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On the Cover

A 60-carat Persian turquois blossom, with a diamond-set calyx, tops a flexible stem of baguette diamonds in this pin designed by Marc Kovan, of New York City. Small turquoises set in 18-karat yellow-gold prongs enhance the brilliance of the small round diamonds that pave the sepals of the calyx. The pin was one of the fifteen that received awards in the Diamond International Awards, at the Waldorf-Astoria, New York City, October, 1961.

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Artificial Coloration of Diamonds

by

A. A. Schulke

Radiations and Their Effects

During the past twelve years thousands of carats of diamonds have been artificially colored by nuclear radiation. Although it has been known for more than fifty years that diamonds could be colored with radioactive materials, the availability of modern nuclear machines, and their powerful sources of radiation, have created a commercial enterprise out of what was once a little more than a scientific curiosity.

All of this early work was done with alpha rays from radium compounds. The result of much of this work has been excellently reported by Lind and Bardwell.(1)

Today, although neutrons are in most general use for the color treatment of diamonds, they are not necessarily the best form of radiation for this work. There are several other types of radiation that can cause these color changes, and it might be interesting to compare and evaluate them for their usefulness in treating gemstones.

In a general sense, these radiations can be classified in three main groups: those in which positively or negatively charged atomic particles penetrate the stone, and remain there; those in which uncharged particles penetrate the stone, and may or may not remain; and by pure energy. In the first group we have protons, deuterons and alpha particles (positively charged), and electrons (negatively charged). In the second group we have only neutrons, and in the third we have X-rays and gamma rays. So far, only the first two groups have been useful for diamond-treatment work.

Although there are many types of machines capable of producing these radiations, up to now only three have had any general use: the cyclotron, for protons, deuterons, alpha particles and neutrons; nuclear reactors, for neutrons; and the Van de Graaff generator, for electrons. Of these, the cyclotron is undoubtedly the most useful, but it is also the most scarce and least available of the group. Much greater skill and experience is also needed to perform irradiations with this machine than with the others.

Most conventional cyclotrons accelerate protons, deuterons and alpha particles in the energy range of about 5 Mev (million electron volts). Despite this high energy, however, the range these particles have in diamond is very limited and any color produced in the stones will be confined to a thin surface layer.

This surface color can be put on either the culet or table, or both; but since the color is only a surface layer, there will be some visible optical effects that, to someone skilled in recognizing them, can be used to determine the type of treatment a stone has had.(2) Having the color on the surface also has a considerable advantage, in that it is difficult to completely ruin a stone because of too much exposure. A stone too dark in color can have its original color restored by grinding off the irradiated surface layer. There will, of course, be some loss in weight, but this is a small premium to pay for the insurance against loss of the entire stone.

The range these particles have in diamond is graphically illustrated in *Figure 1.* The range is given in mils (thousandths of an inch) and the energy in millions of volts.

It is interesting to note that when diamond (or any other material) is irradiated with particles of some given energy, they will *all* penetrate the stone to the depth associated with this energy. If, for example, we irradiate a stone with 18-million-volt deuterons, all of these deuterons will lodge in the stone at a depth of about .021 inches. This does not mean, though, that the color produced by these particles will be a thin green sheet at this depth, because the color we get under these conditions is the result of the passage of the particles *through* the stone, and not from being lodged in it.

It is also interesting to note that protons, deuterons and alpha particles are all basic particles of gases: hydrogen, deuterium and helium, respectively. If, then, we irradiate a stone with alpha particles, we will have a layer containing as many as 10^{15} atoms of helium somewhere within the stone; with protons or deuterons we will have hydrogen. So far, no effect has been observed from this.

Cyclotrons are now being designed and built that will accelerate nuclei of still heavier atoms (such as lithium, beryllium, boron, carbon, nitrogen, neon and argon), and it is possible that some of these will react with diamonds as an impurity and produce an effect not obtained by ionization alone. Scientists at the General Electric Research Laboratory have recently done this by fusing a small amount of boron into natural and man-made diamonds (under high temperature and pressure), and found that the stones became electrically conducting and blue in color—effectively changing them into the rare, type IIb diamonds.

Heat treatment of diamonds that have been cyclotron irradiated to green will almost always change them to some shade of yellow, gold or brown, the final color being directly related to the

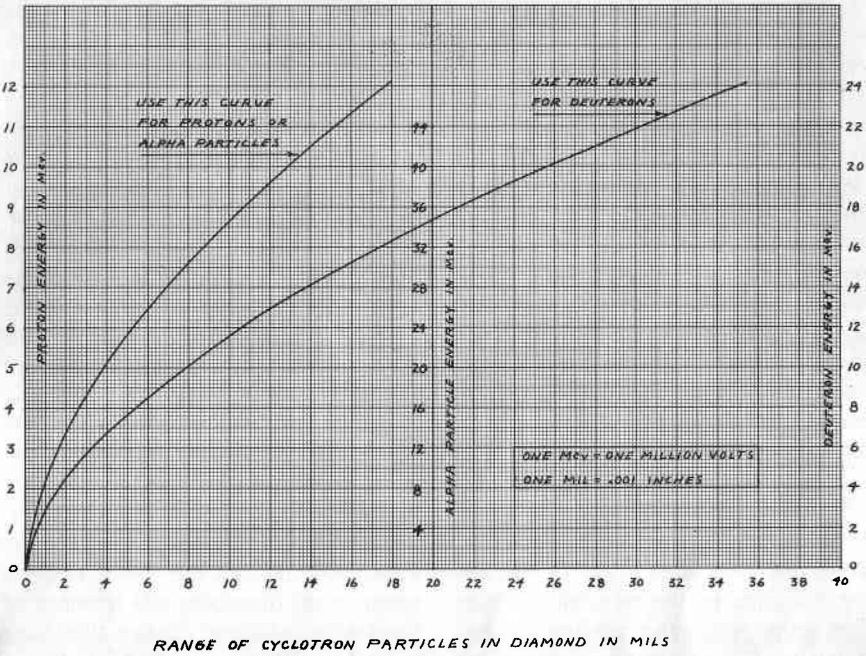

Figure 1

original shade of green. For medium-green stones the heat-treated color will be a light gold; for dark green, a rich gold; and for very dark green or almost black stones, the color will be a mahogany, or red-brown.

Electrons have much the same effect on diamonds as cyclotron particles, and are usually obtained from Van de Graaff machines, in an energy range of about 0.5 Mev to 3 Mev. This seems low, compared to the multimillion-volt particles obtained from cyclotrons; but because the mass of an electron is thousands of times smaller than that of cyclotron particles, electron ranges in diamond are many times greater.

The range of electrons in diamond is illustrated in *Figure 2*. By comparing this graph with the graph of *Figure 1*, we find that a 40-million-volt alpha particle has a range of 12.7 mils (0.0127 inches) in diamond. To obtain this same range from electrons we need only 400 kilovolts.

The color produced in diamond by electron bombardment varies from blue, at energies near 500 kilovolts, to blue-green and green at energies of 2 to 3 million volts. Attractive canary-yellow stones can sometimes be obtained by heating electron-treated stones, but, in general, the colors obtained from heating will be very similar to those obtained from cyclotron-treated stones.

Occasionally, some totally unexpected color, such as pink, will be obtained from electron bombardment but there is no satisfactory explanation for this, and such colors are obtained only by chance.

High-energy electrons also occur in lightning. The average lightning stroke has both the energy and quantity of electrons to color a diamond all the way through. This theory has apparently not been suggested before and has no experimental proof to support it, but it is not inconceivable that some diamonds, favorably located, have been in the path of one or more such strokes and were colored either by direct electron penetration, or by a combination of this and heating by the lightning.

This could well have happened during the formative years of the earth, when lightning was much more frequent than now, and might be the reason for some of the off-color, or even blue-white, stones that are found today. It might also explain why some stones change color when heated.(3)

Although irradiation with electrons and cyclotron particles produce many similar effects in diamond, there are two big differences between the two. With cyclotron particles we introduce substances into the diamond that are foreign to the stone. When electrons lodge in diamond they merely become part of the family of electrons already there, and no contaminating atoms are formed. As we noted, however, this difference has not produced any significant or observed effect in the stone.

The other difference, and one that is very useful, is that with electrons no lingering radioactivity is formed in the diamond and the stones may be examined immediately after irradiation. With cyclotron particles, and with deuterons in particular, quite a bit of radioactivity is produced, and several hours may be required for it to decay to a level safe enough to permit handling the stones.

