

Gems & Gemology

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Gems & Gemology

TABLE OF CONTENTS

FEATURE ARTICLES	63	Gemstone Durability: Design to Display <i>Deborah Dupont Martin</i>
	78	The Occurrence and Gemological Properties of Wessels Mine Sugilite <i>James E. Shigley, John I. Koivula, and C. W. Fryer</i>
NOTES AND NEW TECHNIQUES	90	Three Notable Fancy-Color Diamonds: Purplish Red, Purple-Pink, and Reddish Purple <i>Robert E. Kane</i>
	96	The Separation of Natural from Synthetic Emeralds by Infrared Spectroscopy <i>Carol M. Stockton</i>
	100	The Rutilated Topaz Misnomer <i>John I. Koivula</i>
REGULAR FEATURES	104	Gem Trade Lab Notes
	111	Editorial Forum
	113	Book Reviews
	115	Gemological Abstracts
	122	Gem News

ABOUT THE COVER: A wide variety of gemstones are now available for use in jewelry. While some of the more unusual stones lend themselves to fascinating designs, as evidenced by the 396.3-ct kuznite shown here, they also require special considerations. The article by Deborah Dupont Martin in this issue examines gemstone durability as it affects the handling of gems in various jewelry design, manufacturing, and care procedures. Included is a chart covering durability variables for 31 gem species. The kuznite pendant, set in 18K gold with 6.33 ct of diamonds, is courtesy of Tiffany & Co., New York and Los Angeles. Photo © Harold & Erica Van Pelt - Photographers, Los Angeles, CA.

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GEMSTONE DURABILITY: DESIGN TO DISPLAY

By Deborah Dupont Martin

Knowledge of the durability of a gemstone is critical to understanding the risks involved in the various setting, repair, and cleaning procedures commonly used by the jeweler. Some gemstones need attention in display because of their reaction to heat and/or light. This article reviews gemstone durability considerations for 31 species and their varieties as they affect design decisions as well as repair, cleaning, and display of the piece. In all cases, the reader is advised to consult an experienced bench jeweler before attempting any potentially damaging procedures. The recommendations in this article are offered from a gemological viewpoint and as guidelines only.

ABOUT THE AUTHOR

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In today's market, most jewelers no longer deal solely with traditional gems such as diamonds, rubies, sapphires, and pearls. The increasing availability and popularity of a wide range of colored stones—tanzanite, tsavorite, iolite, and tourmaline (figure 1), to name a few—has opened a host of new possibilities in jewelry, but it has also added a multitude of new risks.

While many in the trade are qualified to deal effectively with most of these stones, virtually everyone associated with the design, manufacture, and sale of jewelry should be aware of the potential problems of a particular gem material. The designer must know which mounting will protect the stone best while still enhancing its natural beauty. The bench jeweler is responsible for determining what stones are at risk in which setting or repair procedures. The salesperson, who has the greatest customer contact, must not only be aware of these design and bench considerations, but must also know the rules involved in various cleaning procedures and be able to advise the customer regarding precautions in care and wear. Some stones even require special display considerations because they are sensitive to light or to the heat that can be produced in a case.

The most important factor in designing, setting, repairing, or cleaning a piece of jewelry is durability. Essentially, durability is the gemstone's ability to resist scratching (hardness), breaking (toughness), and effects caused by heat, light, or chemicals (stability). The present article examines gemstone durability and discusses the limitations and advantages of different settings, repair and cleaning procedures, and display practices for many different stones. A chart is included to provide guidelines relating to durability and how it affects these procedures for 31 gem species and their varieties.

It is important to note that the following information pertains to *natural* gems only, including common enhan-

cements, but not to any man-made materials. The identity of a gem *must* be established before any procedure beyond cleaning with warm soapy water may be attempted. If you cannot determine with certainty whether or not a stone has been enhanced, assume that it has and take the more conservative approach. Many qualified bench jewelers will be able to perform procedures that are not recommended here, but such an individual is not always available. This article, therefore, is intended to serve as guidelines (and guidelines only) in these areas. Since there is some risk involved with any stone, consultation with a qualified bench jeweler is always recommended.

The information in this article was compiled based on Webster (1983), Sinkankas (1972), Palache et al. (1944), Nassau (1984), and the GIA course materials, as well as on the experience of the author and her communications with colleagues in both gemology and jewelry manufacturing. A glossary is included to define some of the more technical terms.

DESIGNING AND MANUFACTURING FOR GEMSTONE SAFETY AND WEARABILITY

Durability determines the safest way a stone may be set and worn. Stones that are very resistant to

most types of setting, cleaning, and repair procedures (e.g., diamond and corundum) may be used in a wide variety of jewelry designs. For stones of lesser durability, however, possible weaknesses must be considered in the selection of a setting style (see chart). A gem with poor toughness, such as topaz, would not be a candidate for a channel or flush style setting; chances are the stone would break. Heat-sensitive stones such as emerald, tsavorite, and tanzanite could be subject to damage if set in a style that requires soldering near stones already in place.

Some inclusions can increase the chance of breakage during setting. Because such inclusions vary from stone to stone, it is wise to examine the stone under magnification before setting it. Fractures or inclusions near the girdle edge, in particular, contribute to the fragility of a stone, as does possible cleavage (e.g., topaz and kunzite). In addition, a number of manufacturing jewelers have reported to the author that some enhancements (such as heating corundum, tanzanite, or blue zircon) may cause brittleness, which results in a gem that is more easily chipped and abraded.

Unusual and "problem" cuts create special design problems. Many stones are asymmetrical or are cut with very deep pavilions, and thus require a special mounting. Other stones have extremely

GLOSSARY

Beads: Small portions of metal raised with a graver from the background metal for the purpose of holding a stone in place or for decoration.

Bright-cut: An incised accent cut made with a flat graver that both cuts and polishes metal at the same time.

Burnisher: A highly polished oval-shaped steel blade that is used to smooth metal.

Burr: A small cutting tool, available in various shapes and sizes, that is inserted into a flexshaft and used to excavate, shape, and cut metal during the setting process.

