Gems & Gemology

FALL 1975

ISSN 0016-62X

GEMS & GEMOLOGY is the quarterly journal of the Gemological Institute of America, an educational institution originated by jewelers for jewelers. In harmony with its position of maintaining an unbiased and uninfluenced position in the jewelry trade, no advertising is accepted. Any opinions expressed in signed articles are understood to be the views of the authors and not of the publishers. Subscription price $3.50 each four issues. Copyright 1975 by Gemological Institute of America, 11940 San Vicente Boulevard, Los Angeles, California 90049, U.S.A.

gems & gemology

VOLUME XV NUMBER 3

FALL 1975

IN THIS ISSUE

A Device for Obtaining Interference Figures For Gemstones*

BY C. S. HURLBUT, JR., Ph.D.
Harvard University

Introduction

Although books on gemology frequently describe and illustrate interference figures, many gemologists have never seen one in a gemstone. This is because the figures are usually observed using a high-powered polarizing (petrographic) microscope and are conventionally obtained using small crystals or thin slices of crystals. With the high power objectives used, the working distance is usually too short to accommodate even a small gemstone. Moreover, the stone must be in a precise crystallographic orientation with respect to the optical axis of the microscope. In the general case, then, it is necessary to rotate the crystal to achieve the desired position. A device to do this, developed by Waldmann, is manufactured by E. Leitz. It requires a polarizing microscope equipped with a universal stage in addition to a hollow sphere within which the gemstone is mounted and surrounded by an immersion liquid. It has two drawbacks. First, the microscope and accessories are expensive and second, it is time-consuming to use. A similar type of accessory, the Moore Sphere, for a time was available from GIA but has been discontinued.

It is the purpose of this article to describe a relatively simple device, a *Crystal Orienter,* to obtain interference figures on transparent crystal fragments or gemstones that range in diameter from 5-20 millimeters. One of its chief attributes is that it is used with a low power binocular microscope with a large working distance, the type most jewelers have at their disposal.

Several manufacturers make microscopes that are suitable. The principal requisite is that there be a means of substage illumination. The model used by the writer is a Bausch and Lomb with a zoom lens giving a continuous variation in magnification from 7X to

---

30X. The instrument must further be converted to a polarizing microscope by equipping it with two polarizing filters, one beneath the stage and the other below the objectives. This is easily done with the B & L by placing beneath the circular glass stage a sheet of *Polaroid* (the polarizer) cut to the same diameter as the glass stage. A smaller circular *Polaroid* sheet (the analyzer) is placed in a threaded ring (supplied by the manufacturer) and screwed into place beneath the objectives. The polarizer and analyzer are jointly called the *polars.* In the conventional positions the polarizer is turned to permit light to vibrate in a north-south direction and the analyzer is adjusted to pass light vibrating only in a east-west direction. Under these conditions no light reaches the eye and the microscope becomes a polariscope. Thus, an anisotropic gemstone will show four positions of darkness when rotated 360° on the stage.

The Crystal Orienter

The crystal orienter is shown in *Figure 1* with a gemstone held in three-prong tweezers, "tricepts." These tweezers are more desirable than other types, for the thin wire prongs obstruct but little of the light passing through the stone. The instrument is so constructed that the gemstone can be rotated about two mutually perpendicular axes. An arm, rotating about an axis parallel to the microscope stage, carries a support to which the tweezers are held in a semicylindrical groove by a spring clip. The long dimension of the tweezers is the second axis and about it the stone can be rotated 360°. By adjusting the position at which the tweezers are supported, one can place the stone so that the two axes of rotation intersect at its center. This point of intersection

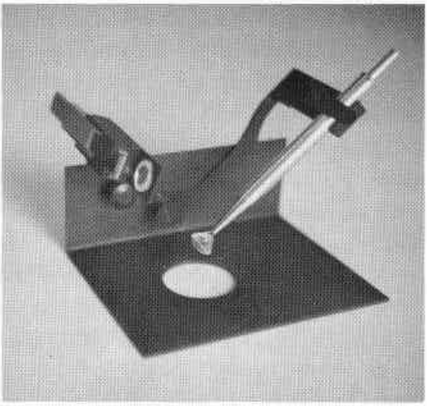


Figure 1. The crystal orienter with gemstone held in three-prong tweezers.

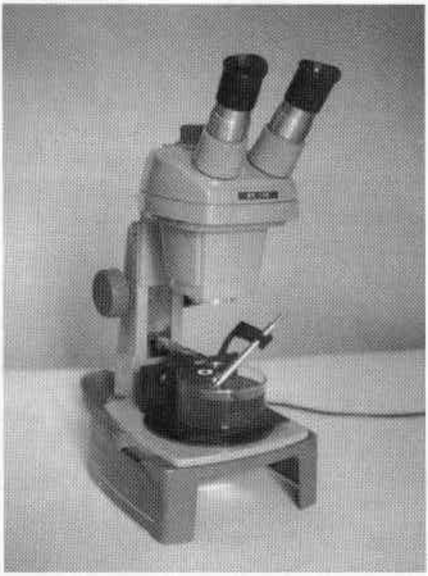


Figure 2. The crystal orienter on microscope stage with gemstone immersed in liquid and the accessory lens swung into position to observe interference figure.

is directly above a hole in the base of the instrument that permits light to pass through from the substage illuminator. When in use, a vessel containing a relatively high refractive index liquid is placed on the base so that the stone can be examined while immersed in the liquid *(Figure 2).* Immersion minimizes the refraction of light from facets, permitting one to see into the stone, and is essential in obtaining an interference figure.

Ideally the immersion liquid and the gemstone should have the same refractive index. However, this is not necessary and any of several liquids can be used. It is desirable to use a single liquid for, unless great care is used, contamination results in changing from one liquid to another. It has been found that monobromonaphthalene (R.I. 1.66) produces good results with stones having refractive indices of 1.45 to 1.95.

Converging polarized light is necessary to obtain an interference figure. Polarizing microscopes usually accomplish this by means of a substage condenser that can be swung into the optical system. In using the *crystal orienter* the effect is produced with ground glass. If a glass immersion vessel is used, as shown in *Figure 2*, the ground glass is placed between it and the microscope stage. In developing this instrument it was found more convenient to use a rectangular, hollow aluminum prism 3 inches long, 2 inches wide and 1 1/2 inches high. Ground glass cemented to one of the open ends forms the base and gives the required effect of converging light.

The Interference Figure

Uniaxial crystals are so named because they have one optic axis, that is, one direction in which light passes through them as through an isotropic substance; there is no birefringence. Biaxial crystals have two such directions. To obtain what is called a centered optic axis figure (either uniaxial or biaxial), the crystal must be rotated so that an optic axis is parallel to the direction in which light passes through the microscope. The desired position can be obtained quickly and easily using the *crystal orienter.*

When an anisotropic gemstone held in the orienter is viewed through the microscope, the probability is that it will appear uniformly bright against a dark field.* A search for an optic axis is made as follows: Rotate the stone slowly 360° about the tweezer axis with the tweezers as nearly horizontal as the immersion vessel permits. If this rotation does not show proximity of an optic axis (how this is noted is described later), rotate upward at intervals of about 10° on the horizontal axis, each time rotating 360° about the tweezer axis. If an optic axis or the proximity to one has not thus been located, the stone must be reoriented in the tweezers and the above procedure repeated. If possible, the tweezer axis should make on reorientation an angle of about 45° with its initial position. The first and second positions should not be at right angles.

Since the rotation possible on the horizontal axis is only slightly more

---

*These conditions offer an excellent opportunity to examine the interior of the stone to observe imperfections, inclusions, etc.

than 45° there is a 50-50 chance that the first position in the tweezers will yield an interference figure. This is true with a randomly cut stone. However, many minerals produce the most pleasing gems when the table is either parallel to or perpendicular to the optic axis. Therefore, the chances of obtaining an interference figure with the first setting are considerably increased if the tweezer axis makes an angle of about 45° with the table.

Polarized light entering an anisotropic crystal is separated into two rays which, when they reach the analyzer, interfere and certain wave lengths are eliminated. The thicker the crystal, the higher its birefringence and the greater the angular deviation of the light path from an optic axis, the more wave lengths are eliminated but the whiter the crystal appears. The absolute birefringence of a gemstone is, of course, constant no matter what the orientation. However, since the stone is not of uniform thickness, the distance light travels through it varies greatly from edge to center. In orienting a stone one should observe the thinnest edges. Here may be seen interference colors, color bands, parallel to the edge as the stone is turned. The colors indicate that an optic axis has been brought more nearly parallel to the light path. Continued turning on either axis that results in broadening of the color bands is indication that an optic axis is approaching parallelism with the light path. Narrowing of the bands indicates a departure from parallelism. In *Figure 3a* color bands can be seen at the edge of a brilliant cut beryl; *Figure 3b* shows a broadening of the bands after the stone has been rotated 15°. When it is impossible to further broaden the bands by rotation, an optic axis is nearly vertical. This is the position desired for obtaining an interference figure.