The process by which a stone is colored by radiation is still not completely understood, but the evidence seems to support the theory that irradiation displaces electrons from positions they normally occupy in the crystal lattice. They then become trapped in vacant spaces between these lattice positions, producing so-called color centers. These displaced electrons have the property of absorbing energy from visible light and re-emitting it at some particular frequency characteristic of the stone, and of the type of radiation it received. For deuteron-treated diamonds this frequency is in the green portion of the light spectrum and the stones reflect a green color. Increasing the intensity of irradiation will not change this basic color but will progressively darken it until, if the exposure is continued long enough, the stone will appear to be completely black.

The energy of the irradiating particles will have some effect on the positions these displaced electrons occupy, and their optical absorption is also affected. This is one reason why diamonds irradiated with electrons of about 500 kilovolts will appear blue, whereas those irradiated with higher energy electrons will reflect a bluish-green or green color.

Heat treatment has a further effect on the displacement of these electrons, moving them to still different energy levels where the frequency of the reflected light will be of a different color.

The displacement of electrons in the diamond structure by irradiation with charged particles is a direct ionizing process and the carbon atoms are af-

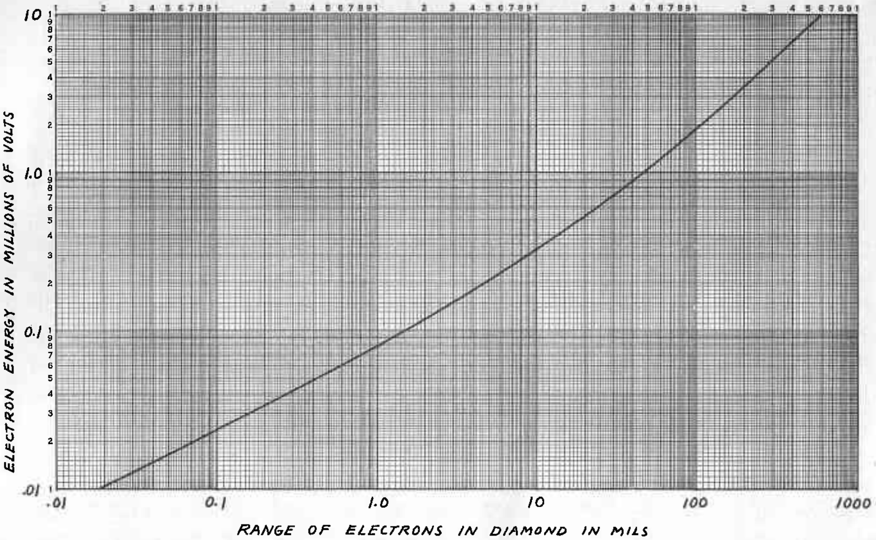

Figure 2

fected very little. With neutrons the process is quite different, because the neutron has no electrical charge.

When neutrons penetrate a diamond, they displace electrons indirectly by first bouncing off atoms of carbon, imparting some of the energy they have to these atoms with each elastic collision. The struck atoms, in turn, are dislodged from their lattice positions, losing some of their electrons in the process. These dislodged atoms are now effectively, moving, charged particles within the diamond, and interact with the electrons of other carbon atoms in much the same way as cyclotron-accelerated particles.

The end result, that of producing a green color in the diamond, is the same; but with neutrons, since the ionizing particles are generated within the stone itself, the diamond will be colored all the way through.

The consensus of most persons who have seen many treated diamonds is that the color obtained with neutrons is not as attractive as the color produced with charged particles. The greens, in particular, have a duller appearance than the surface-treated stones; this is probably due to the light-absorbing effect of the color centers being distributed throughout the body of the stone. There is another disadvantage, too, in that this color cannot be removed by polishing, as with the cyclotron-treated stones, so the risk of losing a stone that has been overexposed with neutrons is much greater.

It should be noted, though, that these effects are produced only with so-called fast neutrons, which is a very loose term with several definitions. In a nuclear reactor, the fast neutrons have a very broad range of energy and are heavily contaminated with slow neutrons. But Pough has observed that slow neutrons (that is, those with an energy of a fraction of a volt or so) are not effective in producing any color change in diamond.(4) In this respect, the cyclotron is again a superior instrument, for, in the irradiation space directly behind a neutron-producing target, the neutrons are all fast.

When diamond is irradiated with energetic particles, some, or all, of the energy of these particles is transferred to the crystal and stored in the lattice structure. This is the most basic of the physical changes that accompany the irradiation of materials and is fundamental to the study of radiation damage, a current, and major, field of study of these effects.

Radiation damage in a solid is the result of displacement of atoms in the solid by particles passing through it, of ionization produced by these particles, and of the irradiating particles that remain in the solid as impurities.

The last of these is the least important to us, because, so far, there apparently have been no detectable effects in diamond from cyclotron particles as impurities. The second item, ionization, produces color in the stones; the first produces effects that are almost all detrimental. These effects will be several thousand times worse with neutrons than with charged particles, and will be much worse with slow neutrons than with fast.

Graphite, in particular, has been the subject of much research in radiation damage, because of its importance as a construction material in nuclear reactors. And since diamond and graphite are elementally the same, the result of much of this work is directly applicable to diamond, too.

Some of these observed effects(5,6,7) in graphite and diamond with intense irradiation are: expansion of the lattice structure, with a corresponding decrease in density of as much as 4%; increase of electrical resistance; a change from the crystal structure to completely amorphous carbon; a decrease in hardness; and increased susceptibility to chipping. No change in the index of refraction in diamond has been observed, however; it was expected but could not be measured (after the test diamond turned green).

When only fast neutrons are used to color a diamond to green, these effects will be negligible; they will be significant when a diamond is treated to a dark green and when slow neutrons are present in reactor quantities and will be appreciable when a stone is treated to black. Most of the radiation damage can be removed by annealing, so that these effects may be insignificant in heat-treated stones. But it should be noted that for those stones treated to black, the annealing temperature is close to the point where the stones become graphitic.

These, then, are the radiations that have been used successfully to color gemstones, and with this as a basis, we might project a bit and speculate on the future possibilities.

It is extremely unlikely that any new color effects in diamond will be produced in nuclear reactors, but they will undoubtedly continue to be used for the routine production of present colors. The most productive research for new colors in diamond will probably have to come from particle accelerators, using new types of charged particles and particles of greater energy than we have now, or from concentrated and extremely radioactive materials.

There is also a strong possibility that reactor neutron treatments will eventually be supplanted by such radioactive materials. Some of these sources are available now, but some work needs to be done to determine the range and permanence of colors obtained with them and the length of exposure required.

Small electron accelerators, operating in the energy range of about 200 kilovolts to 400 kilovolts, could also be developed at relatively low cost, specifically for diamond-treatment work, and it is even possible that an importer or large-volume dealer in gemstones could afford to have his own machine.

It is evident, though, that color effects in diamond, both natural and artificially induced, are neither simple nor easily explained, and despite all the work that has been done to better understand these effects, there is still very much left for us to learn.

Cyclotron Irradiation

Historically, the first reported color change in diamond was made almost twenty years ago by J. M. Cork, who irradiated a few diamonds and crystals with deuterons at the University of Michigan cyclotron in 1942. Apparently, this work was not continued, and terminated with a brief note on the effects he obtained.(8)

Actually the pioneering work in this field had been done almost two years earlier by Martin L. Ehrmann, who irradiated diamonds with charged particles and fast neutrons in the cyclotron at Harvard University. Ehrmann continued his work in 1946 with the cyclotron at Columbia University and reported, in *Gems & Gemology,* some of the results he obtained from both cyclotrons.(9)

Meanwhile, F. H. Pough had been making independent investigations on the effect of radiation on diamond, using slow and fast neutrons and gamma rays from the reactor at Argonne National Laboratory, deuterons from the Columbia University cyclotron, gamma rays from 2½ grams of radium at the Fort Hope refinery in Canada, and X-rays from a powerful new tube at the Machlett Laboratories.

These preliminary investigations, although necessarily limited by more important war work, nevertheless produced much useful information, and were to be the basis for all the gemstone irradiation work being done in this country today.

In 1949, this work was transferred to two of the newest and best cyclotrons then operating: Ehrmann, using the 60-inch cyclotron at the University of California,(10) and Pough, using the 42-inch cyclotron at Washington University in St. Louis.(11) In 1952, Ehrmann also transferred his project to Washington University, where the work continued for another five years.

These two machines are no longer available for these irradiations, and although there are others now that have facilities for this, most diamond treatment work today is being done with fast neutrons from nuclear reactors and to a lesser extent, with electrons from Van de Graaff machines.

