. Although primitive cultures in Africa and Europe had used pipes, it was not until the Golden Century of Holland in the 1600's that sailors brought back the custom of smoking tobacco in a pipe. Tobacco is native to the Americas, and many of the fortunes of early settlers in the Colonies were based on the cultivation of this plant. The Spanish, notorious conquerors of South America, were the first to succumb to nicotine addiction, but the rest of fashionable society soon adopted this habit. All Europe began to reek with the smoke of a thousand tiny fires.

Along with pipe smoking the use of tourmaline spread from the Low

Countries to the capitals of eighteenth century Europe. Along with the mania for this unusual crystal went the name, turmali, coined from the Sinhalese word. In Ceylon (now Sri Lanka), turmali refers to a mixed lot of yellow and brown pebbles found in gem gravels around the island. These lots usually included zircon as well as yellow and brown tourmaline. The first recorded import of tourmaline from Ceylon was in 1703, but other sources in the Western world were known before this time. The island of Elba, known as the prison for Napoleon the First in a later time, produced a variety of colored gems, all with an unusual layer of black color on the free end of the crystal. Brazil also produced a variety of colored tourmaline, but few sources record imports from this area. Since the green tourmalines were being imported under the name "Brazilian Emeralds," it is unlikely that any tourmalines were imported for their own beauty. In every age, other green gems have been substituted for costly and rare specimens of emerald. If only the refractometer had been invented at this time, identification would have been simple!

Scientific authorities in Europe tried to identify and classify the tourmaline from Sri Lanka. The quest for knowledge in this era led them to investigate the bit of parlor magic known as "aschentrekker." The distinctive crystal structure of tourmaline causes two unusual properties, pyroelectricity and piezoelectricity. Scientists today explain the "aschentrekker" as a phenomenon of pyroelectricity, but in ancient times it was a mystery controlled by powers beyond comprehension. Early researchers into the occurrence of pyroelectricity included Thales, who reported that amber would attract dust when rubbed. This observation was made in 600 B.C., well before the founding of GIA. More recent scientists such as Gilbert noted the same effect in several other gems in the Sixteenth century. Gilbert named this strange effect electrification, to commemorate the work of Thales. The root of electrification is electron, the Greek word for amber. Diamond, topaz and glass also can exhibit the power of attraction. The French Academy of Science learned of pyroelectricity when Monsieur Lemery demonstrated it before the members in 1727. To Carolus Linnaeus, the noted Swedish botanist, tourmaline was "borax electricus" or electrical stone. It remained for later research to classify this complex gem more completely.

Rome de Lisle, noted for postulating the rule of the constancy of interfacial angles, concluded that the tourmalines from Sri Lanka were indeed the same as the schorl (black tourmaline) found in mines in Germany. The founder of the science of crystallography, the Abbe Rene Just Hauy, also studied the tourmaline to discover its true nature. But it was not just the French who explored the scientific problem. Benjamin Franklin, hero of early American history, corresponded with English colleagues about tourmaline and its peculiar properties.

John Ruskin, a noted mineralogist, studied the chemistry of tourmaline. In 1858, he explained that tourmaline is composed of:

> "...a little of everything; there's always flint, and clay, and magnesia in it; and the black is iron, according to its fancy; and there's boric acid, if you know what that is; and if you don't, I cannot tell you today; and it doesn't signify; and there's potash and soda; and on the whole, the chemistry of it is more like a medieval doctor's prescription than the making of a respectable mineral."[1]

Recent studies have agreed that the chemical formula of tourmaline is extremely complex. The three main groups are alkali, iron and magnesium based. The chemical formula, to be complete, is: (Na, Ca) (Li, Mg, Al) - (Al, Fe, Mn)$_6$ $(BO_3)_3$ (Si_6O_{18}) (OH). This jumble of parentheses translates into a series of closely related minerals separated by slight chemical variations. Each element shown in the first three pairs of parentheses can substitute for another in the same parentheses. Gemmy material is usually elbaite, a lithium tourmaline. Liddicoatite, though only recently discovered, has been faceted into unusual shapes to show off the common bright green and shocking pink bicolor. However, no cameo artist has yet carved the portrait of the famous gemologist in a specimen of the gem that bears his name.