Chasing hammer: A lightweight, well-balanced hammer that is used in conjunction with a setting punch to work metal, e.g., to push a bezel onto the stone and, with various other hand tools, to create raised and indented decorative patterns.

Flexshaft: A machine that consists of a handpiece

to hold burs and other small rotating tools, connected to a flexible shaft approximately 36 inches (91 cm) in length that attaches to a motor. A foot pedal controls the power.

Flux: A solution (usually a commercial preparation containing borax) used to promote the flow of solder and prevent oxidation in the area.

Graver: A sharp tool used to cut and shape metal. Several different sizes and shapes are commonly used for different types of settings.

Reciprocating hammer: An automatic hammer attachment used in conjunction with the flexshaft in some setting techniques.

Setting punch: A small rod used with a chasing hammer to secure bezels. May be used for channel and flush setting also.

Vector technique: A lateral back-and-forth movement of opposite adjacent pairs of prongs.



Figure 1. Tourmaline is one of the most popular of the “new” colored gems in the marketplace. This pendant (18.83 ct) and the two rings (5.54 and 13.50 ct) are all prong set. Jewelry courtesy of The Collector, La Jolla and Fallbrook, CA; photo © Harold & Erica Van Pelt.

thin girdles, or have sharp points that should be protected; for these stones, a setting must be designed that will protect the girdle or points without causing damage during manufacturing. Extra care must be taken with stones that are both unusually cut and that do not withstand setting procedures well.

How the item will be worn is another factor. Many fragile gems, such as topaz, bicolored tourmaline, tanzanite, kunzite, and pearls, are best set in pendants, earrings, brooches, tie tacks, or in rings designed for occasional wear. Cuff links and bracelets are better suited for stones that are more resistant to abrasion and chipping, such as diamond, corundum, jadeite, and chalcedony. Because the table area of a gemstone is very difficult to protect, it is best to choose a more durable stone for

a ring, which is subject to much harder wear than any other type of jewelry. If the customer insists that you put a fragile stone in a ring that will be worn with some frequency, try protecting it with creative forms of metalwork rising above the table, or select a setting style such as bezel that will minimize the risk.

There are two principal ways to design jewelry: (1) design a piece and then find stones to fit the design (commonly done when producing many pieces from one design, and requires that the stones used be readily available in calibrated sizes), and (2) custom create a piece of jewelry to display a specific stone (the method preferred for fragile or unusually cut gemstones). Both types of design require the use of one or more setting procedures, each of which — as described below — has its own

GEMOLOGICAL GUIDELINES FOR GEMSTONE DURABILITY IN JEWELRY^a

GEM MATERIAL	MOHS Hardness Toughness		POSSIBLE ENHANCEMENTS ^b	SETTING		REPAIR ^c		CLEANING ^d		DISPLAY ^e	
				Prong Bezel Flush Channel Pave	Comments	Jeweler's torch Pickle pot Polishing Thermal shock	Comments	Ultrasonic Steamer	Comments	Heat Sunlight Artificial light	Comments
AMBER	2-2½	Poor	Heat, dye, reconstitution	Red	Red	Red	Burns at low temperatures. Attacked by acids. Avoid abrasive polishing compounds.	Red	Attacked by strong solvents.	Red	May darken with age.
ANDALUSITE	6½-7½	Fair to good		Yellow	Red	Yellow	Heat-sensitive if liquid inclusions present.	Yellow		Yellow	
BERYL Aquamarine & Others	7½-8	Good	Heat, irradiation	Green	Yellow	Green	Avoid heat if liquid inclusions or feathers present.	Yellow	Use extra care if liquid inclusions or feathers present.	Green	Maxixe (irradiated dark blue) will fade when exposed to light.
Emerald	7½-8	Poor to good	Oil, dye, plastic coating	Yellow	Red	Yellow	Avoid heat: may cause fracture or breakage. Polishing compound may get into surface-breaking fractures.	Red	Avoid solvents.	Green	
CHALCEDONY	6½-7	Good	Dye, heat	Green	Red	Yellow	Heat may cause color change.	Yellow		Green	
CHRYSOBERYL	8½	Excellent to good		Green	Green	Green	Alexandrite and cat's-eye may withstand some heat, but best to avoid because of value.	Yellow		Green	
CORAL	3-4	Fair to good	Dye, heat, bleach	Yellow	Red	Yellow	Blacks/burns in torch flame. Attacked by acids.	Red		Yellow	Avoid heat.
CORUNDUM Tp Ruby & Sapphire	9	Excellent except in highly twinned or fractured stones	Heat, oil, dye; diffusion, irradiation (sapphire); glass fillings (ruby)	Green	Red	Green	Avoid extreme heat: may alter color. Soldering flux or pickle solution containing borax may etch surface. Oiled or dyed stones: avoid heat, use care in polishing.	Yellow	Polishing compound may enter inclusions/fractures breaking the surface. Oiled or dyed stones: avoid solvents.	Green	Irradiated: avoid heat and light.
Star Ruby & Sapphire	9		Heat, diffusion, oil, dye	Green	Red	Green		Red		Green	
DIAMOND	10	Good to exceptional	Laser drilling, bleaching, coating	Green	Green	Green	Included stones require extra care.	Green	Use caution if stone contains feathers or is included.	Green	
DIAMOND, COLORED	10	Good to exceptional	Irradiation (with or without heat), coating	Green	Green	Green	Natural green and all irradiated: avoid heat—alters color. Included stones require extra care.	Green		Green	
FELDSPAR Moonstone & Labradorite	6-6½	Poor	Moonstone: blue or black coating on base of cabochon	Yellow	Red	Yellow	Avoid heat: may crack or cleave.	Red	Avoid heat.	Yellow	
FLUORITE	4	Poor	Heat, irradiation	Red	Red	Yellow	Avoid heat: fuses under torch. Decomposed by sulfuric acid.	Red	Avoid heat.	Yellow	Avoid heat.
GARNET	7-7½ Demantoid: 6½-7	Fair to good		Green	Yellow	Green	Avoid thermal shock: likely to cause fractures.	Yellow	Ultrasonic: risky if liquid inclusions present. Avoid thermal shock.	Green	
IOLITE	7-7½	Fair		Yellow	Red	Yellow	Heat may fuse. Attacked by acids.	Green		Green	
IVORY	2½-2¾	Fair	Heat, irradiation, dye, bleach, paint	Yellow	Red	Yellow	Heat causes shrinkage and discoloration. Attacked by chemicals.	Red	Avoid solvents. Clean with cloth dampened in methylated spirits.	Yellow	Yellows with age. Oils, lotions, perfumes, etc. may discolor in handling.
JADE Jadite	6½-7	Exceptional	Heat, irradiation, dye, wax	Green	Yellow	Green	Avoid heat: may cause loss of color. fuses easily. Avoid acids: affected by warm acids.	Green	Treated: avoid strong solvents.	Yellow	Dyed: may fade. ^b
Nephrite	6-6½	Exceptional	Heat, dye, wax	Green	Yellow	Green		Green		Yellow	
JET	2¼-4	Poor		Yellow	Red	Yellow	Avoid heat: burns easily. Acids dull surface.	Red		Green	
LAPIS LAZULI	5-6	Fair	Dye, wax	Yellow	Red	Yellow	Avoid heat: may cause color change; will damage wax. Avoid chemicals.	Red	Dyed: avoid acetone and other solvents.	Yellow	Dyed: may fade. ^b