At Washington University, during the period between 1949 and 1957, more than 8600 diamonds were treated. These ranged in weight from two points to 70 carats and included stones of virtually every known cut, color, imperfection grade and fluorescence. Deuterons, protons, alpha particles and fast neutrons were used, but almost all of the work was done with deuterons at 9.1 Mev, because they were the most convenient to accelerate and their penetration in diamond, 0.0066 inches, was twice as great as that of the protons or alpha particles. Fast neutrons (from 10.2 Mev deuterons or beryllium and lithium targets) were used on several occasions, but they were not favored because of the long irradiation time required.

In the 15 to 30 hours needed to color the stones with neutrons, an equal quantity could be treated with deuterons in only one or two hours. These shorter irradiations made it much more convenient to arrange the work for brief open periods in the cyclotron-operating schedule, without interfering with the regular research programs.

Irradiation with alpha particles, rather than with deuterons, would have speeded up the work considerably, because the induced radioactivity would have been much lower; thus, the finished targets could have been unloaded and the stones inspected within 15 minutes or less. However, in addition to the objections noted, they were seldom used in the machine.

With deuterons, the stones were not safe to handle for one or two hours after irradiation, and the target-holders could not be reused until the following day; even then they were still radioactive enough to require cautious handling. By this time, though, practically none of the diamonds showed any detectable radioactivity.

The larger cyclotron at Berkeley frequently accelerated alpha particles, and these were preferred for diamond-irradiation work. The 40 Mev alpha particles available with this machine penetrated the stones to a depth of about .013 inches — twice that of the 9.1 Mev deuterons from the Washington University machine. The Berkeley cyclotron also accelerated deuterons to 20 Mev, with a range in diamond of .026 inches; but, because of the greatly increased problem of target radioactivity at this energy, it was considered an unimportant advantage and deuterons were seldom used.

The high-energy beam of particles was brought out from the cyclotron through a thin metal window and, when not blocked by a target, appeared as a thin, fan-shaped wedge. Close to the exit window it was only about 1½ inches long and 3/16 inch thick. Several inches further out it was spread to about four inches wide and ¼ inch thick.

A vacuum-tight box was installed at this exit window into which the targets to be bombarded were placed. They had many shapes, but all had which the material to be irradiated was some sort of water-cooled plate onto attached.

For all diamond targets, despite the relatively high thermal conductivity of diamond (better than that of some metals), it was necessary to supply additional cooling to the surfaces of the stones by irradiating them in an atmosphere of helium, which cools six times as effectively as air. Without this cooling they would sometimes get hot enough to change into a yellowish-green color.

The stones, unfortunately, could not

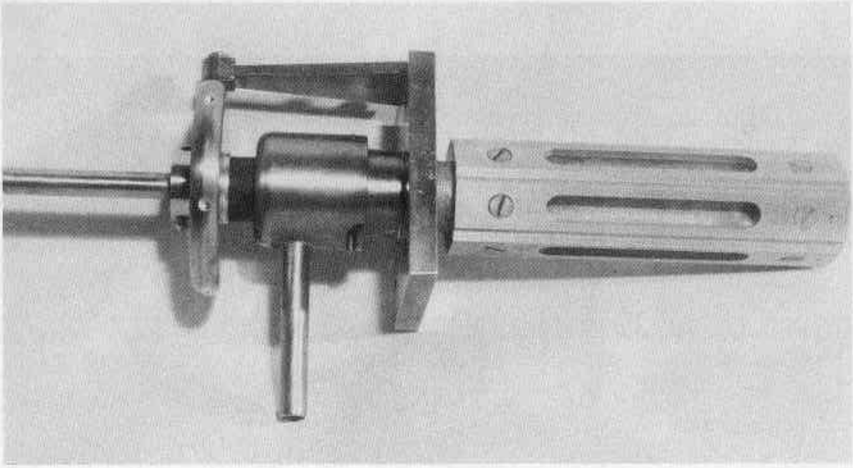

Figure 3

be viewed during the irradiation, because the radiation level from the cyclotron was so high — equivalent to that from seven tons of radium. The entire machine was, in fact, placed underground and heavily shielded with earth and concrete. Even after the machine was shut off, the radiation persisted in the metal parts around the target area and it had to be approached cautiously and the targets removed quickly.

Because of the large quantity of stones to be treated at Washington University, and the problems of time and radioactivity, some thought was given to more efficient target designs. These designs progressed through various stages, from the first painstakingly prepared ones where the stones were crimped into shaped holes in the plates by a jeweler, to the two shown in the photographs. The target-holder in *Figure 3* was mostly used for the larger stones of 10 to 20 carats, which required special orientation, but the assembly in *Figure 4* was preferred. This was effectively six targets in one, because the stones could be mounted on each of six faces, which could be rotated externally to face the beam without removal from the machine. The stones were mounted merely by placing them loosely in channels or holes cut in the water-cooled aluminum plate and holding them in position with a covering foil of .001-inch-thick aluminum clamped to the target plate. This is shown more clearly in *Figure 3*. For the largest stones (i.e., those heavier than 30 or 40 carats) or for those that were exceptionally broad and thin, special holders had to be designed to irradiate them where the beam was more diffused.

For irradiations on the culets, flat shims of aluminum were placed under the faces, so that the culets were all of about the same height. The covering foil was then pressed down over these pointed ends until they poked through the foil. In this way they were not only held securely in position but had direct contact with the cooling helium.

For irradiations on the faces an as-

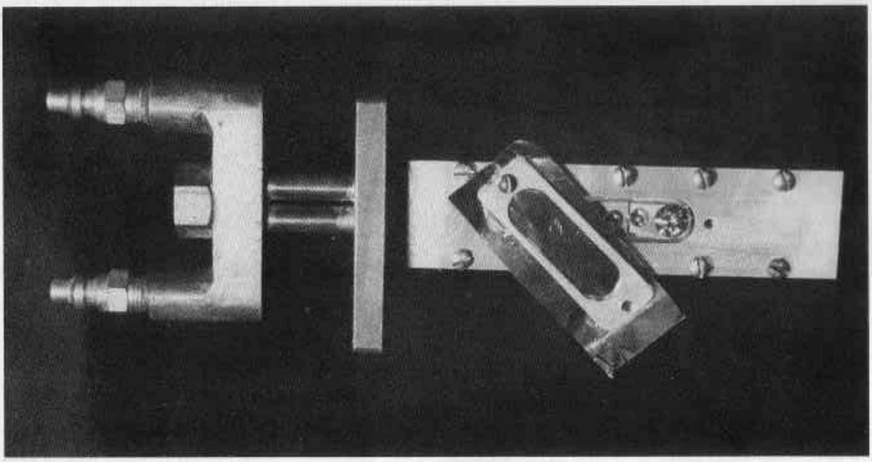

Figure 4

sortment of shims was used, which had small tapered holes bored in them. These not only kept the faces at the same height, but also kept the stones from tilting edgewise into the beam. The faces did not poke through the covering foil but, being relatively broad, had sufficient surface-area contact with the covering foil to be cooled indirectly.

The diamonds were treated on either surface, or both. Stones treated only on the culet appeared very pale when lying face down; although this was objectionable to the trade, it made no difference after they were mounted. The bottom treatment was preferred, because the stones had more sparkle than the top-treated ones. Diamonds treated on the top required about 50% more exposure for the same intensity of color than the bottom-treated ones. They showed color from either side, but face down they were much darker than when seen from the top and also had an objectionable black ring around the girdle. Top treatments were more useful with stones of poor colors than culet treatments, since these colors were somewhat masked by the filtering effect of the colored surface layer. For the trade, most of the stones were treated on both surfaces to give them a uniform green appearance when viewed from either top or bottom, but this more than doubled the cost.

Stones badly flawed with internal cracks could not be successfully treated to either green or gold. The bottom treatment actually emphasized these cracks and they appeared as white reflections against a darker background. The top treatment was better, in that the flaws at least had a little tint to them. Several of the worst stones, those with many internal cracks, were treated on both surfaces until they were totally black, making the flaws completely invisible and the stones very attractive. Other optical effects in the stones have been reported in an earlier issue of *Gems & Gemology.*(12)

The diamonds could not be checked for any chemical impurities, because this test requires destruction of the stone. But it was assumed that because of the great variety of sources and wide range of color quality, the stones were typical in the amount and types of foreign elements usually found in them.

Diamonds have been examined spectrographically by Chesley(13) and Bunting(14) and were found to contain as many as 13 elements. In order of abundance these were: aluminum, silicon, calcium, magnesium, copper, barium, iron, strontium, sodium, silver, titanium, chromium and lead. Any one diamond rarely contained more than seven of these, and aluminum, silicon and calcium were found in all of those tested. Thirty-six other elements were tested for but not found.