Gems of low birefringence are easier to orient than those of high

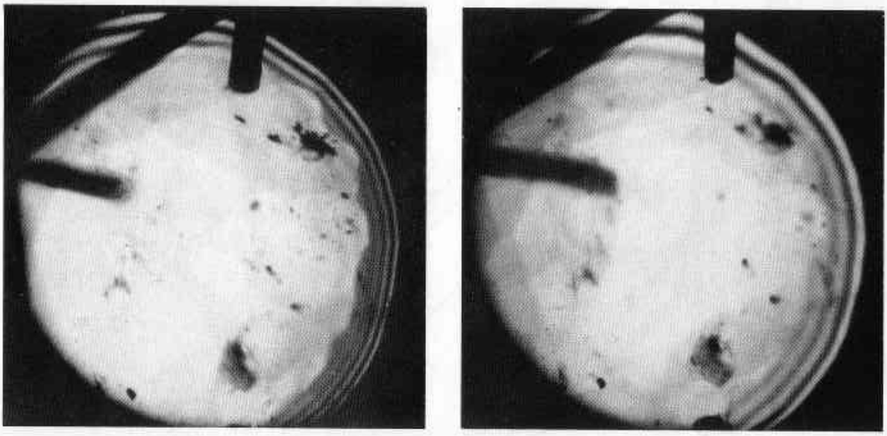


Figure 3. A brilliant cut beryl held in the crystal orienter. Figure 3a (left). The stone has been brought into position so that color bands appear on the thin edges. Figure 3b (right). Broadening of the color bands after the stone has been rotated 15°.

birefringence. Apatite (biref. .005) will show interference color bands when the optic axis is as much as 30° to 40° from its desired position. Whereas, in zircon (biref. .057) the axis must be within 10° to 15° of the vertical before color bands appear.

To observe the interference figure an accessory lens on the *crystal orienter* is swung into position above the stone. The figure appears on the upper part of the lens and the microscope tube should be raised to bring it into sharper focus. If it is not centered, a slight rotation on one or both of the axes of the orienter will bring it to a centered position. Since with a binocular microscope the stone is viewed from two different angles, it is impossible to obtain a perfectly centered interference figure simultaneously from both halves of the optical system. One should, therefore, make the final observations using only one ocular.

A uniaxial optic axis interference figure, *Figure 4a,* is composed of concentric circles of interference colors superimposed on a black cross. The biaxial optic axis interference figure, *Figure 4b,* is made up of curved bands of interference colors crossed by a single dark brush which may be curved or straight.

The Optic Sign

Coupled with other observations the determination of the uniaxial or biaxial character of a gemstone may be sufficient to characterize it and further data may be unnecessary. However, using an optic axis interference figure it is possible to go one step more and determine the optic sign. For, anisotropic crystals in addition to being classed as uniaxial or biaxial are further subdivided as being positive or negative. For example, quartz is uniaxial positive, whereas cordierite is biaxial negative. The optic sign can be obtained from an interference figure by means of a quartz wedge. This is an accessory available from any of the manufacturers of polarizing microscopes.

In a uniaxial interference figure the

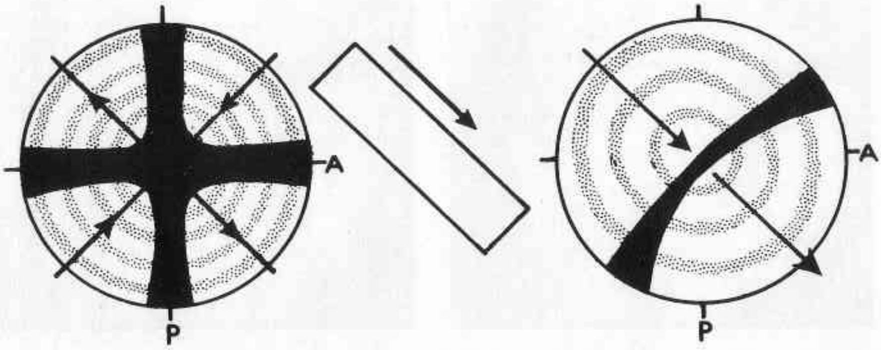


Figure 4. Optic axis interference figures: a (left), uniaxial; b (right), biaxial. The arrows indicate movement of interference colors (stippled bands) in positive crystals when the quartz wedge is passed over the interference figure in the direction indicated.

bars of the black cross will be N - S and E - W, parallel to the vibration directions of the polars. To determine the sign, slowly pass the quartz wedge over the accessory lens at an angle of 45° to the bars of the black cross *(Figure 4a)*. It is necessary that the thin edge of the wedge (always at the opposite end from the handle) be the leading edge in making the observations. This will cause the circles of interference colors to move. In two opposite quadrants they will move toward the center of the figure and in the other two quadrants they will move away from the center. If the movement toward the center is in the quadrants at right angles to the long dimension of the quartz wedge, the crystal is positive. If the movement of the bands is toward the center in the quadrants parallel to the long dimension of the wedge, the crystal is negative.

Determination of the optic sign of a biaxial crystal is not as straightforward as that of a uniaxial crystal. Before it can be accomplished, the single dark band of the biaxial optic axis figure must have its long dimension essentially at 45° to the vibration directions of the polars. That is, it must be in a NW - SE or NE - SW position (see *Figure 4b)*. This is also the position of the maximum curvature of the bar. On initial observation of the figure, the dark band may be in this position. If it is not, the crystal (i.e. the whole *crystal orienter*) must be turned, perhaps as much as 45° to accomplish it. In this orientation, known as the 45° position, the bar in most instances will be curved. The optic sign is then determined by observing the movement of the color bands as the quartz wedge is passed over the accessory lens. The wedge must be moved so that its thin edge approaches the convex side of the black bar. If the color bands move toward the convex side and outward from the concave side, the crystal is positive *(Figure 4b)*. In a negative crystal the color bands move in the opposite direction.

Some biaxial crystals yield optic axis interference figures in which the black bar remains essentially straight in all positions as the *crystal orienter* is turned. In these crystals the optic angle, the angle between the two optic axes, is 90° or nearly 90° and it is impossible to determine the optic sign. However, knowing that the optic angle is essentially 90° is in itself useful information.

(Note: The Crystal Orienter is available from the Kenneth A. Dawson Company, Inc., 106 Concord Avenue, Belmont, Massachusetts 02178.)

Developments and Highlights at GIA's Lab in Los Angeles

By RICHARD T. LIDDICOAT, JR.

An Unusual Cyclotron — Treated Diamond

The number of diamonds that were treated by bombardment in a cyclotron is not large, judging by the few that we encounter in the laboratories in New York and Los Angeles. The quantity of diamonds both cyclotron treated to a green or black color and then heat treated to produce yellow or brown is even less in number and, when one considers those treated other than from either crown or pavilion, the number can almost be counted on a hand or two. Recently, at the GIA laboratory in Los Angeles we received a brown marquise diamond for testing to determine whether the color was natural or treated.

A slightly cloudy nature and some color banding suggested the color might be natural, until Charles Fryer and Peter Yantzer, who were examining the stone, encountered key characteristics that would have been easy to overlook. *Figure 1* shows a color zone which is enhanced by focusing the light just right on it along the keel line. In *Figure 2* a sharp color line is shown along one side of the rough bearded girdle. This is magnified and shown more distinctly in *Figure 3.* The unusual thing about this stone that made it unique in our experience was the fact that it apparently had been treated not from the crown or the pavilion but only from one side of the pavilion. As a result a zone of color produced on one side of the keel line was not duplicated on the other side. The zone of color occurred only a short distance from the girdle along one side but there was nothing visible on the other side. This was a particularly interesting cyclotron-treated stone in which the particle used for bombardment was not a heavy weight

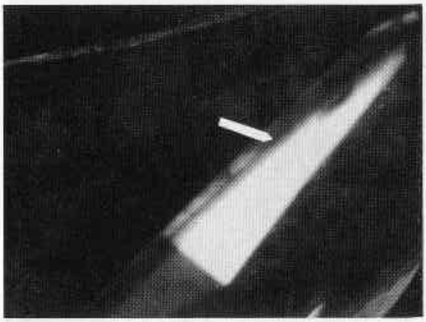


Figure 1.

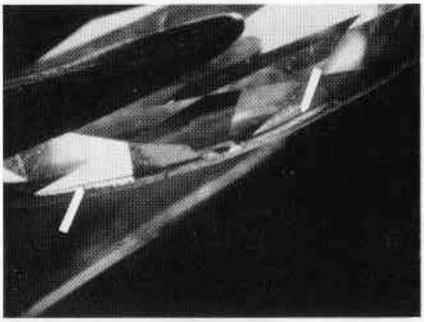


Figure 2.

particle. A heavy particle would have penetrated all the way. The particles used penetrated only a portion of a millimeter.

Color Zoning in an Emerald

In a recent identification of a natural emerald we were very much interested in a color zoning that was reminiscent of Burma rubies. The overall appearance was one of an attractive color, but looking through the stone from the pavilion there were rather large colorless areas. The boundary between those areas was quite sharply patterned. This is shown to a degree at least in *Figure 4.* Near the center of the photograph will be observed a jagged pattern with the color concentrated below the edge of that pattern and a colorless area above. This sawtoothed pattern is occasionally seen in natural emerald but is seldom accompanied by a distinct color boundary as observed in the emerald we examined.

Topaz Inclusions

A year or two ago we found in topaz some almost circular inclusions resembling smoke rings. Perhaps that made the unusual inclusions pictured in *Figure 5* somewhat less startling than they might have been otherwise. The appearance of the inclusions is almost reminiscent of lint or other irregular cloth ravelings. They might be likened to irregular tendrils of smoke. This is really not what one might expect in a crystalline material.

