TECHNIQUES EMPLOYED IN THE IDENTIFICATION OF GEMSTONES*

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The problems attendant to the identification of gemstones would seem to be simple in that only a small number of minerals have gem varieties. Although the number of natural gem minerals is small, the increasing number of synthetics and cleverly contrived imitations plus the limitations imposed by the necessity to return a gemstone to its owner totally undamaged, add to the problems of the person seeking to identify gemstones.

The combination of powder analysis by *x*-ray and by the petrographic microscope provides for the mineralogist conclusive means of identification. Since the jeweler can neither powder a gemstone nor subject it to chemical analysis, some important mineralogical methods are not applicable to gem identification.

The development of gem identification to an exact science has been rather recent. The first of the three most important gemtesting instruments, the refractometer, was adapted for gemtesting purposes by G. F. Herbert Smith in 1905. Until the gem polariscope was developed in 1935 and the dark-field illuminator for gemstones by Robert M. Shipley, Jr., in 1938, the jeweler was forced to rely heavily on the petrographic microscope. That instrument, designed for thin section or powder work, is quite impractical for the examination of gemstones. Thus, as gemtesting developed, property determinations once made laboriously by the use of the petrographic microscope were obtained by utilizing the refractometer, a simple polariscope employing Polaroid film, and a binocular microscope equipped with a dark-field illuminator.

Originally, the polariscope was used only to distinguish between singly and doubly refractive materials and to test for pleochroism. However, other uses developed rather rapidly. Perhaps the most important is the determination of optic character and sign. This may be a very simple determination or rather awkward, depending on the shape to which the stone is cut, its refractive index and its orientation.

Since a transparent cabochon-cut gemstone acts as its own condenser, a gemstone cut in this rounded form displays an interference figure with-

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* The following comments were written in the belief that some of the techniques peculiar to gemstone identification are little known outside that specific field. Much of the material presented here has appeared in books or periodicals in the field of gemology either in Europe or America.

out magnification when examined between crossed Polaroid plates. For example, star sapphire, which must be cut with its axis perpendicular to the girdle plane of the cabochon, shows an interference figure in the polariscope in the same position in which the star appears in reflected light. In a cabochon form of cutting, an optic axis interference figure is visible without magnification in any stone in which an optic axis is more or less tangent to the convex surface. The situation is slightly more complicated with faceted stones but since the shape of a faceted stone generally is roughly spherical or hemispherical, even a faceted stone acts as an inefficient condenser. Thus with magnification, an interference figure may be obtained. In order to do this, the stone, held by the forefinger and thumb, is rotated between crossed Polaroid plates until a brush is observed. The stone is then turned in a plane that will sharpen the brush until interference colors are observed. At that point a lens is inserted between the stone and the upper Polaroid to resolve the figure. For sign, a quartz wedge is employed.

In a faceted stone the orientation of facets with respect to optic axes may be such that a figure is very difficult to resolve. Several rather interesting means of obtaining figures in such cases have been developed over the years. In one, developed by Kenneth M. Moore, a hollow sphere of glass is ground off on one side so that a small bottle top may be cemented to it. Within the neck of the bottle a beeswax holder is mounted under a water-tight rubber cap. The sphere is filled with water and the stone mounted in the beeswax is placed in the water. Then the sphere is rotated between Polaroid plates until interference colors are observed. Magnification in the form of a small lens resolves the figure. In the case of a biaxial stone, the points at which the optic axes are observed are marked in ink or wax pencil on the surface of the glass and the interaxial angle measured roughly.

There are other simple methods to make possible the resolution of an interference figure when interference colors have been located, but the figure has proved difficult to resolve. When a drop of methylene iodide is placed at a point at which colors are seen, the surface tension of the dense liquid causes it to stand up in a drop form. The high refractive index of methylene iodide makes the drop an effective condensing lens. If this proves insufficient, a glass rod with a spherical tip is placed on the methylene iodide and the figure may be seen in the spherical tip.

A student at a class in advanced gemology introduced a clever idea to speed his efforts to obtain figures. He brought to class a jar of very viscous honey, into which he dipped a stone when he had difficulty resolving an interference figure. The honey-coated stone made a more or less spherical mass which behaved as a condensing lens and reduced facet distortions, facilitating his efforts to obtain interference figures otherwise difficult to resolve. This method works nicely with transparent rough as well as faceted material.

Robert M. Shipley, Jr., took the principle of the Federov stage as the basis for a design of a universal motion immersion stage. In this a stone mounted on wax was attached to a small table which could be rotated on its mount. In turn, the table was mounted in a ring that rotated in one plane while an outer ring also rotated but in a plane at 90° to the plane of motion of the inner ring. Rotation of the rings was controlled by gears operated by knobs outside the cell. This facilitated both the resolution of optic axis interference figures, and in biaxial stones the measurement of the interaxial angle.