However, after irradiating a light-yellow cape diamond with neutrons from the reactor at Argonne National Laboratory, Freedman(15) found a radioactivity in the stone that could only have come from gold. He also estimated that about two micrograms of this element was in the stone and suggested that this was the reason for its yellowish color.

That many of these elements were present in the cyclotron-irradiated stones, too, was clearly evident because of the great variation in radioactivity induced in them.

The only detectable activity induced by short deuteron irradiation of absolutely pure diamond should have been nitrogen-13. This radioactive isotope, transmuted from carbon, has a half-life of 9.9 minutes, and an hour after the irradiation less than 0.1% of this should have remained. Longer activities than this were often observed in the stones, however, indicating the presence of other transmuted elements. Radioactivities with half-lives shorter than nitrogen-13 could not be detected, although undoubtedly present, because of the masking effect of the much more intense radiation from the nitrogen.

It is significant, then, that whatever contaminating impurities the stones may have had, these impurities apparently had no effect on the colors obtained. The impurities may have varied greatly but the colors obtained did not and were always predictable—so predictable, in fact, that it became routine to treat stones to match the color of some previously treated one.

It is characteristic of cyclotron beams that the density varies greatly within the area of the beam, and almost day-to-day variations may occur as some electrical or mechanical adjustment of the cyclotron is changed. For diamond irradiations this can be very troublesome, and the beam shape, position and density had to be examined frequently by making autoradiographs of blank target plates.

This variation was so great that at one time a brilliant as small as 3½ carats was streaked and had to be retreated. A few months later the beam had become so diffused that a 14-carat emerald cut (with a single-culet treatment) and a 26-carat heart shape (with a single treatment across the culet and another across the top) were irradiated on the same target that was used for the small brilliant and showed no trace of streaking at all.

The variation in density was even more strikingly demonstrated in another incident (before the necessity for helium cooling was realized) when the center stone in a group of three went through green to a golden-yellow color. The stones on either side of it remained cool enough to stay green.

This effect was minimized by swinging the beam from side to side during the irradiation, to distribute the particles more uniformly from end to end, but little could be done about the width. For most stones, especially the brilliants and emerald cuts, which were treated only on the culets, this gave no trouble at all. For irradiation on the faces, though, extreme care had to be used to avoid streaking. Moreover, many of the larger stones, from about eight carats up, had to have as many as three separate top irradiations, rotating the stones 60° between each treatment.

Despite these difficulties, out of the thousands of diamonds treated, not a single stone was physically damaged from the irradiation. Even those stones that were badly flawed with internal and surface cracks were unharmed by the bombardment.

Accidents were bound to happen, though, and did, but these involved only unwanted color changes. In one case a 2½-carat brilliant was accidentally overexposed on the culet and the stone turned completely black. The original color was restored by polishing the treated coating off the culet (losing about 15 points of weight in the process) and the diamond was treated again, this time to the requested shade of green.

The most difficult stones of all to treat uniformly were the flat triangles and the marquise-cut stones.

The marquise, because of its thin pointed end, always showed a concentration of color there, the points becoming a very dark green while the body of the stone was still fairly light. This effect was reduced somewhat by placing the stones at an angle across the beam, so that the pointed ends were either above or below the intense central part. In several cases, some of the smaller ones, of three carats or so, were made almost uniform in color by adding a second treatment at 90° to the first, the beam going across the body of the stone only and missing both ends.

The triangles were impossible to color uniformly and always showed a dark border along the three edges, no matter how they were oriented or treated.

There were several puzzling differences observed between the effects obtained from this cyclotron work and the work reported by others. There have been several reports(16,17,18) that diamonds treated to green with charged particles or neutrons were restored to their original colors by heat treatment; but of all the stones heat treated at Washington University, none faded to their original color and all turned into some shade of gold. Many attempts were made to fade them, however, and in some cases, hopefully, because the stones were a darker shade of green than requested, but with no success. It was observed, though, that at temperatures of 1200° F. or so, the stones would appear to lighten a little, but this was only because they were beginning to change over from the green to the gold. Close examination always showed that the original green was a little lighter at this point, but was more of a yellowish green than before heating. Stones that were a medium-light green when heated to about 1600° F. would appear to have the color removed. But again, close examination and comparison with a reference stone always showed that these stones actually were a little more capish than before. Perhaps it was this effect that led some researchers to mistake a color change for color removal.

Heating green-treated stones to gold normally required only four to five minutes at 1600° F., but many observations were made throughout the temperature range of 1200° F. to 1900° F. and for heating times from a minute or so to more than an hour.

The length of time the stones were heated appeared to have but little effect on the final color, once the change from green had been made. This change appeared to be complete only at temperatures greater than about 1500° F. and seemed to have a fairly sharp transition temperature, similar to the effect observed in some earlier work in the heat clearing of quartz plates, which had been irradiated to purple.(19) Diamonds heated below 1500° F. retained some of their green color, which gave them a very unattractive yellowish-green appearance.

The exact transition point was difficult to determine because the stones were heated in charcoal rather than in a vacuum, but it was clearly at least 300° F. higher than that reported by Dugdale(20) for his reactor-treated stones. Diamonds that were incompletely cleared could be reheated at any time at 1600° F. to 1900° F. to complete the change to gold. In several cases, it was observed that stones that had been heated to very nice colors at these temperatures could be made still more attractive by a second heat treatment several days later at the same temperature as the first one.

None of the mysterious black spots, first reported by Lind and Bardwell,(21) was observed in any of the stones treated at Washington University. These small carbonlike specks were occasionally found in some stones treated with alpha particles from radium. They were far beyond the range of the radium particles and could be removed by heating the stones.

Ehrmann(22) also observed similar black specks in some stones treated with deuterons with the Harvard cyclotron, but it is not known if these two effects were the same and neither has been satisfactorily explained.

The final color of treated stones was only affected by the original natural color of the stones, the treated color being superimposed on, and blended with, this color. Silver capes gave a bluish green, and for the browner stones the color was more olive. Several very milky stones blended very well with the green and became a very attractive frosty bluish color. It was observed, though, that the brown stones required about 25% more irradiation than the lighter capes for the same intensity of green, but this was expected because of their darker color. The milky stones, which were expected to require about the same exposure as a light-colored cape, actually required almost three times as much.

Fluorescence in the stones was also of considerable importance. It was found that stones that fluoresced a strong blue could not be made into an attractive gold and gave an odd, shifting, greenish-yellow effect to the gold color. On the other hand, the blue fluorescence mixed very well with the green stones, and even seemed to add a little more sparkle to them. Stones that were fluorescent in other colors (e.g., pink, orange, yellow and green) gave no trouble for either treatment, and the fluorescence was either diminished or removed from the stone or masked by the treated color.

Although almost all of this irradiation work was done with deuterons, appreciable quantities of stones were treated with neutrons on several occasions, when the stones to be treated justified the cost of the long bombardment time involved.

For one of these irradiations, five stones, totaling 95 carats, were irradiated in the fast neutron flux directly behind a lithium target. Since the production of cyclotron neutrons is a secondary process, the neutrons being emitted when the target plate is irradiated with deuterons, the neutron intensity was observed to vary as greatly as the beam of deuterons. This variation was evident in the stones after two hours of irradiation, and after this first inspection they were inspected hourly and moved to new positions to ensure uniformity of color.

The total length of time needed to produce a medium-dark green in all of the stones varied with the size: the largest, a 49-carat emerald cut, required 18 hours; a 19-carat emerald cut, 24 hours; and the smallest, several brilliants and emerald cuts of eight to nine carats, needed 34 hours.

Another neutron irradiation, however, using a beryllium target for the emission of neutrons, treated a large quantity of smaller stones to an equivalent green in only 17 hours. This difference was believed to be due to the better geometry of the beryllium target, permitting the stones to get closer to the target, where the neutron density was greater.

The neutron flux from the lithium and beryllium targets was not directly measured for these treatments. From other work, where the beryllium target was used, the total neutron dose required to color diamonds a medium green was calculated to be about 3×10^{17} neutrons per square centimeter.

The cost of treating diamonds in a cyclotron is extremely variable, and a comparison of this cost with that of other machines can only be done in a very general way.

Irradiation costs with particle accelerators: cyclotrons, Van de Graaff machines, linear accelerators and the like range from $50 to $100 per hour. But since this charge is based simply on time and not on the number or quality of diamonds treated, it is not possible to assign a value to the cost of treating a particular stone.

A single cyclotron target, for example, can be loaded with about 20 five-point stones or three 10-carat brilliant-cut diamonds. Either group can be treated to green in less than 15 minutes for the same irradiation charge. A minimum of $60 would therefore mean a cost of $60 per carat for the first group, but only $2 per carat for the second.