MALACHITE	3½-4	Poor	Epoxy, wax			Fuses easily under torch. Attacked by acids.	Avoid chemicals.	
OPAL	5-6½	Poor to fair	Sugar, smoke, oil, plastic, wax			Heat turns stone white or brown and destroys play of color. Thermal shock causes cracking, crazing, fracture.	Avoid thermal shock.	Heat and strong light promote dehydration that results in crazing or fracture.
PEARL	2½-4	Usually good but variable	Irradiation, dye, bleach, peeling, oil, coating	Usually pin set. Thin nacre may chip or fracture easily.		Avoid heat: causes cracking, may cause pearl to turn brown, burn, or split. Attacked by all acids.	Wash gently in warm soapy water, dry thoroughly, and restring.	Dyed: some colors may fade.° Moderate heat and strong light promote dehydration, cracking.
PERIDOT	6½-7	Fair to good		Consider inclusions. Facet edges chip easily.				
QUARTZ Amethyst & Citrine	7	Good	Heat, irradiation, dye			Strong heat turns stone colorless, or amethyst to citrine, or vice versa. Avoid thermal shock.	Avoid thermal shock.	Amethyst may fade with prolonged exposure to strong light and heat.
Other Tp Varieties	7	Good	Heat, irradiation, quench-crackling, dye	May be included or fractured.		Avoid thermal shock: may cause fractures. Avoid heat: smoky turns colorless.	Avoid thermal shock.	
Tiger's-eye & Rose Quartz	7	Good	Tiger's-eye: heat, dye, bleach Rose: Irradiation, quench-crackling, dye			Avoid thermal shock.	Avoid thermal shock.	Dyed: may fade.° Rose: may fade.
SHELL	2½-3½	Poor to good	Dye			Avoid heat: blackens in flame. Avoid acids.		Dyed: may fade.°
SPINEL	8	Good		May be brittle.		Light colors may fade in intense heat.		
SPODUMENE Kunzite	6½-7	Poor	Irradiation	Cleavage: 2 perfect.		Fuses easily under torch. Avoid thermal shock.	Avoid thermal shock.	Kunzite commonly fades. Irradiated green fades (in minutes to hours).
SUGILITE	5½-6½	Good						
TOPAZ	8	Poor	Heat and/or irradiation	Cleavage: 1 perfect. Often contains liquid inclusions. Light blows may damage.		Avoid heat: may cause change/loss of color. Thermal shock will cause internal breaks.	Avoid thermal shock.	Some browns fade. Irradiated yellow to yellowish brown fades.
TOURMALINE	7-7½	Fair	Heat, irradiation Cat's-eye: acid, sealed tubes	Parti-colors tend to break at color zones. Heavily included stones or those with liquid inclusions require extra care.		Heat: some greens change color. Thermal shock may cause breakage; Parti-colors break at color zones.	Avoid thermal shock.	
TURQUOISE	5-6	Poor to good	Oil, wax, plastic coating/impregnation; dye	Scratches easily.		Avoid heat and chemicals. Heat causes depreciation. Polishing compound will discolor.	Avoid heat and chemicals. Ultrasonic solution may discolor.	Porous: skin oils, lotions, etc., may discolor in handling.
ZIRCON	6-7½	Fair to poor	Heat	Brittle: abrades easily.		Avoid heat: may cause color change.		Heated: some revert to original color when exposed to light.
ZOISITE Tanzanite	6-7	Poor	Heat	Cleavage: 1 perfect. Brittle: abrades easily.		Avoid heat: fuses under torch.	Avoid thermal shock.	

KEY TO COLOR RATINGS

- Relatively safe
- Use caution
- Use extreme caution
- Avoid

These "ratings" are based on the proper use of the rated technique as indicated in the accompanying article. Unless otherwise noted in one of the "comments" sections, they are for unenhanced stones only. Synthetic stones, man-made simulants, and assembled materials are not covered by this chart.

The cut of the individual stone and the presence of fractures and inclusions will affect the durability of any gem. Likewise, the risk factor for the various settings and certain repair procedures depends to some extent on the skill of the individual bench jeweler. This chart is presented from a gemological viewpoint and as guidelines only; whenever possible, consult an experienced bench jeweler before deciding on a procedure. Remember, above all, if you cannot afford to break the stone or it is irreplaceable, do not try any potentially damaging procedure.

POSSIBLE ENHANCEMENTS

With the principal exception of glass fillings in ruby (see Kane, 1985), these enhancements are from Nassau (1984). For further information, please consult Dr. Nassau's book.

Dye: Any porous stone, or any stone with fractures breaking the surface, may be dyed. If there is any doubt, for the purpose of these guidelines assume that the stone has been dyed.