FIG. 1. The illuminator polariscope.

Because of the thickness of the average gemstone, in a biaxial figure only one "eye" is seen at a time and the brush appears to be straight unless the 2V angle is very small. The Bx_a direction is determined from the difference in the clarity and sharpness of the interference rings toward and away from that direction.

The polariscope also is used to distinguish between anomalous and true double refraction, which is a difficult determination for the beginner. It is accomplished by first rotating the specimen between crossed Polaroids to the position of maximum light transmission through the stone. While holding the specimen in this position, the analyzer is rotated toward the polarizer vibration direction (in other words, from dark to light). Birefringent material will either darken slightly (possible if pleochroic) or retain the same light intensity. Strained isotropic materials will pass more light as the analyzer is rotated away from the 90° position. This method is effective for most gem materials but may be useless with badly strained isotropic materials—particularly some garnets, amber, and plastics.

Developments in jewel refractometer techniques in recent years have multiplied its utility to the gemologist. For many years it was used almost exclusively to obtain a refractive index figure which could be read easily only to about .01 in white light. Readings were obtained only from fairly broad flat surfaces. Using white light without filters, a reading appears as a single, broad, partial spectrum for gemstones with a birefringence up to about .010 or .012. Although filters or monochromatic light have been employed for many years to sharpen readings, the analysis of optic character on the basis of the behavior of the index readings as the stone is rotated is a more recent practice.

When a stone is being tested on a refractometer hemisphere, the direction analyzed by the instrument is that parallel both to the top surface of the hemisphere and to the long axis of the instrument. In other words, if a prism face of a tetragonal or hexagonal crystal were placed on a hemisphere with its *c* axis parallel to the long axis of the instrument, a single reading would be evident.

Rotation of the crystal on the hemisphere will bring a second reading into evidence with maximum birefringence reached when the *c* axis is at 90° to the long axis of the refractometer. If the basal pinacoid of this crystal were placed on the hemisphere, two readings would be seen which would be constant at maximum birefringence during rotation on that facet. On a facet with any other orientation, sign is determined by noting whether the high or low reading is constant. Regardless of orientation, any facet on a uniaxial gemstone will give maximum birefringence upon rotation of the stone on the hemisphere. Only when a facet is perpendicular to the optic axis is it necessary to take a second reading to determine optic sign.

The analysis of birefringence for a biaxial gemstone on a refractometer is only slightly more complicated. For most orientations, the two readings vary as the biaxial gemstone is rotated. For biaxial gemstones, sign is determined by noting whether α or γ varies more or to which β is closer. A rough approximation of the value of 2V is made by the relative position of β index with respect to α and γ. If β is about midway between, 2V is near 90°.

On a facet perpendicular to γ (the acute bisectrix in a positive mineral) one reading remains constant at the γ value and the other varies from α to β. On a facet cut perpendicular to α (the obtuse bisectrix in a positive mineral), the α index is constant and the other reading varies from a minimum value of β to a maximum of γ. On a facet parallel to the principal section, β is constant and the other reading varies from α to γ. On facets oriented in other than these directions, α and γ may be determined by noting minimum and maximum readings, but β is more difficult to pinpoint. The sign is obtainable if one of the readings moves across the midpoint between the extremes which represent α and γ values.

At one time many gemologists favored refractometers with rotating hemispheres to facilitate analysis of birefringence. More recently the increased cost attendant to the manufacture of such instruments has caused most gem men to favor refractometers with fixed hemispheres or sections of a hemicylinder.

Since World War II, two refractometers have been manufactured in quantity in the United States, the Erb & Gray and the Gem. Both instruments employ very simple optical systems consisting only of a diffusing screen at the light portal, the dense contact glass, a scale, a means of effecting a change of light path (in one case, a prism and in the other, a first-surface mirror), and a small magnifier. Each employs a movable eyepiece arm which may be removed from the system. It was this latter feature which led Lester B. Benson, Jr., to the discovery of a means by which accurate refractive index readings could be made on curved surfaces as well as facets much too small to give readings by conventional means. Benson noticed that when no magnification was used that the contact between gem and hemisphere appeared as a tiny spot on the scale. By moving the eye back and forth over the scale, and viewing it with lower magnification than that afforded by the eyepiece lens, readings were easily obtained from surfaces on which none was visible otherwise. Curved surfaces reversed the light and dark sides of a reading, but accurate readings could be made with ease. Thus the value of the refractometer in gemtesting increased materially.