Semitransparent Jadeite

Occasionally we encounter jadeite that so closely approaches transparency that it is faceted. Such an

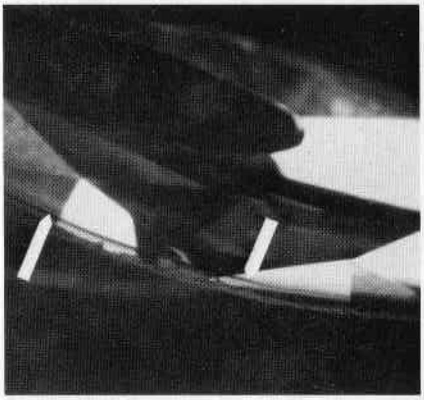


Figure 3.

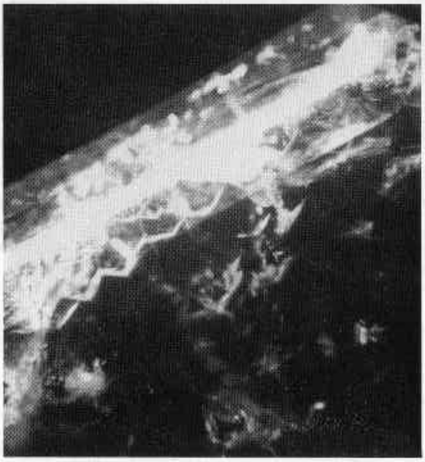


Figure 4.

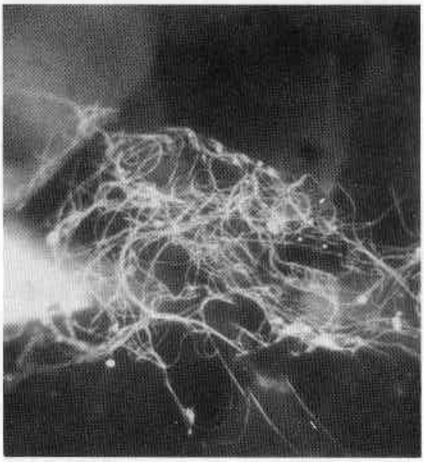


Figure 5.

emerald-cut light gray jadeite was sent in for identification and was photographed by both transmitted and reflected light. It is shown by transmitted light in *Figure 6* and by reflected light in *Figure 7.*

Marble Sword

The laboratory is often called upon to identify foreign carvings. Recently, we received for identification a ceremonial sword, seen in *Figure 8,* which turned out to be marble. *Figure 9*

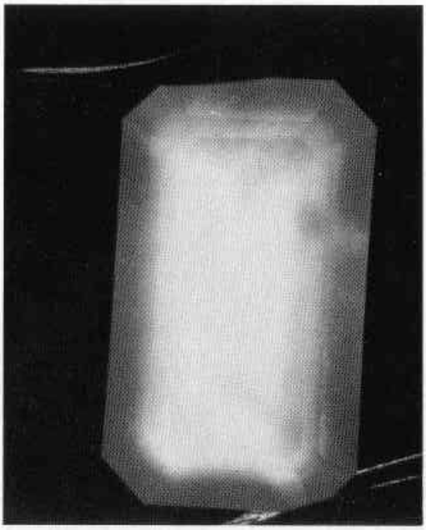


Figure 6.

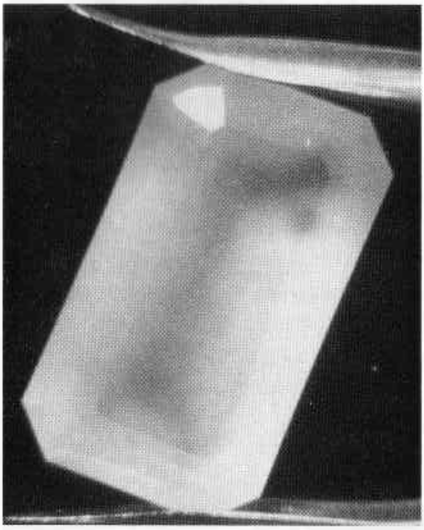


Figure 7.

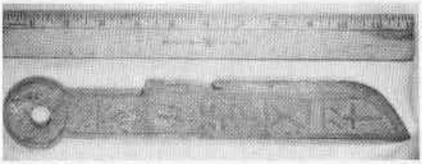


Figure 8.

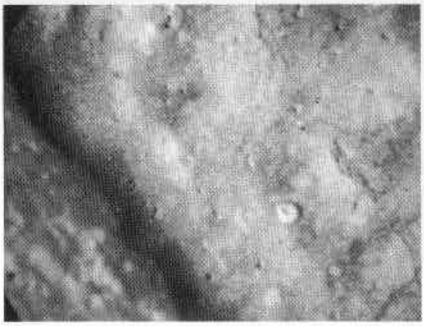


Figure 9.

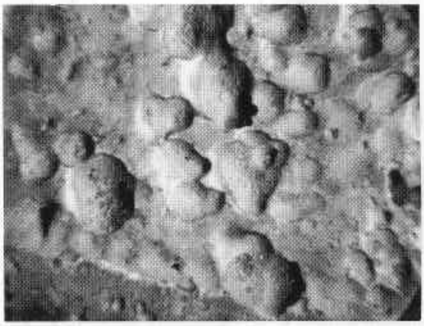


Figure 10.

shows an area on its surface with a tiny fossil foraminifer or gastropod under 50x. The heavily etched surface is shown under 10x in *Figure 10.* We've received quite a number of marble carvings for identification in recent months. Also, we have identified a number of hololith bracelets made of marble, many of which had been dyed to resemble jadeite. The dye is either a green or a rusty orange color and usually occurs in patches.

Moldavite

One type of material we are seldom called upon to identify is moldavite. We had one in for identification which showed the typical roiled moldavite appearance under magnification. It is shown in *Figure 11* under 10x, and the large number of bubbles may be clearly seen at this magnification. The typical swirled structure is more evident in *Figure 12*, taken under 40x. An oval bubble and a large irregular blob of apparently only partially melted material is present in *Figure 13* at 63x.

Inclusions in Amethyst

Figure 14 shows inclusions that resemble those seen in a flux-grown

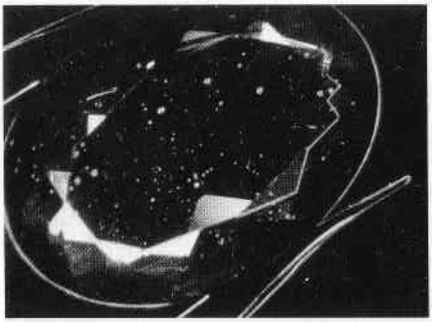


Figure 11.

Figure 12.

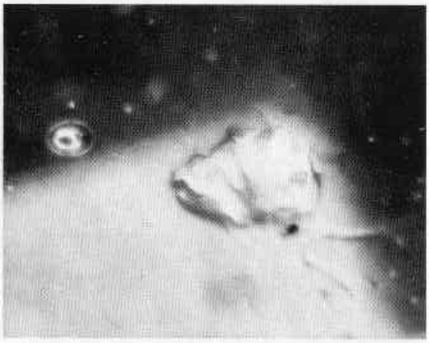


Figure 13.

synthetic material. Actually, the rhombohedral arrangement is typical of the color distribution often seen in amethyst, of which this photograph is taken.

Treated Green Diamond

In the process of determining the origin of color in a dark green diamond (which proved to have been treated in a nuclear reactor), we observed a very interesting pattern of minute inclusions. The dark Maltese cross under the table was formed by the absence of cottony inclusions in the darker areas. (See *Figure 15.*) The whiter areas are those in which the inclusions are abundant.

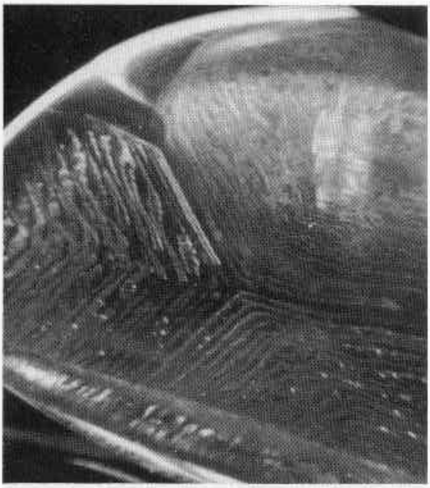


Figure 14.

An Interesting Inclusion in a Colorless Diamond

While grading a round brilliant, we found a square-shaped group of sugary inclusions. These were surrounded by a square rim of similar inclusions as seen in *Figure 16* with a needle pro-

Figure 15.

Figure 16.

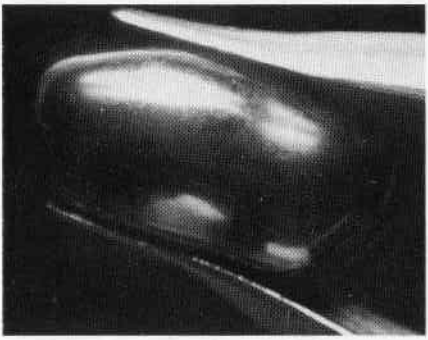


Figure 17.

jecting from the center and continuing well into the diamond.

Limonite

We were asked to test an unusual dark brown polished baroque with a metallic luster. (See *Figure 17.*) The baroque in question proved to be the mineral limonite. This is not a commonly encountered gem material in the jewelry industry.

Acknowledgements

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

To *Robin Banchik*, resident student, for eight pieces of rough emerald to be used in our colored stone classes.

To *Yoshiko Doi,* G. G., AGT, Tokyo, Japan, for two "metajade" cabochons and one piece of interesting glass simulating emerald for our reference collection.