Also, dyes vary greatly in stability. Fading may occur during repair, cleaning, or display if an inappropriate dye has been used (Nassau and Kane, 1983).

Corundum: Diffusion-treatment is most commonly seen in blue sapphires; this method of enhancement is seen rarely in other colors of corundum.

Heat enhancement: may cause brittleness.

REPAIR

The reaction of a stone to any repair procedure will also vary depending on the inclusions in the stone, the type of torch, pickle solution, and polishing compound used, as well as on the skill of the person performing the procedure. All stones are at risk of thermal shock (abrupt temperature change) if heated too rapidly with a torch or if placed in a pickle pot or water while the stone is still hot. Because there is some risk involved with any stone, whenever possible remove the stone from the mounting before beginning the repair.

CLEANING

The reaction of a stone to either cleaning procedure will also vary depending on the inclusions in the stone, the solution used in the ultrasonic, and the amount of time the stone remains in the ultrasonic, as well as on the procedure used in steaming. All stones are at

risk of thermal shock if taken from the steamer and placed directly in the ultrasonic or water before they have sufficiently cooled.

Caution is advised regarding solvents and other chemicals, including ammonia, which is a common constituent of most household cleaners.

Boiling is not recommended for any stone except diamond, and only for diamond when absolutely necessary and proper procedures are followed.

DISPLAY

Heat refers here to heat generated in a display case by sunlight or artificial light.

PEARLS

The durability of both natural and cultured pearls will vary depending on the condition and thickness of the nacre.

advantages and disadvantages with regard to displaying the stone and protecting it both during the setting procedure and subsequent wear.

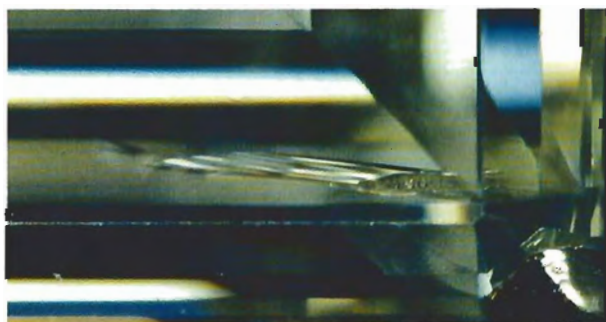
Again, an extremely skilled setter may be able to perform any of these setting techniques on any given stone. If such a setter is available, the possibilities are virtually unlimited. The following guidelines, however, are provided to help those who do not have manufacturing experience or the setter who has not worked with some of these stones. Ultimately, the skill of the setter will determine whether a certain setting style can be used for a particular stone.

Prong Setting. This is probably the most common type of setting. It can be used in virtually any type of jewelry for setting almost any cut of stone (again, see figure 1). Some stones, however, require more care than others (see chart).

Prong setting involves placing a stone in either a head or basket mounting, which may be premade or custom fabricated to fit the specific stone. A "head" is usually diestruck and made to fit any stone of a standard calibrated size. A basket is more often cast or fabricated from wire to fit a particular stone. There may be any number of prongs, depending on the size and shape of the stone, and the mounting style.

When deciding whether or not to use a prong setting, consider whether the stone can withstand the pressure caused by the prongs being bent over the girdle edge onto the crown and then tightened into place. Even diamond may sustain damage if a setter is heavy handed when bending a prong over the crown (figure 2). If the stone has an extremely thin girdle, is fractured, or cleaves easily, an

Figure 2. Excessive pressure applied during prong setting may damage any stone, even diamond, as shown by the stress feather seen here. Photo © Tino Hammid.



alternative method would be first to cut and fit the seat (the area where the stone rests on the prongs) to an inexpensive synthetic stone of the same proportions. After the prongs have been shaped, slip the fragile stone into place and tighten the prongs by vector technique.

Although prong setting can be performed on almost any stone, it does not offer as much protection as other setting styles. When designing for a stone that chips, abrades, or cleaves easily (e.g., emerald, tanzanite, kunzite) consider a setting style that covers the girdle area to maximize the wearability of the piece.

Bezel Setting. This is an excellent way to protect the girdle and pavilion areas of many gemstones (figure 3). It is effectively used alone or in combination with other setting styles.

A bezel is a rim of metal that is soldered onto a mounting. The bezel is first shaped to fit around the girdle of the stone being set before it is soldered in place. Procedures for setting the stone differ slightly depending on whether the stone is faceted or cabochon cut, and, if cabochon cut, whether an open- or closed-back setting is being used. Cast bezels are also available, but they are not as pliable and, therefore, are harder to work with and expose the stone to greater risk.

Although bezel setting has been used most commonly on cabochon-cut stones, it is now being used with greater frequency on faceted stones. The primary advantage with this type of setting is that the band of metal surrounding the girdle of the stone offers protection, yet is thin enough to be burnished over the stone without causing damage if care is exercised in the procedure. A bezel can be especially effective with unusual cuts. The thin line of metal encircling the stone leads the eye to and around the gem, creating a focal point in the design.

A related procedure, tube setting, has gained popularity in recent years (again, see figure 3). A tapered or straight tube, rather than a rim, is used for this style. Because the metal for a tube setting is usually thicker than that of a bezel, more pressure is required in burnishing and this technique is recommended only for diamond or corundum.

Flush Setting. This type of setting creates a very smooth, tailored look (figure 4) and is a popular style for men's rings. The stones are set low and the



Figure 3. Bezel settings help protect the girdle and pavilion areas of any gemstone, but are particularly useful for stones that are less durable or, like the bezel-set emerald shown here, have a tendency to chip or crack. Tube setting requires more pressure in burnishing than a regular bezel setting and so is recommended only for more durable stones, such as the diamonds shown here. Emerald ring by Silverhorn, Montecito, CA; diamond ring by The Altobelli Jewelers, North Hollywood, CA. Photo © Tino Hammid.