Irradiation charges for reactors are more complex, varying greatly from place to place. Some have a flat charge as low as $15 per week, plus a flat $15 handling charge per sample container. Others charge as much as $20 per hour. All have variable rates and generally adapt the charge according to the difficulty of the sample to be irradiated and how much handling is required.

Irradiation space is much more generous in reactors than in accelerators. In a typical reactor a single container can be used to hold hundreds of carats of diamonds or just a few melee. The charge is the same for either container. But since the neutron intensity between reactors varies greatly, the time required to color diamonds may be as low as an hour or two in one reactor to 100 hours or more in another.

In any case, though, the comparison of cost is somewhat academic, because one seldom has enough diamonds to treat to make most efficient use of the facilities available.

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Developments and Highlights

at the

GEM TRADE LAB

in New York

by

Robert Crowningshield

Director of Eastern Headquarters

Radium-Treated Diamonds

We have examined several green diamonds that proved to be radium treated by "taking their own pictures" when placed on a covered X-ray film. *Figure 1* is the autophotograph of a particularly "hot" three-carat stone. Another, much larger, stone was purchased in Europe just after World War I and remained in the hands of one family until now.

Serpentine

An unusually bright-green material recently presented to dealers as Burma jade was determined to be serpentine. *Figure 2* illustrates the somewhat mottled appearance of these stones. Examination in reflected light with the spectroscope showed the unmistakable presence of chromium, as illustrated by the bands in the red end of the spectrum in *Figure 3*.

"Yunnan Jade"

Another recently encountered dark-green stone from Burma was found to be a kind of jadite called "Yunnan jade." Since the specimens presented to the Laboratory were cut very thin, it was possible to pass light through them and study the resulting absorption spectrum. It was a rather unusual spectrum, since the red transmission could be seen above the 7000 Å limit. *Figure 4* illustrates the transmitted-light spectrum of this material. In reflected light, the only source possible on thicker pieces, the spectrum was less diagnostic *(Figure 5)*. The refractive index, specific gravity and surface appearance were normal for jadeite.

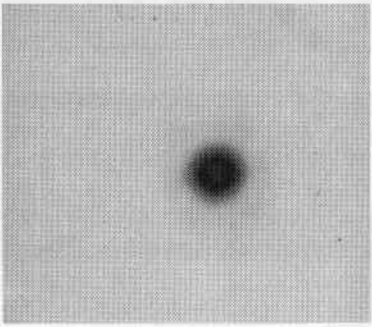


Figure 1

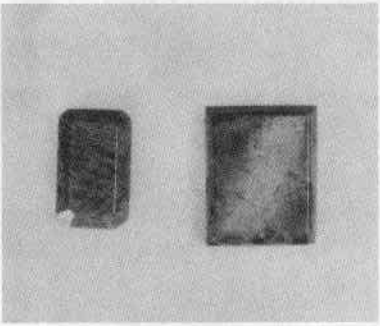


Figure 2

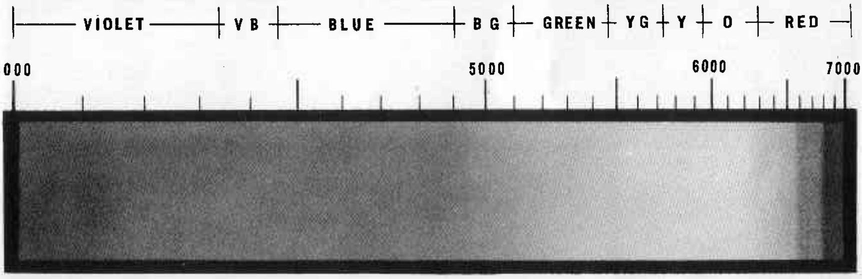


Figure 3

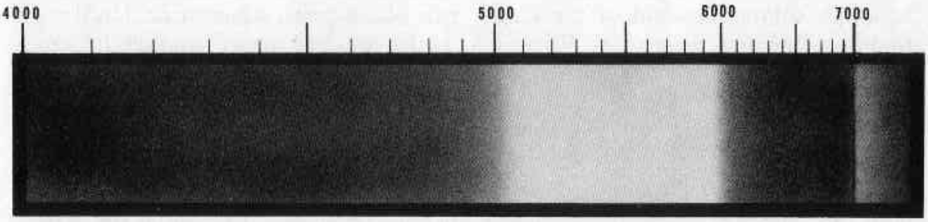


Figure 4

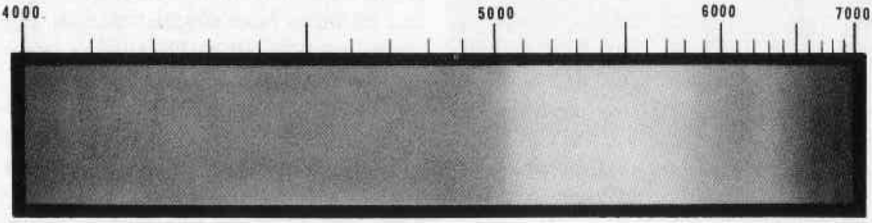


Figure 5

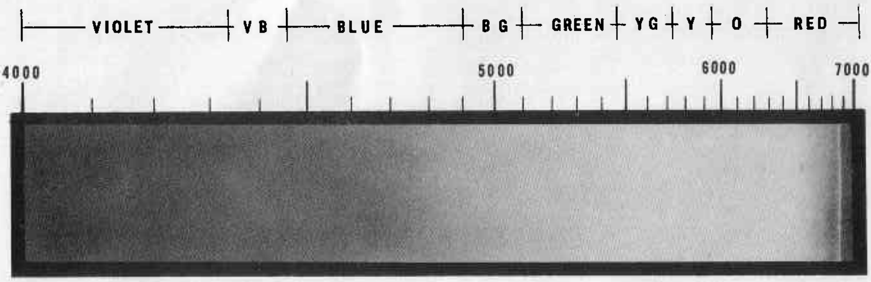


Figure 6

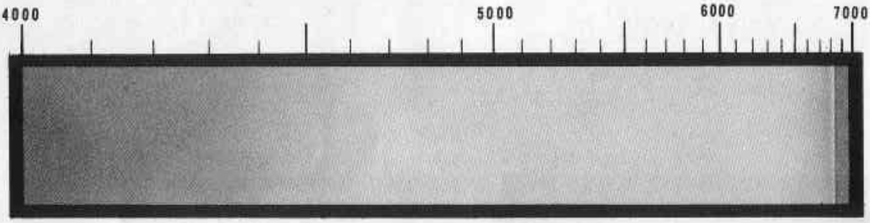


Figure 7

Brazilian Pegmatite Emerald

We recently identified a large, flawless, pale-colored emerald of the kind found in Brazilian pegmatites. When a powerful, thin beam of light was passed through the stone, in order to study the absorption spectrum, we were surprised to see that in the path of the light the stone was a bright red; yet, under both long and short ultraviolet, the stone remained green. It was no surprise, then, to see a fluorescent line in the red, as illustrated in the absorption spectrum for the stone *(Figure 6)*. We checked several other similar stones that we were able to locate in the trade, and all but the very lightest color behaved similarly.

Bluish-Green Chrysoberyl

In the collection of Jerome B. Wiss, late President of Wiss Sons, Inc., and onetime Chairman of the GIA Board of Governors, there has long been an unusual chrysoberyl that resembles a very pale bluish-green aquamarine. Until recently, we had never studied its absorption spectrum carefully. *Figure 7* shows that the stone owes some of its color to chromium, since the lines in the red are typical. Another stone that owes its color to chromium, yet is blue-green in color, is euclase. Because of the eye's insensitivity to the red end of the spectrum, a spectroscopist must make a special effort to examine that part of the spectrum, either with filters or by using careful light adjustments.

"Purpurine"

An interesting material long favored by Italian craftsmen and by the famed Russian jeweler, Fabergé, is a red, opaque kind of enamel that has a crystalline-appearing surface when examined under the microscope. Actually, rather than crystalline, it appears to be composed of myriads of fern leaves of several sizes randomly distributed. The refractive index of the material is approximately 1.64 and the specific gravity is about 3.77. *Figure 8* (reproduced from Kenneth Snowman's handsome volume entitled *The Art of Carl Fabergé*) shows a small peasant girl on a nephrite stand. Many years ago, a figurine like this was presented to the Laboratory for the identification of the red material (dark in the photograph), and at that time the only name for it that we discovered was "purpurine." *Figure 9* illustrates its rather unusual absorption spectrum in strong reflected light. A similar figurine is now in the possession of the Metropolitan Museum of Art. Lately, we have encountered purpurine as the base for small Italian bone-mosaic jewelry items.