In order to make such readings, the amount of contact liquid must be kept to a minimum for accuracy. When the cabochon is resting on the droplet, the spot should not extend over two to three .01 divisions on the scale. As the eye is moved back and forth over the scale, the spot is seen to change abruptly from dark to light. When white light is employed, a blue-green line may separate the light and dark zones at the reading, but if the spot is tiny, the line of color may not be visible. If no blue-green line is observed, the reading is taken at a point midway between the point at which the spot is last dark and first light as the line of sight moves from the low to the high numbers on the scale.

Magnification of the interior of a gemstone is a very important phase of gemtesting because of the synthetic counterparts of corundum, spinel and the emerald variety of beryl, and the many imitations and dyed stones on the market. The rather narrow gap between the melting point at about 2100° C. and boiling point about 100° higher makes synthetic corundum difficult to produce by the Verneuil process without gas bubbles. The presence of gas bubbles and/or curved accumulation lines formed during the growth of the boule prove synthetic origin. In order to examine the interior of a gemstone effectively, careful lighting is essential. Without dark-field illumination, it is all but impossible to detect minute inclusions. As a matter of fact, even large inclusions are undetectable in fairly dark mounted stones under ordinary lighting. When

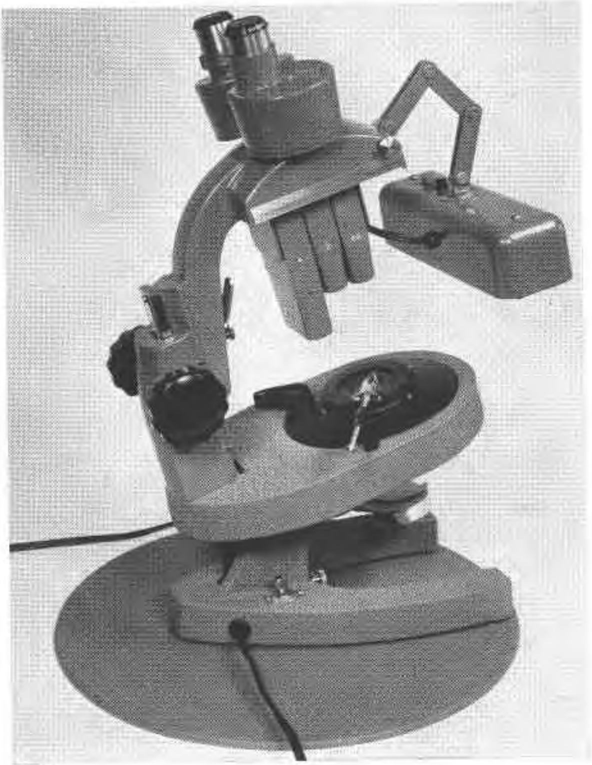

FIG. 2. The "gemolite" with overhead light source.

transparency and lighting permit resolution of the opposite side of a gemstone, a very close approximation of birefringence may be made by an experienced observer. Doubling of facet edges may be seen in a stone of one carat size when the birefringence is as low as .004.

In 1937 an illuminator employing the dark-field principle was first designed for gemstone examination by Robert Shipley, Jr. Binocular-magnification is used for the depth perception it affords and the convenience of upright image, long working distance and large field. Magnifications of 10× to 60× provided by low-powered objectives and high-powered eyepieces are used most effectively in gem identification.

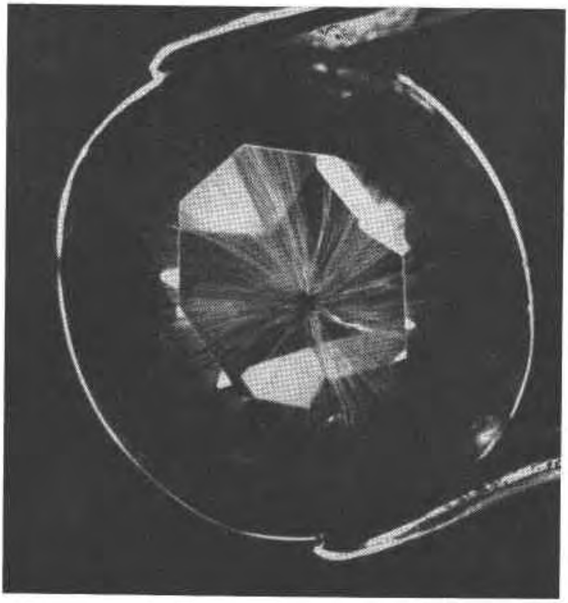

FIG. 3. Radial fibrous inclusions in the demantoid variety of andradite garnet 10×.

While few gemstones have inclusions so characteristic as to permit identification beyond question, frequently magnification of the interior will give the experienced individual clues to the identity of a gemstone—and, often leave him morally certain what it is. However, a sight identification based on inclusions, should be confirmed by other tests.