Figure 4. Although flush setting offers good protection to the girdle area, it is best used for durable stones such as the yellow and white diamonds shown here, because of the stress created during the setting process. An experienced bench jeweler, however, can set even a relatively fragile stone in this style, as evidenced here by the andalusite flush-set in a gypsy mounting. Diamond ring by Steven C. Martin, The Gold Masters, Woodland Hills, CA; andalusite ring by Kremenz, New York; photo © Tino Hammid.

girdle edge is protected; however, flush setting is recommended only for durable stones because of the stress created during the setting procedure.

In this style, stones are set so that 5%–10% of the crown area is covered by metal with no visible means of being held in place. The stone is placed in a seat burred into the metal and then metal is burnished over and around the circumference of the stone with a punch and a chasing hammer, reciprocating hammer, or burnisher. Even stones considered durable may be damaged if the stone is accidentally struck during the setting process. Various shapes of stones may be flush set, but caution is required in the setting of sharp points.

This setting is best used for diamond and, with care, corundum. Other stones require a very delicate touch and extreme care to prevent breakage. This technique is not recommended for stones that are fragile or easily cleaved.

A gypsy mounting is a ring style with a moderate to high dome at the top of the ring in

which a center stone is often flush set (again, see figure 4). The center stone and any accent stones may be enhanced further by bright cutting the metal that surrounds them.

Channel Setting. This is an excellent way to enhance ring shanks or to lead the eye to a central focal point. Channel setting provides a very clean, tailored look (figure 5) and may be accomplished with round brilliant-cut, baguette, or, quite effectively, Quadrillion (square brilliant)-cut stones. An advantage of channel setting is that the stones are set low in the mounting and are protected at the girdle.

In this method, a seat is burred between two walls of metal which form a channel. The stone is then pressed into place, first one side and then the other. This style of setting is best accomplished with durable stones such as diamond or corundum. There is a significant risk of breakage with less durable stones (depending on fractures or inclu-



Figure 5. Diamonds and rubies (or any other variety of corundum) are best suited for channel setting because of their durability. Ring courtesy of the Altobelli Jewelers, North Hollywood, CA; photo © Tino Hammid.

sions in the stone as well as, very importantly, the skill of the setter). There is a high probability that a stone that cleaves easily will not withstand this setting procedure.

A variation is the flat channel, which extends across a flat or straight area. A continuous seat is burred along the length of the channel and the stones are slid into place. Beads are then raised in the channel with a graver to hold the stones in place. This method is recommended for use with rectangular or square-cut stones. Because the stones are slid, rather than pressed, into place, there is less risk of breakage during the setting of a flat channel than a regular channel. Exercise care, however, with stones that may be scratched by the metal.

Pavé Setting. Pavé is an excellent way to add elegance and distinction to many designs. Pavé in yellow gold may enhance the color of diamonds that fall into the yellow range of the diamond color-grading scale, while pavé in white gold or platinum does not add a yellow cast to more colorless diamonds. It can be used very effectively to enhance and draw attention to a more fragile stone that has been set in a different style, such as bezel. There are two types of pavé (figure 6): classic, in

which stones of the same size are lined up girdle to girdle in three or more staggered rows; and commercial, in which stones of varying sizes are somewhat randomly fit into a given area of metal.

In this technique, the stones are arranged on the metal, seats are burred, and beads are raised over the edge of the girdle onto the stone with a sharp graver. Again, care must be exercised since one slip of the graver can chip the stone. Diamond and corundum are most commonly used for this setting style because they are the most durable. Many fragile stones, such as tanzanite, tourmaline, topaz, and kunzite, cannot withstand the pressure of being pavé set.

Figure 6. Both commercial pavé (top) and classic pavé (bottom) are best accomplished with more durable stones such as diamond or corundum. Diamond earring by Harry Winston, Inc., New York; brooch plate by Chuck Atmore, GIA, Santa Monica, CA; photo © Tino Hammid.



Inlay. Although not as common as the other techniques described above, inlay is used to create a visual picture of pattern. Opaque gem materials (e.g., turquoise, coral, mother-of-pearl, etc.) are most commonly used for inlay, but virtually all translucent to transparent stones (particularly opal, amethyst, and frosted rock crystal quartz) may be inlaid to produce a smooth, tailored look.

First, a metal channel or pattern of sections separated by metal walls is created. Gem materials are cut to fit these channels or sections and are then secured in place by an adhesive, usually epoxy. A related technique is intarsia (Elliott, 1986). Chips of opaque gem materials may also be used to fill pattern sections by first filling the section with colored epoxy and then fitting the chips into it. The chips are then ground off even with the metal walls and the piece is polished.

General Durability Considerations in Designing with Colored Stones. These setting styles may be used alone or in combination with one another to effectively enhance and draw attention to the stone(s) being presented. To safeguard fragile stones, however, planning for protection is best done in the design stage.

One of the best ways to protect fragile gems is to design a mounting in which metalwork is sculpted up around the gem to at least the girdle level (figure 7). This area is often subject to chipping, as evident in figure 8. Another method to achieve protection is to set more durable stones around the fragile gem. Be extremely careful, however, to make sure that a harder stone does not actually touch a less durable one, as this is a common cause of damage during subsequent wear (figure 9).

When using more than one stone in a design, be aware, and make your customer aware, of the risks involved with the less durable as well as the more durable gem. Diamonds and pearls, a popular combination, offer a particularly good example of the need for caution. Diamond can resist most setting, repair, and cleaning techniques, as well as most abuse during wear. Pearls are much more fragile and cannot withstand heat, polishing, or harsh cleaning solutions. Pearls strung with diamond rondels risk abrasion, while those strung with gold beads risk both abrasion and discoloration. Even a pearl enhancer can abrade or discolor the pearls and cause wear to the silk.