Either heat or pressure can generate an electrical charge in the hemimorphic structure of tourmaline. The power of the "aschentrekker" is due to the difference in electrical charge that can be created at the ends of a tourmaline crystal. The phenomenon responsible for this effect is pyroelectricity. Pyroelectricity is another word that has its origins in the Greek language. Pyro means heat or fire, while electricity is from the original Greek word for amber. Heat, whether in the form of sunlight or friction, can cause tourmaline to attract dust and bits of paper. A crystal of tourmaline in a sunny display window will accumulate dust and lint particles as long as the sun shines. If a slender pencil of tourmaline is rubbed hard with a woolen cloth, the same effect can be seen. The gem will pull bits of dust closer as if by magic. Bright, intense lamps of a jeweler's showcase can also heat the tourmaline enough so that it will soon be covered with a layer of fine dust. The heat loosens or breaks the atomic bonds on the surface of the gem, resulting in the movement of electrons within the crystal, and an electrical charge at the ends of the long c axis. When the crystal cools, the electrons are drawn back into their original position, causing a reversal of the electrical charges in the crystal. When a pencil of tourmaline is inserted into the bowl of a pipe, the warm ashes heat the crystal, creating an electrical

[1]"The Tourmaline", by Louis Zara, "Mineral Digest", Winter 1973, p. 35.

charge that pulls the ashes out of the bowl.

Similar to pyroelectricity is the phenomenon of piezoelectricity. Both phenomena are due to changes in the electrical field of a tourmaline crystal, but the piezoelectric charge is caused by pressure, not heat. The piezoelectric charge was discovered in 1881, by two of the famous Curie family, Pierre and Jacques. When pressure is applied down the length of the c axis, an electrical current is generated that creates a positive charge on one end of the crystal, and a negative charge on the opposite end of the crystal. This pressure also causes a slight rearrangement of the electrons in the crystal, creating opposite charges at the ends of the crystal. Although few crystals show this phenomenon strongly, it can be used in a variety of industrial applications.

The amount of current created is directly related to the amount of pressure on the crystal and the size of the area that is compressed by the pressure. A strong alternating current can be created in a piece of tourmaline if it is struck repeatedly along the c or long axis. When the pressure is on, the current flows in the opposite direction. While a very slight pressure will not cause a current, pressure gauges of tourmaline have been used to record the power of surf breaking on a sea wall. More common uses of pressure gauges of tourmaline include depth recording devices in submarines, and blast pressure indicators.

Tourmaline is a remarkable gem, not only for its striking beauty, but also for its many industrial uses. The variety of colors make tourmaline appealing to every fashion and style. Since tourmaline is not well known to the buying public, the merchandising possibilities are limitless. Because of the glamour of tourmaline, it will rarely be in a jeweler's window long enough to draw dust. The true value of the "aschentrekker" is in its power to enchant and attract anyone who appreciates this exceptional gem.

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1980 Schuetz Design Contest Winner

The winner of the 1980 George A. Schuetz Memorial Fund Jewelry Design Contest was Susan Hastings Bates, who works for Laykin et Cie. in San Francisco, California. Ms. Bates' design, pictured here, is for a pair of men's cufflinks in 18K yellow gold, each set with two trilliant-cut diamonds in platinum prongs. There are two 18K pressure hinges on the backs of the cufflinks.

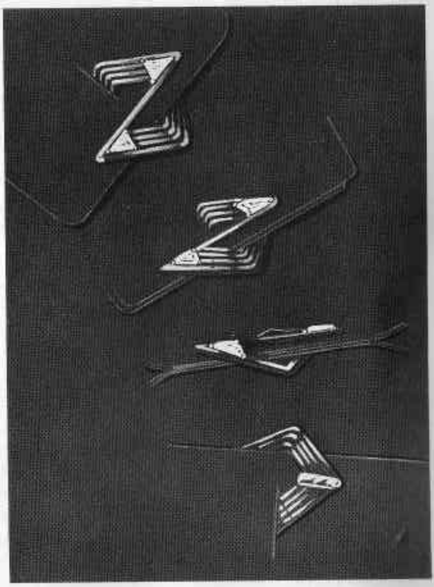
Second Place in the judging was awarded to Rose Kam Sun Wong of Victoria, British Columbia, Canada, for a man's ring set with a black pearl and black chalcedony. Third Place went to Sara A. Hitt of Palo Alto, California, for cufflinks set with four 15-point diamonds and black onyx.