Figure 8

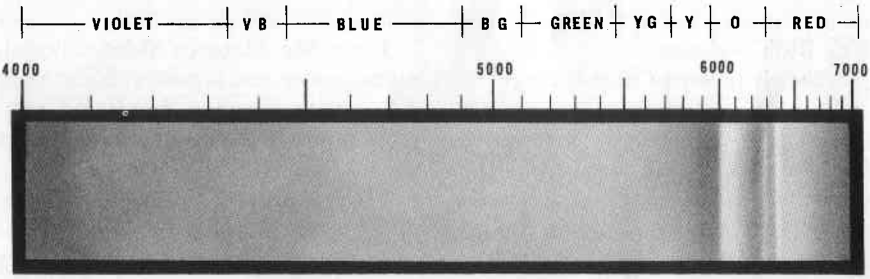


Figure 9

Another Diamond Found at Murfreesboro Mine

Figure 10 is a photograph of a rough diamond, that was reputedly found in a recently reopened section of the diamond pipe at Murfreesboro, Arkansas; *Figure 11* is the resulting fashioned stone. The rough weighed approximately .83 carat; the cut stone, about

Figure 10

Figure 11

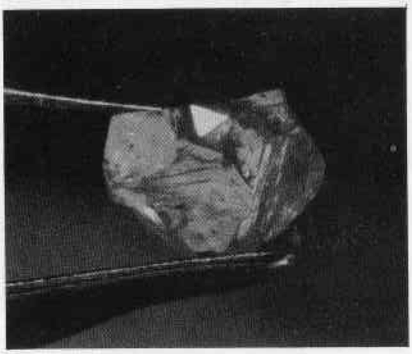


Figure 12

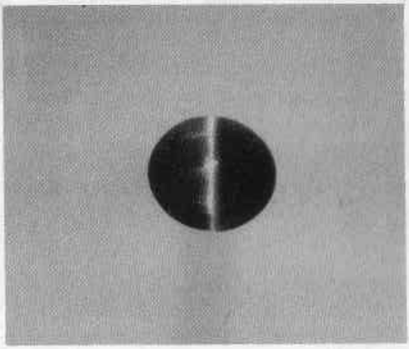


Figure 13

.44 carat. We examined the stone before and after cutting through the courtesy of Mr. Stanley Kahn, GIA student, of Pine Bluff, Arkansas.

Sapphire with Color Change

One of the most unusual stones submitted in recent months was a very light-colored, almost flawless emerald-cut sapphire of nearly thirty carats. The green color was seen only in daylight or an adequate substitute for daylight. In incandescent light the stone changed to a light red-violet color.

Acknowledgements

Figure 12 shows a cleavage section of a diamond on the surface of which is exposed a nearly perfect octahedron. The specimen was gratefully received recently from **Lazare Kaplan and Sons,** New York City. Also received from the Kaplan firm was another cleavage section on the surface of which is a tiny red crystal, which, by means of a powerful objective and the spectroscope, we identified as chrome pyrope garnet. By a stroke of good fortune, a similar gift came from diamond polisher **Arthur Ringer,** New York City.

We wish to acknowledge with thanks the gift of a lovely specimen of branch coral received from student **Bill Mazza,** whose firm, B. fu C. Mazza, specializes in coral.

From **Mr. Herman Eldot,** colored-stone dealer and lapidary, New York City, we received a handsome amethyst crystal measuring more than six inches in length.

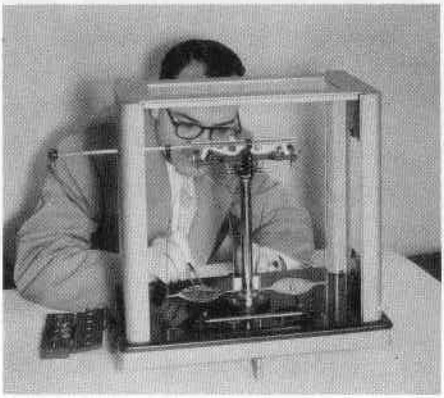
Mr. Robert Lee, Hong Kong Gems, Ltd., Hong Kong, gave us two specimens of green grossularite resembling fine jade.

From **Mr. Joe Baumgold,** Baumgold Brothers, diamond merchants, New York City, we received an important gift of diamond crystals: diamonds in successive stages of polishing, cutting and sawing; old-mine diamonds; and other specimens that will be of great value in class work. We are very grateful for this gift.

We are grateful to student **Joseph J. Smith,** New York City stone dealer, for adding to the range of colors of tourmalines in our collection, and for a nice black star sapphire.

To Laboratory member, **Robert Nelson, Jr.,** we are indebted for a handsome blue cat's-eye tourmaline *(Figure 13).*

Developments and Highlights



at the

GEM TRADE LAB
in Los Angeles

by

Richard T. Liddicoat, Jr.

Who Will Pay the Piper?

Less than a year ago, a chipped diamond was submitted to the Laboratory for an estimate of the loss of weight during recutting. The stone was badly spread and slightly shallow in the pavilion. As a consequence, it could have been recut to proportions more closely approximating those of the ideal cut without a reduction in value. Figures were given showing what the stone would weigh after a simple repair job, what it would weigh if recut enough to round up the girdle and remove the chip, and what it would weigh if recut to ideal proportions.

Recently, the stone was returned to the Laboratory for a report on a new damage claim. We reported, among other things, that the stone had not been recut the first time but only repaired; as a result, the girdle remained thin and the susceptibility to further damage high. Later, we learned that the insurance company refused to assume responsibility for the second claim. We also discovered that the company had given the insured $100 to have the stone recut, on the basis of the first report. (The earlier report had stated further that if the stone were recut to better proportions, there would be no loss in value, despite the loss of weight.) The owner went to a jeweler who charged her $35 to repair the damaged spot, and the insured pocketed the $65 difference. The question now is this: is the insurance company liable for the second damage, since the stone was only repaired and not recut? Apparently, the company's position is that complete recutting would have eliminated the danger.

Unvarnished Truth about Uncolored Jade

When two rings set with jadeite cabochons were sized and returned to a customer, she claimed that the color of one had lightened considerably in the process. The shop man insisted that he had been careful and that he had never had jade fade. However, the customer pointed out that the two stones matched in color before the sizing.

Knowing the story, we fully expected to detect dye, but tests for dye were negative.

In this case the solution was not gemological. The manufacturer's shop man was asked whether the stone had come out of the mounting during the sizing. The answer was in the affirmative. When the flat cabochon was turned over, the two jades again matched.

Moral: When jade fade, seek shop drop.

Wishful Thinking!

Even when inexpensive jewelry is sold without misrepresentation, owners seem prone to attribute remarkably rapid value appreciation to their purchases. Recently a woman called at the Laboratory with a ring, stating that she believed it to be set with an alexandrite. She made a one-hundred-mile trip through heavy traffic to have the stone tested. In talking to her, it became obvious that she had bought the ring for less than $50 as a "synthetic alexandrite" and had decided to sell it. However, the stone, which had been purchased in Mexico, was regarded by the owner to have such an attractive color change that she finally concluded that it must be natural. The combined expense of the trip and the testing fee was approximately equal to the value of the ring – which proved to be synthetic alexandrite-like sapphire.

Ultrasonic Cleaning

A few weeks ago, a jeweler brought one of his customers to us so that the Laboratory staff could examine a damaged diamond. The damage had become obvious to the woman only after the stone had been cleaned by the jeweler; she had concluded that it must have resulted from ultrasonic cleaning. Unfortunately, it had not been examined when the jeweler accepted it.

Our examination under magnification showed a typical shell-shaped break with tiny steplike cleavage surfaces. We had never heard of a diamond breaking in an ultrasonic cleaner, but if it were responsible for a break in a diamond under great internal stress, we would expect it to be a clean cleavage, rather than this type of breakage, which is so characteristic of that caused by a blow on the exposed girdle. In other words, we would expect the relief of strain to take a different pattern from that expected from a blow delivered against the sharp girdle of a stone.

Faded, Dyed-Green Jadeite

Some jewelers have expressed concern over the difficulty of detecting the dye in dyed-green jadeite after it has faded. If the stone has faded to its original color, the fact that it was once dyed is no longer important. In other words, it is only when the stone has been improved in appearance beyond its actual color that the dye affects value. If the dye fades entirely, the stone reverts to its original condition and value.