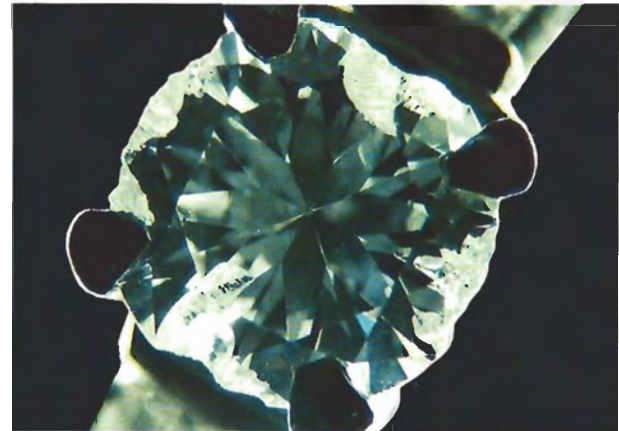
Many manufacturing procedures are done be-



Figure 7. One way to protect a potentially fragile girdle is to design the setting so that metal surrounds this area of the stone. Diamond ring by C. Y. Sheng, GIA, Santa Monica, CA; emerald ring by The Altobelli Jewelers, North Hollywood, CA; photo © Tino Hammid.

fore the stones are set and thus pose no threat to the gem. Most setting procedures are accomplished without the use of the torch, the potentially most dangerous of the jeweler's tools. Occasionally, though, the design of an item will require that some stones be set prior to completing the mounting. In cases such as this, the stones set first

Figure 8. Even with diamond, the girdle can be severely damaged if it is not adequately protected.



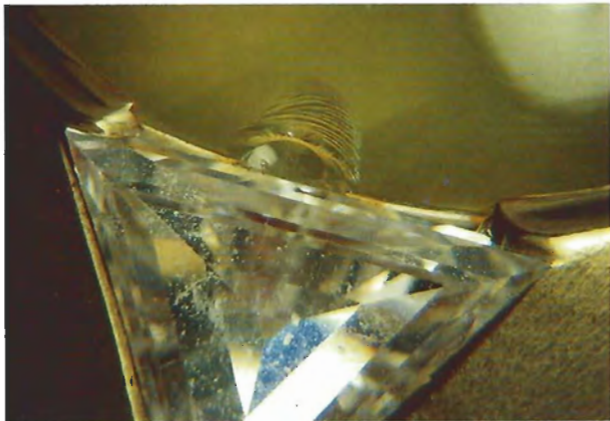


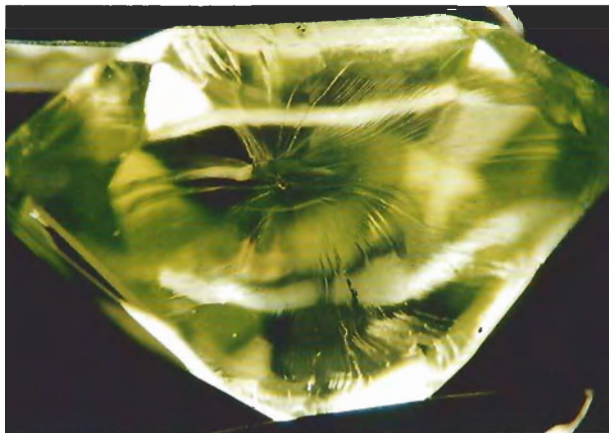
Figure 9. An improperly set diamond can chip or otherwise abrade a less durable stone, as evidenced by the diamond and chrysoberyl ring seen here.

must be able to withstand the heat of the soldering process (see chart and "Repair" section below). Because of their resistance to heat, diamonds are commonly used as accent stones in this type of setting.

REPAIR

Jobs received at the repair bench (sizing, half-shanking, retipping) can sometimes be accomplished with the stones still in the mounting if the bench jeweler is knowledgeable about the durability of the stones and the effect on them of the various tools and procedures used in repair (see chart). It is also important to take into consideration the presence of inclusions in the stone and the

Figure 10. The heat from a torch may cause inclusions in a stone to expand and ultimately fracture or break the host gem, as illustrated by the heat-damaged peridot shown here.



possibility that it has been enhanced in a manner that might affect its durability. Many gems (e.g., emerald, topaz, tourmaline) contain liquid inclusions that may expand and rupture when heated by the jeweler's torch, causing the stone to fracture or even break (figure 10). In the case of an irradiated yellow sapphire, which as a variety of corundum is durable, the vibrant yellow color imparted by the irradiation process fades rapidly when held close to a simple flame (Keller, 1982). A torch could not be used close to such a stone without adversely affecting the color. The pickle pot and polishing wheels should also be used with consideration to the potential damage they may cause.

Jewelry should be thoroughly cleaned before any repair procedure is begun. No repair should be attempted with the stone in place until the gem has been identified.

Jeweler's Torch. The torch is one of the jeweler's most frequently used tools. It is essential to many aspects of repair and fabrication work, from basic sizings to the intricate fabrication of wire baskets and filigree work. Whenever possible, the stone should be removed from the mounting before the repair procedure. When the item must be soldered with the stones in place, caution is critical (figure 11). There are some jobs that can be accomplished without removing the stones *if* the stones can

Figure 11. Use of the torch during a retipping procedure on the center diamond resulted in the permanent clouding of the surrounding peridots, which are very heat sensitive.





Figure 12. Improper use of the jeweler's torch caused permanent clouding and cracking of the diamond on the left, shown here with an undamaged diamond. Photo by Robert Weldon.

take heat, if no inclusions are present that could cause damage, and if no enhancement has been done that could be altered by heat. The skill of the person performing the repair and the type of torch being used are important factors in the success of soldering close to any stone.

Even diamonds may cloud or crack under the jeweler's torch (figure 12). Clouding, which may occur when heat is applied to a dirty stone, is often permanent; since it is confined to the surface, however, it may be removed by repolishing the facets on a lap. Uneven heating may cause a diamond to cleave. Any heating procedure should be done with an even, gentle, constant motion. Keep the torch moving in a repetitive cycle across the stone and prongs being repaired (this is especially important if the stone is large). Natural green, and all colors of irradiated, diamonds may change color if heated, so remove these stones from the piece before attempting repair work (D. Moran and D.V. Manson, pers. comm., 1987).

The expansion of inclusions (such as carbon dioxide fluid inclusions; see Koivula, 1986) as well as uneven heating of the stone can cause fractures or breakage in corundum. In addition, use of a borax-containing soldering flux or pickle solution may etch the surface of corundum (figure 13). Use caution when working with star corundum. Black star sapphire can withstand heat if extreme care is used, but star ruby and other colors of star sapphire are extremely susceptible to fracture. Corundum could be inadvertently heat-treated by the torch, which might cause the color to change (R. Kane, pers. comm., 1987).