To *Toni Garrett,* GIA student, Lamp Post Antiques, Tulsa, Oklahoma, for a large selection of cut synthetic stones including ruby, sapphire, spinel, glass and natural opal to be used in our gem identification classes.

To *Ben Gordon,* G.G., of Gordon Jewelry Corporation, Houston, Texas, for yet another generous gift of numerous cabochons and faceted stones of various kinds of natural, synthetic, and imitation gem materials. These will be put to good use by our students in the gem identification course.

To *Elaine Ho,* G.G., of World Jewel Trade Center, Ltd., Bangkok, Thailand, for 24 doublets with natural sapphire tops and synthetic sapphire or synthetic ruby pavilions for class use.

To *Betty Magyari,* of Magyari's Jewelry, Westlake Village, California, for a welcome assortment of miscellaneous rough and cut stones to be used in our colored stone classes.

To *Steven J. Mara,* of Greyfriars Company, Inc., Yonkers, New York, for a 0.67 ct. diamond which will be used as a recutting problem in the diamond course.

To *Donald Mountfort*, F.G.A.A., Sydney, Australia, for a gracious gift of miscellaneous Australian opals and other gem minerals for reference and class use.

To *Glenn Nord,* G.G., of GSI Gem Corporation, Los Angeles, California, for a much-needed collection of 23 diamond melee for class identification stones.

To *Marianne Shale,* G. G., Beverly Hills, California, for a timely specimen of "turquoise-blue" ceruleite for our reference and student collection.

To *D. W. Ward,* GIA student, San Diego, California, for a selection of glass imitation turquoise cabochons to be used in resident testing sets.

Faceting Limits

BY BRUCE L. HARDING
Holden, Massachusetts

Introduction

The pavilion and bezel slopes commonly recommended for faceting are the result of trial-and-error and human judgment. This explains why references differ in their recommendations.

Trial-and-error is an effective way to solve complex problems until a better way comes along, but it usually finds only the best solution in the range of experimentation. Other good solutions may exist – beyond the bad ones – but are found only by accident. This has been as true in faceting as in many other scientific fields.

Inspired by an exceptionally brilliant but strangely-cut emerald, the writer went in search of these other solutions and found that there are indeed two or three areas of good design for each gem material.

This article presents the first and most important result of that search – charts for each of the common faceting materials which show areas of good and bad pavilion and bezel slope combinations; it also defines maximum and minimum table sizes briefly (more later). The faceter can choose from the various "good" areas according to what *he* thinks is best or to suit the limited proportions of his rough material.

The text describes the formation of these charts so that you can understand them better. Technical details are omitted; it is assumed that you are either familiar with gemology optics or don't care. The mathematics involved are quite simple but are deferred to an appendix for those who care to understand them or who may need to create additional charts.

Objectives

Figures 1 through *8* show a grid which represents all combinations of pavilion slopes from 35° to 45° and bezel slopes from 0° to 60°. Pavilion

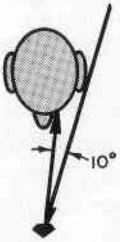


Figure 1.

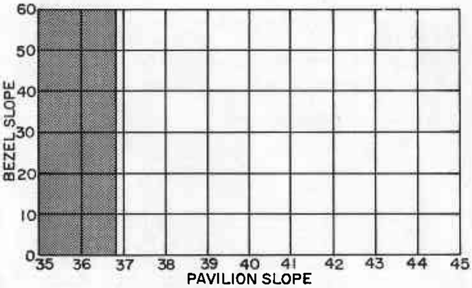


Figure 2.

slopes greater than 45° are not considered in this initial discussion but will be described in future articles as they apply to certain facets.

It is easier to define that which is bad about a gem than that which is good, so the object of this study is to delete areas of the grid which represent poor designs. Dark shading will be used for the worst conditions, medium shading for those which are less severe, and light shading for minor faults. "Best" designs will then lie in the areas of lightest shading.

Dead Center

If the pavilion slope is less than the critical angle, no reflections can be seen through the table when looking into it perpendicularly; furthermore, reflections through the table cannot be seen from more than one side of the pavilion in other positions.

This "dead" center condition is very undesirable so pavilion slopes less than the critical angle are shaded dark on the grid, as shown for peridot in *Figure 1.*

The Viewer's Head

Rays which are reflected to the viewer's eye must come from directions which missed his head. *Figure 2* shows that at a viewing distance of one foot, as when examining a stone prior to purchase, the angle (or divergence)

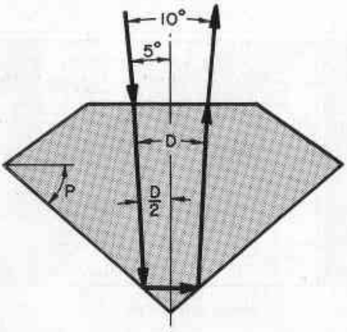


Figure 3A.

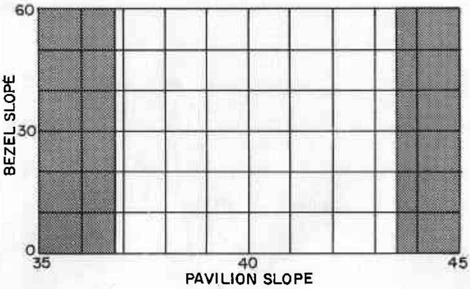


Figure 3B.

between incident and reflected directions of *the same ray* must be at least 10°; otherwise the viewer will see reflections of himself.

Table-to-Table Rays

Figure 3A shows a ray entering and leaving the table, being reflected off both sides of the pavilion. For each pavilion slope *P* the internal divergence *D* (=180°–4P) is constant regardless of the ray angles. The corresponding external divergence is larger and varies according to the refractive index of the material and the ray angles; it is minimum when it is symmetrical as shown in *Figure 3A.*

For this minimum external divergence to be 10°, the pavilion slope is about 1.5° more or less than 45°. Slopes between these values produce less divergence, so that they are shaded dark in *Figure 3B.*

Table-to-Bezel Rays

Figure 4A shows a ray entering the table perpendicularly, which returns to the bezel at an angle B–D to the bezel normal. By refraction, the corresponding external angle must be B±10° to provide the required minimum divergence of 10°.

Figure 4B shows plots of the two bezel slopes which satisfy this condition for each pavilion slope. Slope combinations between these plots produce divergence less than 10°. Because a large portion of returned light passes this way, this area is shaded dark.

Bezel-to-Table Rays

Rays which enter the bezel and leave via the table follow paths identical to those described above, except in the opposite direction; accordingly, the shaded area of *Figure 4B* applies to these rays also.

Bezel-to-Bezel Rays

Figure 5A shows a symmetrical ray entering one bezel and leaving via the other; its internal angles to the bezel normals are B–D/2. By refraction, the corresponding external angles must be B±5° to provide the required minimum divergence of 10°.

Figure 5B shows plots of the two bezel slopes which satisfy this condition for each pavilion slope. Slope

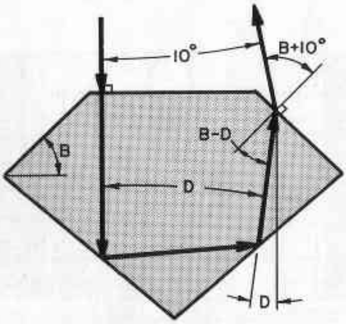


Figure 4A.

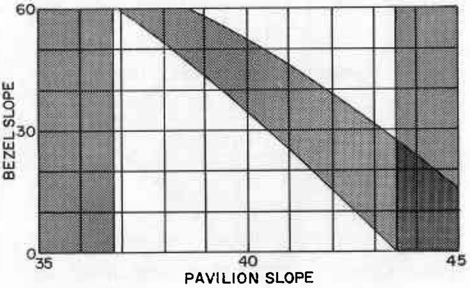


Figure 4B.

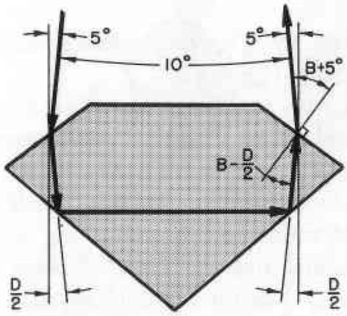


Figure 5A.

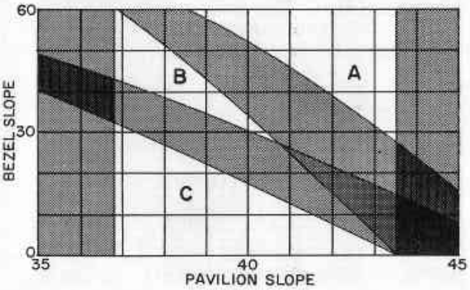


Figure 5B.

combinations between these plots produce divergence less than 10°. Because the major portion of returned light passes this way, this area is also shaded dark.

The Basic Faceting Chart

Figure 5B is the basic "faceting chart" which indicates the well-known critical angle limitation and the areas which violate the 10° minimum divergence imposed by the viewer's head. These separate the chart into three unshaded areas which are labeled Zones A, B and C for simple reference.

Most recommended designs lie in Zone A; those for refractive indexes from 1.6 to 1.7, however, lie in Zone B. This explains the odd discontinuity in faceting data which must have puzzled inquisitive faceters. It is curious that experimenters found their way into Zone B for these stones only. There are no commonly recommended designs in Zone C; however, it applies to the exceptional emerald which inspired this study.