Some very interesting characteristics are sometimes revealed under magnification. For example, emeralds from Colombia and the Urals may be distinguished from one another by the shape of minute tabular crystals found in liquid and gas-filled cavities. In Colombian emeralds the flat crystals are square in outline, while in the Uralian product they are diamond-shaped.

The demantoid variety of andradite garnet almost always contains brown radiating fibers unlike inclusions found in any other gemstone. The hessonite variety of grossularite garnet has a characteristic appearance under magnification which is reminiscent of sugar dissolving in water.

However, the key use of magnification is simply to distinguish the man-made from the natural. In some cases, this is the most difficult problem in gem identification, despite which some jewelers make "identifications" by sight, and some mineralogists "identify" with magnification and lighting equipment totally inadequate for the resolution of essential characteristics.

There are many effective imitations to trap the unwary. Glass imitations of turquois and gem varieties of chalcedony may have refractive indices in the same range and the same specific gravity. However, the vitreous luster on minute conchoidal fractures on glass contrasts with the waxy to dull luster on fracture surfaces of both chalcedony and turquois. Glass imitations of transparent gemstones usually are simple to identify. However, they are made to duplicate very closely the color and properties of some gemstones, with refractory angular materials added to the melt to simulate the flawed appearance of a natural gemstone. The fashioned stones are then mounted so that a prong prevents a refractometer reading. Such an imitation of emerald mounted in platinum with diamonds has fooled many a pawnbroker and many a jeweler.

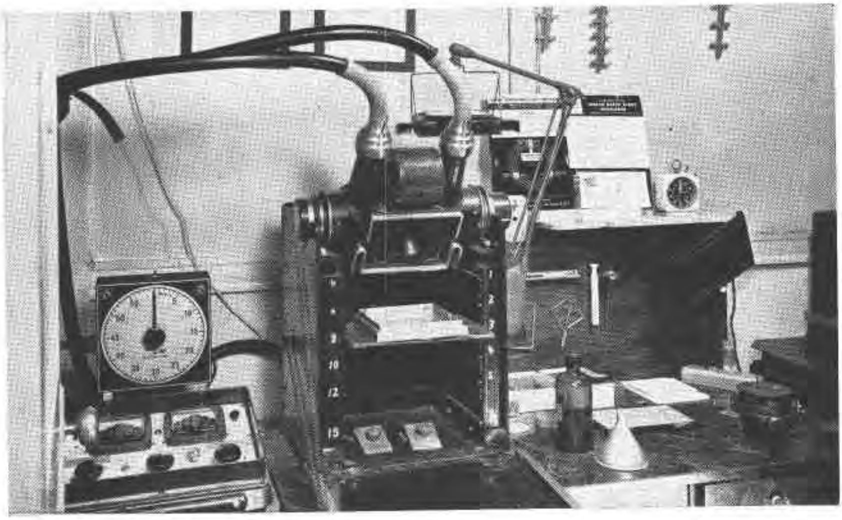

FIG. 4. Pearl radiography equipment utilizing a Picker tube with tungsten target.

Doublets made of two pieces of diamond or one of diamond and one of glass or zircon, and mounted to conceal the separation plane, are also found. A colorless gemstone may be coated to impart a beautiful color and then mounted to protect the coated pavilion from detection. Magnification with proper lighting will detect such efforts to defraud.

One difficult identification for the gemologist is the separation of cultured from natural pearls. Since the surface layers of nacre deposited by the mollusk are essentially identical, only a study of the interior will permit identification. The most practical method of identification is x-radiography. The nucleus used in pearl culture is a bead fashioned from the shell of a fresh water pelecypod. Before accreting nacre, the host mollusk deposits a fairly thick layer of conchiolin, a substance considerably more transparent to x-rays than either the shell bead or the new nacre. As a result, the cultured pearl shows a heavy dark circular line on the negative a fraction of a millimeter from the outer edge.

A clue to identity is furnished by the fact that the fresh water shell used in pearl culture operations fluoresces strongly under x-rays, while the salt water pearls do not. Using soft x-rays and an immersion technique to counteract the spherical shape of the pearls, x-radiography provides an exact means of identification.

For the most part, gem materials may be identified conclusively by refractometer, polariscope and binocular microscope. Sometimes a specific gravity determination is an additional requirement. The dichroscope often is useful. Even particularly difficult identifications of transparent faceted material very rarely require any additional tests. That historical gemtesting device, the hardness point, is almost never employed by the trained gem man. Instruments designed specifically for his needs and fairly recent improvements of his testing techniques have enabled the trained gemologist to identify gem material with assurance and dispatch.

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