Synthetic Alexandrite-like Sapphire

Synthetic alexandrite-like sapphire is often submitted to the Laboratory for identification. This variety of synthetic sapphire is one that should be identified readily by eye or very low magnification, because curved striae are especially prominent in it. The striae are usually detectable easily by unaided eye through the table. Of course, the daylight and artificial-light colors do not bear any resemblance to the alexandrite variety of chrysoberyl. Although the resemblance to alexandrite-like natural sapphire is closer, it still is considerably different. The color change in natural sapphire is usually blue to violetish blue, rather than from the blue-gray to amethyst colors seen in the synthetic corundum.

Fine Jadeite Cabochon

We recently were asked to test a green cabochon in a platinum ring that proved to be jadeite of very fine translucent quality. However, the mounting reduced the beauty of the stone materially, since a pierced metal plate below the stone left only a small opening to the finger. As a result, the apparent color of the stone was so dark that much of its true beauty was concealed. Without the plate, which served no useful purpose, the stone would have appeared more representative of its actual high quality.

A new "Mikimoto" — Mr. Uda

We had the opportunity to discuss fresh-water cultured-pearl production with the originator of lake cultured-pearl fisheries, Mr. Seiichiro Uda, of Lake Biwa, Japan. Mr. Uda gave us some very interesting sidelights on his process, which will be the subject of a later article in *Gems & Gemology.* Upon his return to Japan, Mr. Uda kindly forwarded to us a number of examples of the various stages of growth of the shell of the fresh-water clam, *Hyriopsis-Schlegeli,* which is the host mollusc.

Early production was quite irregular in shape, with average dimensions of 6 x 3 mm., but Mr. Uda's ingenuity has improved the picture considerably. Unlike the salt-water pearl-culturing process, no mother-of-pearl bead is used. Instead, mantle tissue alone is employed to initiate the process. Several incisions are made near the outer edge of the mantle tissue into which are placed small pieces of the outer side of the mantle from another clam. As a result, these pearls do not have a solid nucleus. The life expectancy of *Hyriopsis-Schlegeli* is approximately twice the seven or eight years for the salt-water mollusc. This fact led Uda to an interesting experiment. To harvest the pearls, Uda extracted them carefully from the live clam, to prevent serious injury. The clams were then returned to the water. In the process of forming the cultured pearls, a pearl sac is lined with nacre-producing epithelium cells, which, if the clam is not harmed, will produce another pearl in the next several years. This second crop of pearls from the same clam is much less baroque; in fact, perhaps 10% are spherical or reasonably so. The detection of such pearls is the subject of the forthcoming article mentioned earlier.

Upon his return to Japan, Mr. Uda kindly sent us a set of six shells representing the various stages of shell growth from early age to maturity. In addition, he sent us a large number of cultured pearls representing a wide variety in color, size and shape. We were very appreciative for both the information and the generous gifts of shells and pearls.

The New Princess Cut

We have had a number of questions about the new Princess Cut that was announced recently in England by its inventor, Mr. Arpad Nagy. The cut, illustrated in cross section, is indeed revolutionary, but pictures of stones cut in this style make it seem that its nature is obvious to the eye. Robert Crowningshield, who has seen several diamonds cut in this style, had this to say about it:

> "The 41° pavilion angle does make for considerable brilliance; however, since the stones that I saw resembled rows of baguettes set side by side, the result did not resemble what the layman pictures to be a diamond.
>
> "In my opinion, the new cut has novelty appeal and would make handsome, expensive buttons, unusual tie tacks and cufflinks, and rather stiff jewelry in pins and other pieces, due to the difficulty of modulating designs for them. As an engagement-ring stone, the new cut would represent a departure that would probably require elaborate promotion for acceptance."

Crowningshield concludes:

> "I do not look for diamond cutters soon to be slicing up octahedra into 1.5-millimeter slices for Princess Cuts!"

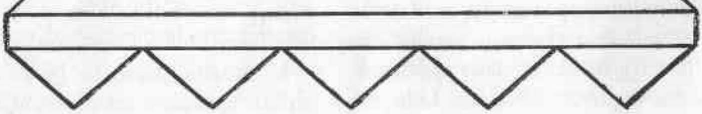
It occurs to us, however, that this might provide a practical use for macles cleaved along the twinning plane or for flats.

Acknowledgements

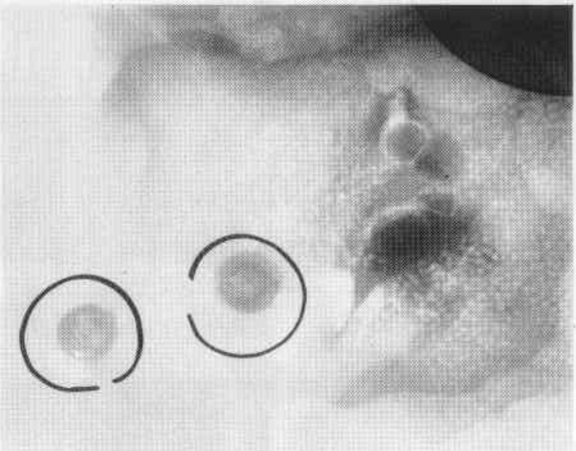
From student **Harry Fink,** Tujunga, California, we received a beautiful idocrase cabochon that could be confused easily with gem jadeite.

Through the courtesy of **Sol Shalovitz,** Los Angeles gemstone dealer, we received faceted epidote and andalusite and a crystal of topaz. Another gift, was a pseudomorphic replacement of a snail shell by marcasite.

Student **Harold Tivol,** Kansas City, Mo., donated ten melee and diamond fragments for laboratory use. He also donated a peach-colored sapphire and



Cross section of the Princess-cut diamond



X-radiograph showing pearl attached to its shell

a blue sapphire that make excellent class stones.

From **Sam Romson,** Montreal, Canada, we received a small parcel of gem-quality sphalerite, which can be used for specimen material and for faceting stones for use in practice sets.

Bill Ilfeld, Santa Fe, New Mexico, kindly donated specimens of blue common opal rough and some very interesting treated chrysocolla.

We wish to thank **Marvin Hime,** Beverly Hills jeweler, for the gift of a blister pearl attached to its shell (see photo).

Australian Emerald

The following data on a new emerald material from Australia was communicated to us by Edward Gubelin, Ph.D., C.G., of Lucerne, Switzerland.

R.I. (distant-vision method)	1.67
S.G.	2.71
Absorption spectrum	showing sharp chromium lines at 6830 Å, 6800 Å, 6620 Å, 6460 Å, 6370 Å
Chelsea color filter	strong pink
Fluoroscope (through crossed filters)	glowing red, velvety appearance
U.V.	3650 Å inert 2537 Å inert

The Spectroscopic Recognition of Natural Black Pearls

by

Robert Crowningshield

Recently, while working with Lester Benson's new spectroscope set-up *(Gems & Gemology, Spring, 1961),* the writer discovered that the light transmitted through some unworked pearl-bearing shells showed two distinct absorption spectra, depending on whether the outside of the shell was nonfluorescent or fluoresced red or brown under long-wave ultraviolet. By isolating plates of pure conchiolin at the edge of the shells and observing them with the spectroscope, it was determined that the conchiolin caused both the absorption spectrum and the fluorescence. *Figure 1* illustrates the absorption spectrum of conchiolin from *Pinctada Martensii,* the Japanese cultured-pearl producer. *Figure 2* illustrates the spectrum of red-brown to black conchiolin from one variety of black-pearl bearer, species not determined. The spectrum observed was as spectacular as any we have seen.

From this initial work, it was obvious that observation of pearls themselves might prove fruitful. But first, mother-of-pearl from which all conchiolin was removed was examined; it was taken from the shells mentioned above. No absorption spectrum was observed in any of the white material from *Pinctada Martensii* (nor in any other mother-of-pearl subsequently examined). The mother-of-pearl of a faint reddish tint from the black pearl shell from which all the black conchiolin had been removed passed a rich red-brown light. As usual for brown light, the blue and violet end of the spectrum was strongly absorbed, but the absorption band at approximately 5100 Å. was present within this specimen.