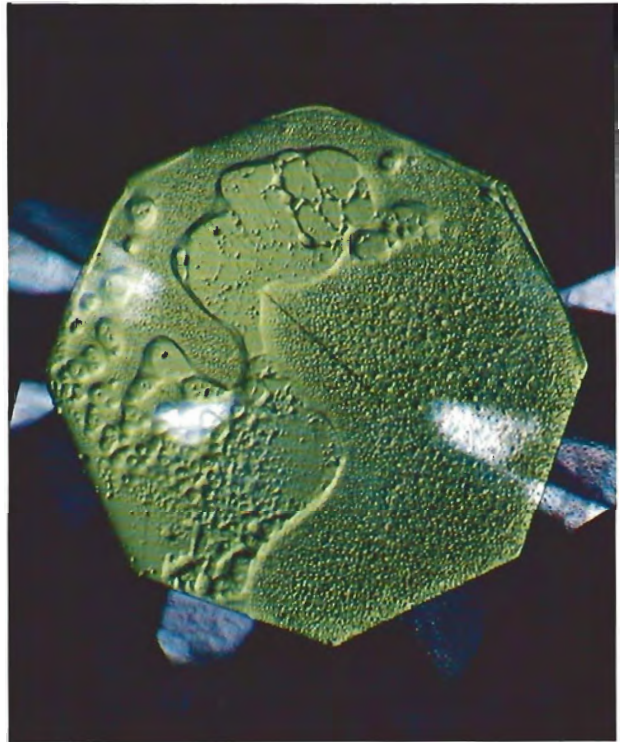


Figure 13. The use of a borax-containing soldering flux resulted in severe etching of the table of this sapphire. Photo by Robert E. Kane.

The use of the torch in conjunction with virtually all other stones is very risky; heat must be applied with extreme caution if at all and only by a qualified bench jeweler. There are, however, some techniques for protecting heat-sensitive stones when work must be done on an area away from the stone itself: (1) bury the stone in wet sand; (2) wrap the stone in florist's putty or clay for support and then submerge it in a container of water until the water level is at stone height, leaving, in the case of a ring, the shank exposed; or (3) pin the piece stone-down onto a wet sponge. Again, though, even these techniques should be attempted only by an experienced bench person.

Pickle Pot. The pickle pot usually contains a buffered sodium bisulphate solution (usually 2.2 lbs. to 1 gal. of water). This solution is used to remove surface oxides (e.g., copper oxide) created when the metal is heated during soldering or annealing.

Because pickling solutions are usually kept at a warm temperature (160°F/91°C), and warm acids adversely affect many types of stones, caution is

suggested in the use of the pickle pot. Peridot, for example, is easily etched by the pickling solution and may require repolishing (figure 14).

Thermal shock (sudden temperature change) is a common factor in damage to stones (figure 15). One of the most serious mistakes a jeweler can make is to take a stone-set item directly from torch work and place it into the pickle pot. If the stone is relatively hot when it enters the pickle solution (note that the center of the stone stays hot longer than the surface), the sudden change in temperature may internally shatter it (even diamond is susceptible to thermal shock; see figure 16). Jewelers who routinely use water to cool a hot item for better handling place the stone in similar danger.

Polishing. Be aware that some gold is removed every time you polish a piece. Special care should be taken in polishing pavé-set pieces to make sure that beads are not weakened or removed, which could result in the loss of the stones. Even prongs may be polished off to the point of needing to be retipped. A light touch at the polishing wheel is recommended, especially when polishing over stones. Those stones with a hardness of 5 or less can be damaged by Tripoli, a commonly used abrasive type of polishing compound, which creates minute surface scratches and dulls the polish of the stone. If too much pressure is applied during polishing, facet junctions may be rounded or completely polished away on some gemstones. Particu-

Figure 14. The surface of this peridot was badly etched by the pickling solution. Photo by Robert E. Kane.

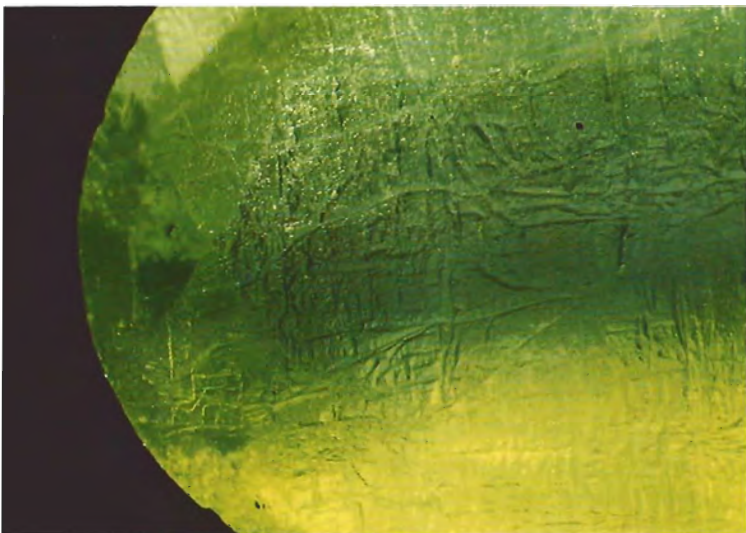


Figure 15. Thermal shock during a repair procedure on the mounting caused extensive internal cracking in this once-beautiful peridot.

lar care is recommended when polishing near turquoise, lapis lazuli, and opal (which may also absorb the compound).

The best way to avoid polishing damage is to keep the polishing wheel off the surface of the stone. When you are polishing prongs, use a mini felt wheel and the flexshaft for greater control of the area being polished, or cover the top of your stone with masking tape to protect it. Rouge, a buffing compound that is used for the final luster, is safe with most stones. *Never* polish pearls, however, as the compounds will abrade and discolor the nacre. For this reason, pearls are set after all other stones have been set and the final buffing and cleaning have been completed.