The First Place winner is awarded a $500 scholarship to be used for any jewelry-related training at any institution of the winner's choosing.

The Panel of Judges, who select the winning entry on the basis of beauty and originality of design, feasibility of wear, manufacturability and the effective use of materials, included:

Howard J. Henkes, Henkes Jewelers, Los Angeles, CA.

Edward Newman, graphic designer and illustrator, Santa Monica, CA.



Pepi Kelman, designer, Nova Styling Inc., Los Angeles, CA.

Carl S. Chilstrom, GIA Staff, Santa Monica, CA.

Our thanks to the Panel of the Judges and to all the contestants, and our congratulations to the winner. The Schuetz Contest, which is for men's jewelry specifically, is held annually, and anyone who wishes to enter in 1981 should contact GIA for contest rules and entry blanks after October.

GIA

Gems & Gemology

CALL FOR MANUSCRIPTS

In 1981, the Gemological Institute of America will celebrate 50 years of leadership in the study and teaching of gemology. In conjunction with this celebration, the Institute is totally restructuring its publication, GEMS & GEMOLOGY, to better serve the gemological community. This new professional journal will promote research in gemology and communication among all those interested in gemstones and gem materials.

Editor in Chief, Richard T. Liddicoat, Jr., President of GIA, will be assisted in the development of the new journal by Associate Editors Peter C. Keller, Ph.D. and D. Vincent Manson, Ph.D. and by Managing Editor Alice S. Keller.

Prospective authors are invited to submit manuscripts from all relevant fields, including (but not limited to) colored stones, diamonds, gem instruments, gem localities, synthetics, gemstones for the collector, pearls, and the jewelry arts. Manuscripts may be submitted as original contributions (original studies and laboratory or field research), gemology in review (comprehensive reviews of topics in the field), and notes and new techniques (brief preliminary communications of recent discoveries or developments in gemology). Authors are encouraged to submit both color and black-and-white photos and suitable line illustrations to support their articles where appropriate.

All submitted manuscripts will be promptly reviewed by at least two members of GEMS & GEMOLOGY's distinguished editorial review board. Authors will remain anonymous during the selection process so that all articles will be reviewed on the basis of merit alone. Every effort will be made to publish papers as quickly as possible after acceptance. The new GEMS & GEMOLOGY will be published quarterly, beginning with the Spring 1981 issue.

Please direct requests for style sheets and other editorial communications to:

Alice S. Keller, Managing Editor
GEMS & GEMOLOGY
1660 Stewart Street
Santa Monica, CA 90404

The New GEMS & GEMOLOGY Suggestions for Authors

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.

Gemology in Review — comprehensive reviews of topics in the field. A maximum of 8,000 words (32 double-spaced, typewritten pages) is recommended.

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.

References. References should be used for any information that is taken directly from another publication, to document ideas and facts attributed to—or facts discovered by—another writer, and to refer the reader to other sources for additional information on a particular subject. Please cite references in the text by the last name of the author(s) and the year of publication—plus the specific page referred to, if appropriate—in parentheses (e.g., Liddicoat and Copeland, 1967, p. 10). The references listed at the end of the paper should be typed double spaced in alphabetical order by the last name of the senior author. Please 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:

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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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Please send three copies of each manuscript (and three sets of figures and labels) as well as material for all sections to the Editorial Office, in care of:

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Only manuscripts that have not appeared elsewhere in any but abstract form and are not under review elsewhere will be considered for publication. No payment is made for articles published in G&G.

Review Process

Manuscripts are examined by the Editor, one of the Associate Editors, and at least two reviewers. The authors will remain anonymous to the reviewers. Decisions of the Editor are final. All material accepted for publication is subject to copyediting; authors will receive galley proofs for review and are held fully responsible for the content of their articles.

Reprints

Authors of all articles appearing in G&G will receive 50 free reprints approximately one month following publication. Additional reprints may be ordered directly from the Editorial Office.

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:

One year = $16.50 (U.S.)
$20.50 (foreign)
Three years = $45.00 (U.S.)
$55.00 (foreign)

Special rates for students actively involved in a GIA program:

One year = $12.00 (U.S.)
$16.00 (foreign)

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.