Note that the shading is intensified when one shaded area overlaps another; this indicates the worse situation of two bad conditions at the same design points.

Additional criteria will now be added to this basic faceting chart.

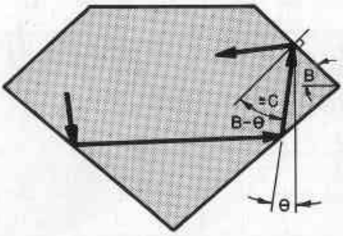


Figure 6A.

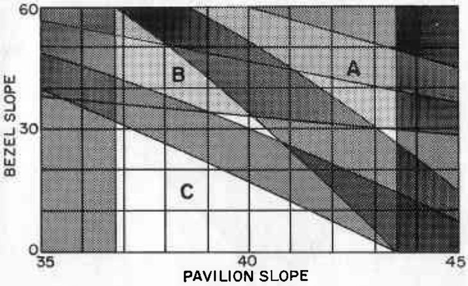


Figure 6B.

Internal Reflections From the Bezel

Figure 6A shows an internal ray approaching the bezel at an angle θ to the gem axis. If its angle B–θ to the bezel normal is more than the critical angle *C*, it will be reflected back into the stone. The probability is that such rays will ultimately be lost through the pavilion (see future sequel), so such reflections are to be avoided as much as possible.

The maximum angle θ of a ray reflected from the pavilion is 180°–C–3P; if this ray is reflected as shown in *Figure 6A,* then *all rays* reflected from the pavilion are reflected back by the bezel. Designs which cause this intolerable condition are indicated by the dark area in the upper right of *Figure 6B.*

According to *Figure 5A,* a symmetrical bezel-to-bezel ray approaches the bezel at an angle B–D/2 to the bezel normal. If this angle is greater than the critical angle *C*, then *all bezel-to-bezel* rays are reflected because they cannot enter the first bezel at an angle which prevents such reflection from the second bezel. Designs which cause this bad condition are indicated by a medium-shaded diagonal area in *Figure 6B.*

Some rays will be reflected back by the bezel unless the minimum internal angle θ (=C–P) is not reflected. Designs corresponding to this limited back-reflection are indicated by the light-shaded diagonal area of *Figure 6B;* the area below this corresponds to designs with no internal reflections from the bezel, except for the following unusual situation.

With very low bezel and pavilion slopes, it is possible to have θ_{max} greater than *B* such that θ–B is greater than *C.* This causes reflections of some rays and is shown by a light shaded diagonal at the lower left for refractive indexes greater than 1.7.

Range of Reflections Through Table

Figure 7A shows the extreme angles of a ray reflecting off both sides of the pavilion: θ_{min} = C–P (negative) and θ_{max} = 180°–C–3P (because D = 180°–4P). The corresponding external angles ϕ_{min} and ϕ_{max} are the limits at which the viewer can see reflections through the table from the far and near sides of the pavilion, respectively.

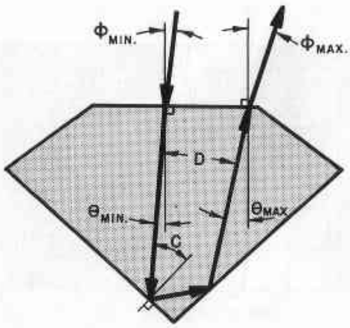


Figure 7A.

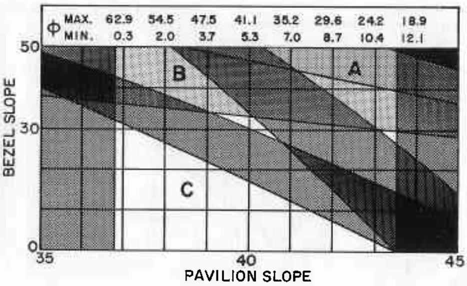


Figure 7B.

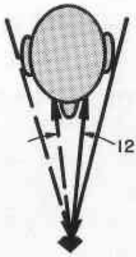


Figure 8A.

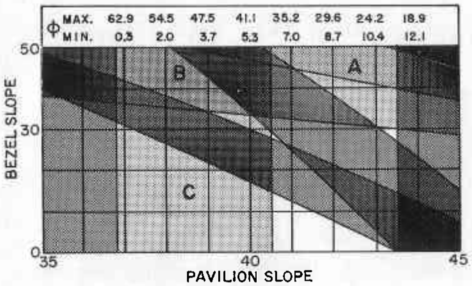


Figure 8B.

Angle ϕ_{min} is therefore the limit for seeing reflections from *both sides at once.*

These limits are noted across the top of the faceting chart in *Figure 7B* for each pavilion slope. Note that as one limit increases, the other decreases.

"Live" Center

For ultimate liveliness it should be possible to see reflections in the table from both sides of the pavilion with *both eyes* at once. At a viewing distance of one foot, as shown in *Figure 8A*, the angle between reflections to both eyes (two different rays) is about 12°. To see reflections from both sides with both eyes, therefore, the minimum external table reflection angle ϕ_{min} must be at least 6°.

Designs which do not satisfy this condition are shaded light at the left of *Figure 8B.*

Faceter's Options

The faceter should choose a design from one of the lighter areas of the chart according to what he thinks is "best" . . .

1) increase pavilion slope for wider range of "live" center,
2) decrease pavilion slope for wider range of table reflections,

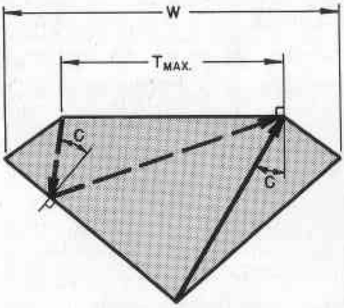


Figure 9.

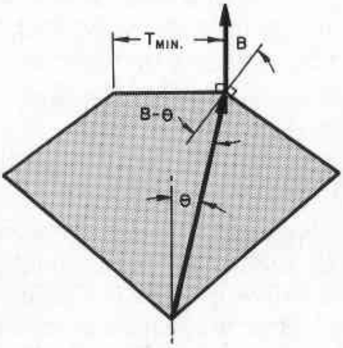


Figure 10.

3) increase bezel slope for greater dispersion,
4) decrease bezel slope for greater brightness.

Maximum Table Width

Internal rays which hit the table at more than the critical angle to its normal will be reflected back into the gem and probably be lost through the pavilion. This can be avoided by limiting the table size so that any such rays hit the bezel instead of the table. *Figure 9* shows the two extreme rays which cause this problem; oddly, they both define the same maximum table size.

Calculations show that this maximum table size is seldom less than 75% of girdle width for most stones faceted by amateurs (it is 53% for diamond with standard slopes).

Minimum Table Width

The only justification for a minimum table size is to prevent seeing reflections of the culet in the bezel when looking perpendicular to the table. *Figure 10* shows that this limit is defined by a ray from the culet to the edge of the table which is bent perpendicular to the table by the bezel.

Calculations show that this minimum table size is seldom more than 50% of girdle width.

Optimum Table Width

Charts of maximum and minimum table widths, according to these criteria, will be presented vs. pavilion and bezel slope combinations for various refractive indexes in a future article. Another sequel will show that most of the light returned to the viewer passes through the bezel, so this is an argument against large tables.

Temporarily, therefore, table widths from 50% to 60% should be considered ideal until more data or criteria are available.

Charts for Specific Materials
(see facing page)

Faceting charts are shown for eight different refractive indexes representing common faceting materials; for other materials, use the chart with the closest refractive index, or make your own if the RI is over 1.9. Marks on these charts represent designs recommended by three common references; a solid dot indicates references referred to as 1 and 2; a circle indicates another reference 3.

The table on page 86 summarizes these data and indicates designs which appear to be best according to the charts. Designs which the chart indicates as not recommended are shown in parentheses.

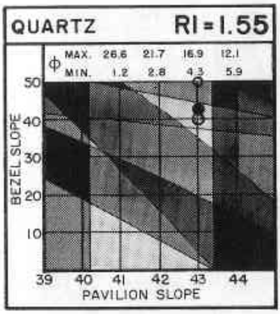
Comments

The charts agree with references 1 and 2 in all examples but one and disagree with reference 3 in all but part of two. Reference 3 recommends the same angles for many stones; for RI's greater than 1.6 these designs give almost zero divergences for table-to-bezel rays – perhaps this was the author's intent, being unaware of the viewer's head problem.