Next, known natural gray and black pearls were observed. All those that fluoresced red, brown or pink under long-wave ultraviolet and that would pass even a dull red-brown glow showed either the full spectrum, as in *Figure 2,* or a less distinct variation of it, as in *Figure 3.* This latter spectrum was quite obvious when very light-gray pearls with pinkish fluorescence were examined. If only a small rim of reddish-brown light was transmitted, then only the line at 6225 Å. was visible in the red, with a sharp cutout at approximately 5775 Å., beyond which all light was absorbed *(Figure 4.)* Some of the pearls examined were so opaque that they transmitted no light whatsoever. These included some of the most at-

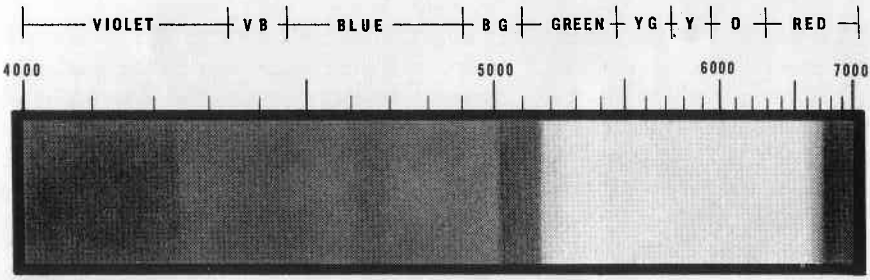


Figure 1

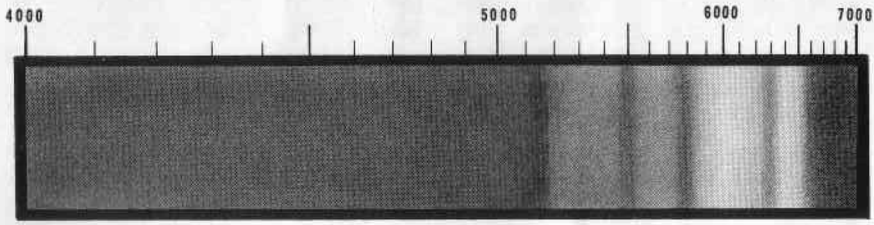


Figure 2

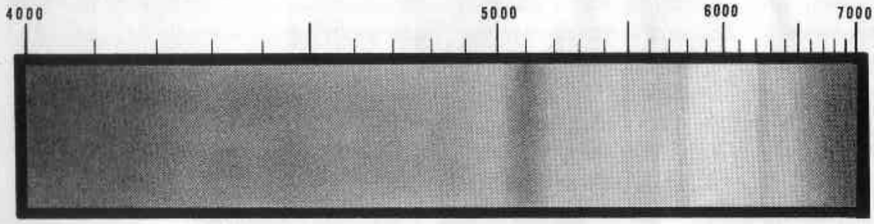


Figure 3

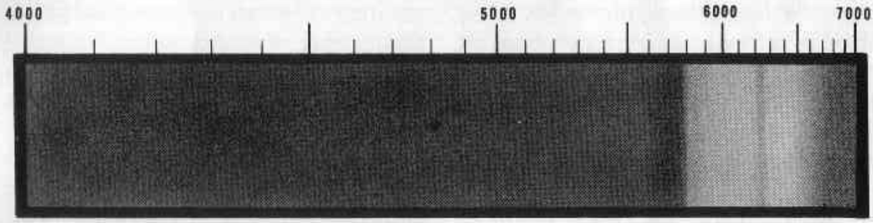


Figure 4

tractive nacreous pearls, as well as some of the least attractive concretions that lacked nacre entirely, although both types showed red under ultraviolet. It is inferred from this that most very black natural pearls probably contain a great deal of conchiolin, a material that in its pure form (such as a section of the shell edge) is opaque, unless thin-sectioned to less than one-half millimeter, when it will transmit an intense red-brown light. Direct reflected light, such as that used for spectroscopic analysis of turquois, could not be used to analyze black pearls.

In a few cases among the pearls tested, some that did not fluoresce red under long-wave ultraviolet but did transmit light showed the 5100 Å. band alone. It is interesting in this connection to note that pure conchiolin from the black-pearl producer, *Pinctada Margaritifera,* of Lower California, showed the same spectrum as conchiolin from the *Pinctada Martensii (Figure 1).* Again, the inference is that dark-colored pearls contain rather more conchiolin than light-colored pearls (or mother-of-pearl), and therefore carry with them evidence of the conchiolin absorption.

Conchiolin from as many shells as possible was examined. Of the three types of abalone from the California coast (species *Haliotis),* the red showed two medium-strong bands in the yellow and green, whereas the green abalone showed a strong band in the red, making the absorption spectrum resemble that of dyed jadeite. The black abalone showed no absorption lines. It must be reported that no specimen of abalone shell stripped of its outer conchiolin, or any worked jewelry items we could find, showed any absorption bands. The nonpearl-bearing Philippine window shell *(Placuna Placenta)* showed the same spectrum as *Pinctada Martensii* and *Pinctada Margaritifera (Figure 1).* Neither fresh-water pearl shell nor the pearls themselves showed any absorption lines, regardless of the body color of the pearls. The same was true of edible oysters and clam shells and their concretions. Undoubtedly, observation of conchiolin from many of the countless varieties of sea shells would show absorption spectra, but our primary interest is pearl and particularly the detection of natural versus artificially colored black pearl.

In general, both artificially colored natural and cultured black pearls do not pass light as freely as natural-colored pearls. Some of the latest center-dyed cultured black pearls will pass a dull red-brown light; when this is analyzed, there is no absorption band at 6225 Å. This, together with the greenish (instead of reddish) fluorescence under long-wave ultraviolet, is indicative of an artificially colored pearl or cultured pearl. An X-radiograph would, of course, detect a cultured pearl, in which case its being black would be considered proof of artificial coloration.

Although we have been able to examine only a few of the many types of pearl-bearing salt-water shells, through the courtesy of Mr. Harold Tritt, New York City dealer in black pearls, we have examined hundreds of black pearls with very consistent results, as herein reported. The exceptions to the reddish fluorescence, coupled with distinctive absorption spectra for natural black pearls, include the rare black pearl that does not fluoresce red but remains inert and does not pass enough light to analyze with the spectroscope, and the nonfluorescent black pearl that passes light freely but that does not exhibit any diagnostic absorption spectrum. The latter type, mentioned by Lester Benson in his valuable article in the Summer, 1960, issue of *Gems & Gemology,* shows peculiar subsurface markings and green-

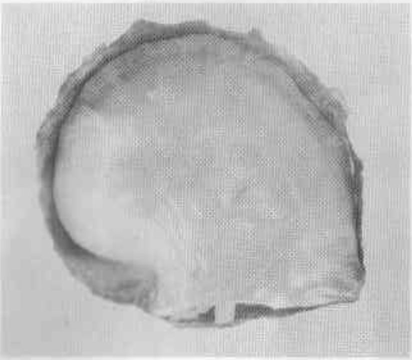


Figure 5

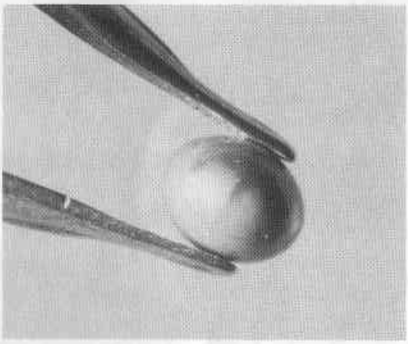


Figure 6

ish-translucent nacre. We have not been able to determine the species of pearl-bearer that produces this type of pearl. Its great transparency to a beam of light with a greenish-yellow color transmitted is unknown to artificially colored black pearls.

Many questions remain unanswered regarding the presence of diagnostic absorption spectra for pearls and shell. In the case of the pearls showing the distinct absorption, as in *Figure 2,* a spectrum that superficially resembles that of a dark almandite garnet, one asks if iron, too, could cause the similarity? If, as it seems, conchiolin, an apparently amorphous material, is the cause of the spectacular spectrum, why is it almost alone among gem materials that are amorphous but have distinctive spectra?

Although the observations reported here are a significant addition to the value of spectroscopy, they are primarily of value in reinforcing the initial information presented by Lester Benson in the article referred to above. It is hoped that further work can be done on known shell species and the pearls they produce, as well as an investigation of the role that conchiolin plays in pearl makeup, together with the nature of conchiolin itself in relation to the absorption spectra herein reported.

(Note: *Figure 5* is a photograph about one-quarter actual size of a shell of *Pinctada Margaritifera,* variety *Matzantlantica,* from La Paz, Lower California. The shell has a characteristic greenish edge of conchiolin and was the source of conchiolin for study.)

Figure 6 is a photograph of a half-drilled black button pearl that the Laboratory identified as a "natural pearl, artificially colored," and a question was raised as to the report. When it was removed from its eight-prong setting, the owner could see that fading had taken place wherever the pearl was not covered by the setting. In the photograph, the darker areas where two of the prongs were located can be seen. The pearl transmitted a red-brown light, but fluoresced greenish, instead of red, and did not exhibit any absorption lines. It has been determined by the Los Angeles Laboratory that certain types of black-treated cultured pearls will lose color on exposure to ultraviolet light, and presumably, over a period of time, the ultraviolet in sunlight would do the same.