If it were important to find one design which was suitable to all stones, the closest solutions according to these charts would be: P/B = 43°/35° (Zone

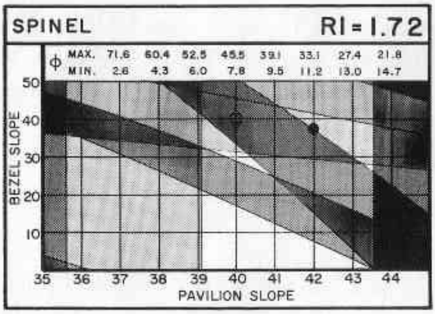
FACETING CHARTS

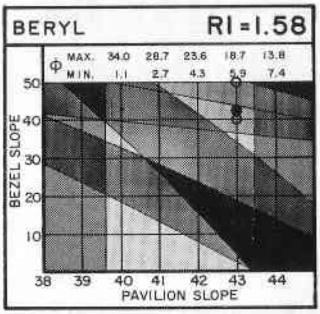
LIGHTEST AREA = BEST DESIGN

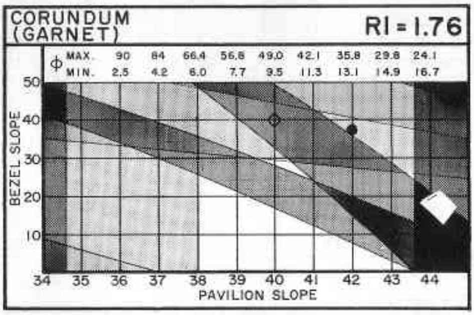


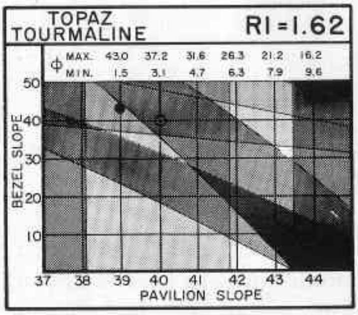
INCREASE DISPERSION ↑

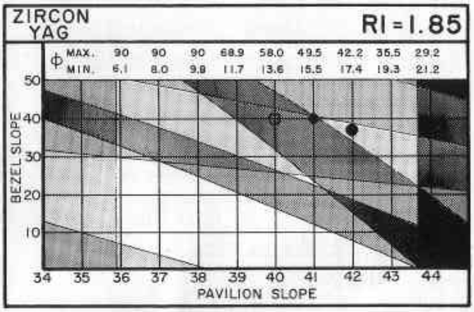
INCREASE BRIGHTNESS ↓

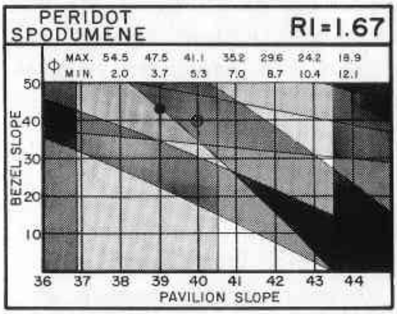


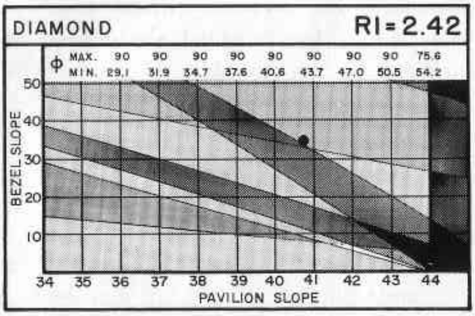












P/B	COMMON RECOMMENDATIONS		RECOMMENDED PER CHARTS		
	1 and 2	3	Zone A	Zone B	Zone C*
quartz	43/42	43/40-50	43/37	—	—
beryl	43/42	43/40-50	43/35	40/34	40/18
topaz & tourmaline	39/43	(40/40)	43/33 42/41	40/34 39/37	40/17 39/23
peridot & spodumene	(40/42) 39/43	(40/40)	43/32 42/39	40/32 39/36	39/22 38/27
spinel & grossular	42/37	(40/40)	43/31 42/37	40/31 39/35	39/21 38/26
corundum & garnets	42/37	(40/40)	43/30 42/36	40/30 39/33 38/36	39/20 38/25 37/30
low zircon & YAG	41/40 42/37	(40/40)	43/28 42/34	40/28 39/31 38/34	39/20 38/24 37/28
diamond	40.8/34.5 (Tolkowsky)[4]		43/20 42/26	41/18 40/21 39/24	38/20 37/20 36/20

*Zone C includes the Table as a bezel with zero slope. Experimental cuts in this zone are brilliant but look strange and may not be desirable.

A), = 40°/32° (Zone B), = 40°/17° (Zone C).

It is interesting to note that there are no good designs for the pavilion slope of 41°.

It is also interesting to note that pavilion slope is more critical than bezel slope; that is why I always cut the pavilion first (in addition to other reasons) – if I run short of material I can always "fudge" the crown a bit.

Zones A, B and C are of particular interest in re-cutting. A worn stone cut per Zone A can be recut per Zone B, and again per Zone C, always retaining the same girdle so that it can be replaced in the same setting; beauty will be retained and weight loss will be minimized. I have done this and it works!

Although it is possible to design a gem where the viewer's head is not an obstruction, the viewer's body is another problem and will always produce a dark area in the gem. A sequel will show that this dark area is most noticeable when the gem is cut in Zone C.

Conclusions

It is important to note that this analysis has three limitations:

1) *It assumes that pavilion and bezel slopes are constant:*

This is essentially true for brilliant cuts, but not for step cuts.

2) *It assumes that opposite facets have a common normal plane:* This is true for round, square, and rectangular girdle shapes, but not for oval, pear, marquise, etc.

3) *It assumes that rays are in a plane through the gem axis:* This is only a small part of all rays, but these are the only ones which can be analyzed simply.

The first two assumptions are also inherent in the design slopes recommended by various references; such data were developed by trial-and-error on round brilliant cuts but may be used as approximate guides for other cuts.

It is most significant, however, that the theoretical results show good correlation with those proven by trial-and-error, despite the third limitation described above. This indicates the validity of the method.

The key to this study was the effect of the viewer's head, which can be observed by close study of reflections in a cut gem. Other criteria which may have been overlooked will be added in later articles. Several sequels are already in process which probe specific aspects of the problem in more detail.

As it stands, this is believed to be one of the better faceting guides to date. Comments from readers will be welcomed and reviewed toward making it even better.

Reference

1. GIA *Colored Stone Course* (1975), Los Angeles, California

2. Soukup, E.J. (1962) *Facet Cutters Handbook,* Gemac Corp, Mentone, California, 64 pages

3. Sinkankas, J. (1962) *Gem Cutting – A Lapidary's Manual,* 2nd edition, Van Nostrand Reinhold Company, New York, 197 pages.

4. Tolkowsky, Marcel (1919) *Diamond Design,* Spon & Chamberlain, New York, 104 pages.

APPENDIX

The following nomenclature and formulas were used in this analysis:

R = refractive index
D = internal divergence
P = pavilion slope
θ = internal ray angle
T = table width
C = critical angle ($\sin C = 1/R$)
D' = external divergence
B = bezel slope
ϕ = external ray angle
W = girdle width

Table-to-table rays blocked (Figure 3):

$\sin D' = R \sin D$ . . . where: $D = 4(45^\circ - P)$, $D' = \pm 10^\circ$

Table-to-bezel rays blocked, and vice versa *(Figure 4):*

$\sin(B - \phi) = R \sin(B - D)$ . . . where: $\phi = \pm 10^\circ$

Bezel-to-bezel rays blocked (Figure 5):

$\sin(B - \phi) = R \sin(B - D/2)$ . . . where: $\phi = \pm 5^\circ$

Internal reflection from bezel (Figure 6):

$B_{max} = \theta + C$ *(Figure 7A)* $\quad B_{min} = \theta - C$ (not illustrated)

Maximum pavilion ray angle ($\theta_{max} = 180^\circ - C - 3P$):

$B_{max} = 180^\circ - 3P \quad B_{min} = 180^\circ - 2C - 3P$

Mean bezel-to-bezel ray ($\theta = D/2 = 90^\circ - 2P$):

$B_{max} = 90^\circ + C - 2P \quad B_{min}$ = too low to matter

Minimum internal ray angle ($\theta_{min} = C - P$):

$B_{max} = 2C - P \quad B_{min}$ = too low to matter

"Live center" seen by both eyes (Figure 8):

$\sin\phi - R \sin(C - P)$ . . . where: $\phi = -6^\circ$

Maximum table size (Figure 9):

$$\frac{T}{W}\text{max} = \tan C \, \frac{\tan P + \tan B}{\tan C \tan B + 1}$$

Minimum table size (Figure 10):

$$\frac{T}{W}\text{min} = \tan\theta \, \frac{\tan P + \tan B}{\tan\theta \tan B + 1} \quad \text{. . . where: } \sin B = R \sin(B - \theta)$$

Derivations of formulas will be provided upon request from the author: Bruce Harding, 33 Anthony Drive, Holden, Mass. 01520.

Developments and Highlights at GIA's Lab in New York

By ROBERT CROWNINGSHIELD

Synthetic Rubies

We have had only a few occasions to test flux-grown synthetic rubies and have been somewhat surprised since they are known to be available in Far Eastern markets. Recently, we were able to purchase, following identification in the Laboratory, a quantity of Thai cut stones in the 1/2-carat to 2-carat range. The parcel contained

Figure 1.

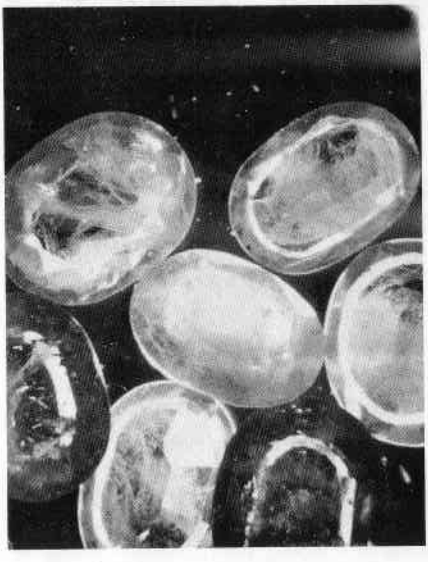


Figure 2.

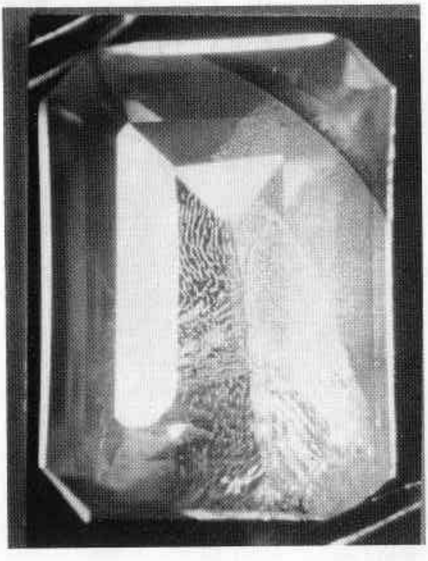


Figure 3.

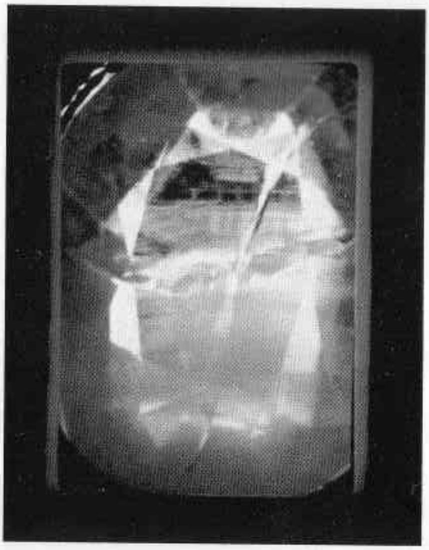


Figure 4.

several hundred stones which varied considerably in color and to the unaided eye were very convincing. *Figure 1* is a dark-field photograph of several of them. Most of the stones had the bluish band or bands we have associated with some of the Chatham flux-grown rubies, but which are by no means limited to that manufacturer's product *(Figure 2).*

Two unusual flame-fusion (Verneuil) synthetic rubies are shown in *Figures 3* and *4.* In *Figure 3* a quench-crackled synthetic ruby is further falsified by numerous scratches on the pavilion of the stone. This was presumably done with a fine diamond point. The glassiness associated with the usual synthetic ruby has been diminished, and the stone has a quite convincing appearance to the unaided eye. *Figure 4* shows the curved striae in an old stone running in opposite directions, starting at the center of the stone. With the cracks and numerous fine gas bubbles, the stone had been assumed to be natural by several jewelers before being submitted to the Laboratory.

Natural Sapphire Fooler

It is easy to see why a student would think the inclusions shown in *Figure 5* are in a synthetic sapphire. *Figure 6,* however, shows what appear to be gas bubbles are in reality rounded negative crystals with their associated fingerprint in a natural sapphire. Differences in lighting, of course, account for the difference in appearance.

Black Is Popular

The past few months have brought a large number of black polished

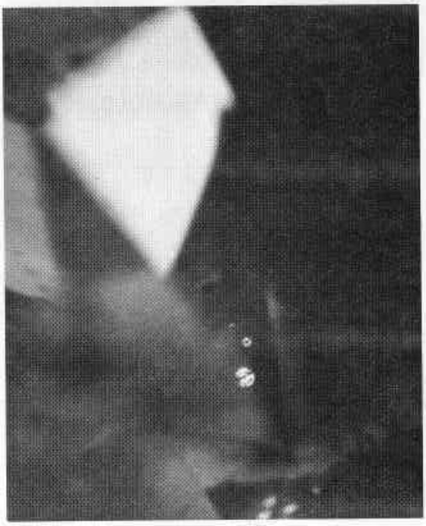


Figure 5.

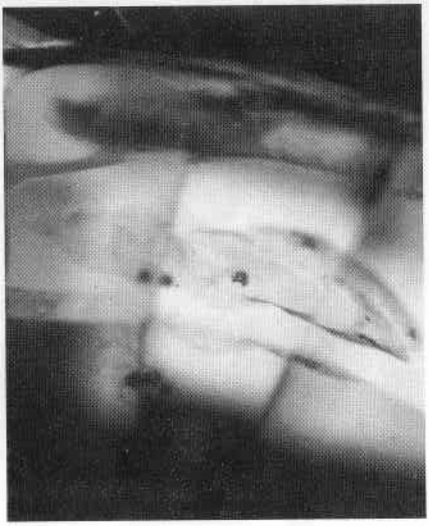


Figure 6.

stones into the Laboratory for identification. They have included black nephrite, obsidian, ordinary glass, "Imori stone," black coral, black diamond, serpentine, chalcedony and jet. Quite a few were in the form of stylish hoops.

More Corundum

Recently, one of our staff gemologists brought in a friend's gold ring containing an unusual pale brownish-orange round brilliant. The refractive indices were so unexpected that we began a search of the literature for something we must have forgotten. They were 1.755 – 1.763. It would seem to rule out sapphire. We could not find anything in the literature, so we proceeded to determine whether or not the stone was natural. No inclusions were visible, but the uniaxial interference figure showed distinct chevrons when we used Professor Plato's immersion test. It must be an unusual synthetic sapphire.

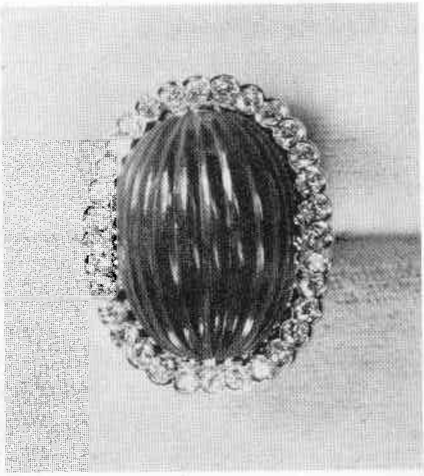


Figure 7.

Figure 8.

A pale blue, translucent, melon-cut stone illustrated in *Figure 7* initially appeared to be an elaborately set blue chalcedony – probably dyed. It was a surprise to find it was a natural Ceylon sapphire.

"Emerald"

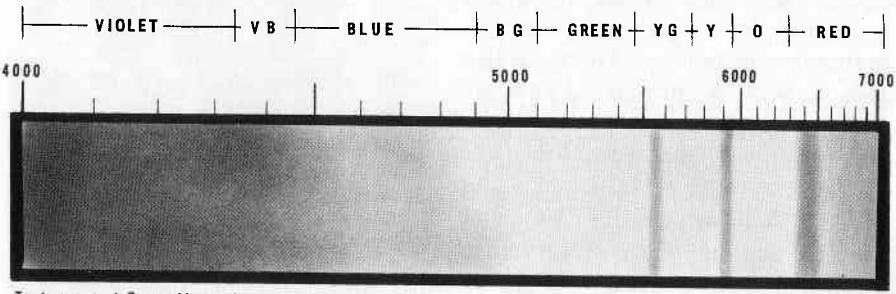
Another uncut emerald hoax is illustrated in *Figure 8*. It is a pale green beryl crystal onto which hard green enamel has been baked. Rough treatment in company with other crystals chipped some of the green away, causing the bearer to doubt his purchase.

YAG in Color

The Laboratory has had very few occasions to test other than colorless yttrium aluminum oxide stones (YAG). We did have the opportunity to test an intense "sky" blue, well-fashioned emerald-cut stone of 25 carats. The absorption spectrum, as seen in *Figure 9*, is reminiscent of cobalt.

Kornerupine

In the past few months we have seen and heard about more kornerupine than we have in 20 years. First, Mr. Campbell Bridges of Kenyan green grossularite fame (*Gems & Gemology*, Page 290, Summer, 1974) showed us bright green vanadium kornerupine from Kenya. Specimens of this – a handsome cat's-eye and a faceted stone were presented to members of the International Gemmological Conference in Washington, D.C. in October by Dr. Eduard



Intense blue Yttrium Aluminum Oxide ----24.89 cts.--------------

Figure 9.

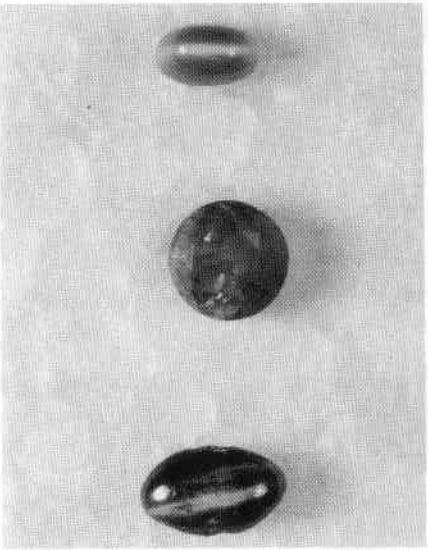


Figure 10.

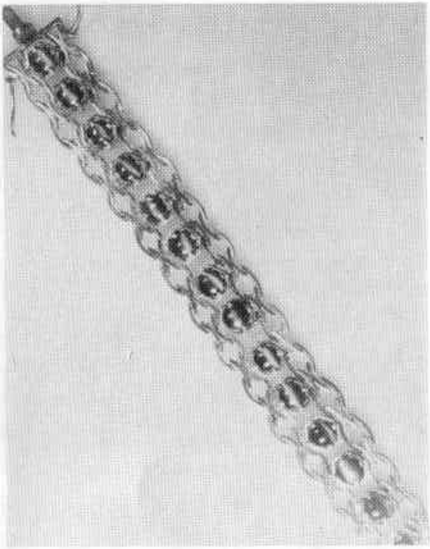


Figure 11.

Gübelin. At the same meeting samples of a dark brown cat's-eye from Sri Lanka were presented to members by Dr. Jan Kanis of Salisbury, Rhodesia who had secured a number of the stones on a trip to that country. All three stones are shown in *Figure 10.* It did not occur to us that the stones could ever become commercially available, though the green stones are very beautiful. However, we were surprised to receive a bracelet for testing with 18 translucent quite well-matched brown cat's-eye kornerupines. *(Figure 11)*. We saw our first cat's-eye kornerupine in 1967, though we did not recognize it at the time *(Gems & Gemology*, Summer, 1974).

Prosopite

Although Chuck Fryer working with Mr. Pete Dunn of the Smithsonian Institution has reported the occurrence of cuttable prosopite resembling turquoise, we had never seen the material. When a staff member was contemplating a turquoise for her collection she tested a beautiful oval cabochon weighing 9.90 carats. The refractive index, however, was 1.51; S.G. 2.65 with a granular fracture and no spectrum; and hardness about 4½ to 5. Work done at the Smithsonian by

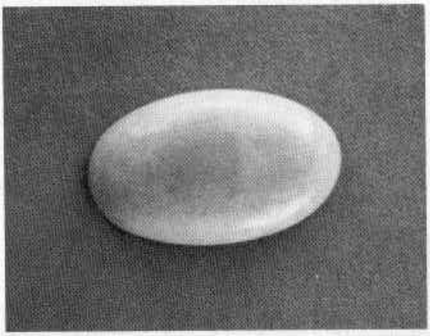


Figure 12.

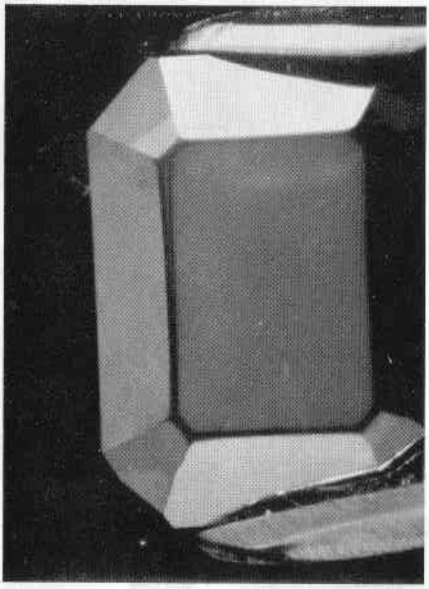


Figure 13.

Mr. Dunn on this specimen indicates a prosopite structure but with some unexplained anomalies in chemistry which are still being investigated. The 1975 *Glossary of Mineral Species* indicates the composition of prosopite is: $CaAl_2(F,OH)_8$. This stone takes an excellent polish but it has become somewhat mottled during the course of being examined and tested *(Figure 12).*

An Imitation Zincite or Cuprite

A dark red emerald cut stone with an adamantine – almost sub-metallic luster was offered to a collector as cuprite. The fact that this rare material has been discovered recently and cut stones offered for sale at reasonable prices suggested that the stone was as stated. However, the absorption spectrum was unquestionably that of almandite as were the inclusions. Careful examination of the surface disclosed nothing suspicious, but on a hunch the writer ran the table of the stone across a paper with a small amount of moistened cerium oxide. Now it was possible to see in *Figure 13* that beneath a sputtered coating was a common almandite.

Acknowledgements

In addition to the two diamonds with inclusions mentioned above we wish to express our sincere appreciation for the following gifts:

To Graduate *Steve Kranich* for the 9.90 carat prosopite cabochon herein described.

To *M. Codiani* for a selection of many natural and synthetic stones for use in classes.

To *Clyde Duneier, Inc.*, New York, for much needed examples of green jade-like "Iimori stone" for use in classes.

To the travelling precious stone merchant, *Abe Nassi*, New York, for an excellent collection of 40 beautiful emeralds for class use.

To *William A. Mosher*, C.G., Port Huron, Michigan, for the two halves of a peridot with a garnet inclusion. The high coefficient of expansion of the garnet undoubtedly was the culprit in the breaking of the stone.

To *Joyeria Nancy*, Cartagena, Colombia, who used the good offices of our friend Italo de Vivo to deliver a handsome emerald in matrix specimen. Nancy, a GIA student, was concerned after having read of all the imitation emerald in matrix specimens that we may not have seen a real one!

World Diamond Production...1974

(Ed. note: Reprinted from the Mineral Trade Notes, U.S. Department of the Interior, Bureau of Mines, Vol. 72, No. 6, June, 1975.)

According to preliminary data compiled by the Bureau of Mines, world production of natural diamond increased some 945,000 carats in 1974. Principal producing countries of gem-quality diamond were the Republic of South Africa, the U.S.S.R., Angola, and the Territory of South-West Africa; the Republic of the Zaire, the U.S.S.R., the Republic of South Africa, and Ghana were the leading producing countries of industrial diamond. World diamond production by country is shown in the following table:

Diamond: World production, by country[1]
(Thousand carats)

Country	1973			1974[p]		
	Gem	Industrial	Total	Gem	Industrial	Total
Africa:						
Angola	1,594	531	2,125	1,600	500	[e]2,100
Botswana	362	2,054	2,416	408	2,310	2,718
Central African Republic	251	129	380	300	150	[e]450
Ghana	232	2,085	2,317	257	2,316	2,573
Guinea[e]	25	55	80	25	55	80
Ivory Coast	120	180	300	130	190	[e]320
Lesotho[2]	1	[r]8	9	2	9	11
Liberia[3]	[r]509	[r]308	[r]817	377	259	636
Sierra Leone[3]	646	758	1,404	670	1,000	[e]1,670
South Africa, Republic of:						
Premier mine	625	1,876	2,501	605	1,817	2,422
Other De Beers Co.[5]	2,368	1,938	4,306	2,397	1,961	4,358
Other	455	303	758	433	289	722
Total	3,448	4,117	7,565	3,435	4,067	7,502
South-West Africa, Territory of	1,520	80	1,600	1,491	79	1,570
Tanzania	[r]251	[r]250	[r]501	275	275	[e]550
Zaire	[r]1,082	[r]11,858	12,940	1,100	11,900	[e]13,000
Other areas:						
Brazil[e]	160	160	320	160	160	320
Guyana	[r]31	[r]21	52	30	20	50
India	18	3	21	17	3	[e]20
Indonesia[e]	12	3	15	12	3	15
U.S.S.R.[e]	1,900	7,600	9,500	1,950	7,850	9,800
Venezuela	[r]315	[r]463	[r]778	280	420	700
World total	12,477	30,663	43,140	12,519	31,566	44,085

[e] Estimate.

[p] Preliminary.

[r] Revised.

[1] Total (gem plus industrial) diamond output for each country is actually reported except where indicated to be an estimate by footnote. In contrast, the detailed separate reporting of gem diamond and industrial diamond represents Bureau of Mines estimates in the case of every country except Central African Republic, (1973), Lesotho, (1973), Liberia, Guyana, (1973), and Venezuela, (1973), where sources give both total output and detail. The estimated distribution of total output between gem and industrial diamond is conjectural in the case of a number of countries, based on unofficial information of varying reliability.

[2] Exports of diamond originating is Lesotho; excludes stones imported for cutting and subsequently reexported.

[3] Exports.

[4] Revised from data in previous edition, which were for years ending August 31 of that stated, to normal calendar year basis.

[5] All company output from the Republic of South Africa except for that from the Premier mine; also excludes company output from the Territory of South-West Africa and Botswana.

Book Reviews

By ROBERT GAAL, Ph.D.

THE RETAIL JEWELLER'S GUIDE, by Kenneth Blakemore. 2nd Ed., Published by Iliffe Books, London, 1973. 280 pages. Hardbound with numerous illustrations. Price: £5.00 in U.K.

This book replaces "The Retail Jeweller's Handbook" as a reference book and textbook in Britain. Because of numerous developments in the trade, this necessary revision brings up-to-date information on such timely subjects as quartz watches and hallmarking to those long in the trade.

The intent of "The Retail Jeweller's Guide" is the same as in previous editions in that it is a reference handbook of knowledge, written primarily to provide newcomers as well as those established in the retail jewelry trade with the necessary new information about the goods that they will probably handle during their careers. The subjects covered include metals, gems, antique silver, hallmarks on gold and silver, how silverwares are made, jewelry of the past, the making of jewelry, the history of watches and clocks, today's watches and clocks, and many other subjects all in fascinating detail. Valuable new inclusions are the illustrated section on common market hallmarks and the amplified and expanded glossaries of trade and technical terms. Useful tables have been added to the appendix. Although this book is written for a British audience, almost anyone involved in the jewelry trade will find this book of considerable interest and of practical use.

Some of the information in the section of "The Gems" needs correcting, notably, on page 45 – strontium titanate has less than three times as much fire as diamond, *not* four times; garnets are silicates and *not* sulfides as stated by the author; synthetic rutile is 7.5 times more dispersive than diamond and *not* six times as printed. Also, some of the recent developments in the synthetic gemstone market are not listed such as synthetic opals, turquoise, alexandrite, and types of hydrothermal synthetic rubies other than the Chatham. Furthermore, the GIA's lowest color grade for diamond is Z and not R, as stated on page 40. Below a color grade of Z, we are dealing with "fancy colors." Except for a few other minor inconsistencies, this book is reasonably accurate and should be of value to the British jeweler.