CLEANING

Proper cleaning is an essential part of gemstone maintenance. Gemologists must usually clean a stone-set jewelry item before they can identify or appraise it. Bench jewelers clean items to remove surface dirt before repair jobs and to remove any buffing compound residue that remains after final buffing. Jewelers routinely clean case items to brighten their appearance.

Although there are several methods for cleaning jewelry, the safest by far is the use of warm, soapy water and a soft-bristle brush. This method provides gentle cleaning without risk of damage for almost any stone, and is the only one recommended if the identity of the stone has not yet been determined. Although this procedure can be used



Figure 16. Even the most durable of gemstones, diamond, can be severely damaged by thermal shock.

for pearls, do not scrub the pearls forcefully, but rather brush them gently to remove surface dirt, especially, in and around the drill hole. Be sure to rinse the pearls thoroughly, since any soap residue will attract dirt. Pearls that are strung should be placed on a soft clean towel until both the pearls and the silk are completely dry (at least 24 hours). Never hang pearls to dry, as this causes the silk to stretch, weakening and possibly fraying it. Because of the possible damage to the silk caused by the washing process, the author recommends that pearls be restrung after they have been cleaned and thoroughly dried.

Many of the "dips" sold for cleaning jewelry contain ammonia and should be used with caution, if at all. Another fairly common home practice is to clean jewelry with a toothbrush and toothpaste. Again, caution is advised, as toothpaste and similar cleansers are very abrasive and will scratch soft stones. Compressed gas (canned air), used by some in the trade, may cause thermal shock if a room-temperature stone is submitted to a blast of this supercooled gas.

Two instruments commonly used for cleaning jewelry are the ultrasonic and the steamer. The ultrasonic cleaner is effective in removing dirt and buffing compound from areas that cannot be easily cleaned with a brush (e.g., the pavilion area of a mounted stone). The steamer removes any residue from cleaning or polishing and forces residue out of intricate (e.g., filigree) or hard-to-reach areas. Used properly, these two cleaners produce excellent

results on many stones, but they can be disastrous for others (see chart). *Extreme* caution and very limited exposure to each method are recommended, since there are risks involved in using them on *any* gem material. Regardless of the cleaning method used, always carefully examine the stone prior to and immediately after cleaning to check for possible damage.

Ultrasonic Cleaner. The ultrasonic works on the principle of tiny bubbles imploding against the item. These bubbles are caused by vibrations generated by high-frequency (20–40 Hz), high-intensity sound waves that travel through the liquid. This action both scrubs exposed surfaces and produces heat that is potentially damaging to many sensitive, porous, or enhanced stones (see chart).

Ammonia and water, a solution commonly used in the ultrasonic, may damage the surface of sensitive stones as it heats up. A gentle solution, such as polishing compound remover (which does not contain ammonia), is effective for removing buffing compounds and risks less damage to the surfaces of stones (and metals) being cleaned. For cleaning jewelry, a mild liquid soap or liquid dishwashing detergent (check for ammonia content) is recommended. Caution is still required with sensitive stones.

Porous stones (e.g., turquoise, malachite, lapis lazuli) may absorb some of the cleaning solution, which could cause discoloration. Stones that have been oiled, such as emerald (and some ruby) may appear to lose color and gain inclusions as the oil is driven out of fractures (figure 17). Dyed stones may suffer a similar reaction. Pearls may have cracks beneath the surface of the nacre that can be enlarged or brought to the surface by the vibration of the ultrasonic. Other gem materials with internal fractures or cleavages run the same risk. Even stones that are normally considered safe for cleaning in the ultrasonic may be at risk if left for more than a few minutes. Extended exposure to the vibrating motion could cause the expansion of fractures or cleavages that might have been unharmed if exposed for a shorter period.

Steam Cleaner. The steamer is another useful but potentially dangerous tool. It cleans and dries jewelry by way of a compressed blast of steam. This blast forces dirt and oils away from the area where the steam is hitting the stone. Steaming often adds that "extra sparkle" to stones and



Figure 17. Most emeralds in the trade today are oiled (left). Their appearance may be altered radically (right) when the oil is driven out of the fractures by a procedure such as cleaning in an ultrasonic. Photos © Tino Hammid.

removes any residue from ultrasonic cleaning. Although the steamer may force dirt into fractures (figure 18) or inclusions that break the surface of a stone that is not relatively clean to begin with, the greatest potential danger of steaming is thermal shock.

Introducing the change in temperature gradually is very important. It is best to hold the jewelry item securely by its mounting with plastic-coated tweezers (the coating prevents scratching and slipping). Begin the temperature change by running warm, then hot, water over the stone, and then begin steaming by holding the item in the outer fringes of the steam. Gradually lift the piece into the blast of steam (this allows time for an even temperature change). Once the stone is acclimated, short, frequent blasts of steam work best during the cleaning process. However, care should be taken to steam large stones evenly, as an isolated blast of steam on a small section will cause that area to heat up and expand faster than the rest of the stone, resulting in fracture.

Occasionally, steam cleaning will leave a film or the stone-set item will still appear dirty; often it is then put back into the ultrasonic or directly into running water. This can be a costly mistake, because the process of steaming heats up the stone considerably (steam temperature is approximately 300°F/149°C at 67 psi) and the lower temperature

may cause thermal shock and shatter the stone. To minimize the risk, always allow a steamed stone to cool for a few minutes before any further cleaning is attempted.

Boiling. This procedure is not recommended for any stones other than diamond. Even then it should be used only with extreme caution, since inclusions in the diamond could be adversely affected by the heat. If you feel you must boil a diamond, the safest procedure is to place the stone

Figure 18. This star sapphire was stained when dirt was forced into the fractures during steam cleaning.



in cold water and gradually bring the water to a boil. *Never* put the stone directly into boiling water. Allow the stone to cool thoroughly after boiling before any further work is done.

DISPLAY

Display plays a significant role in the sale of jewelry. Attractive display cases highlighting unusual loose stones and/or unique pieces capture the attention of potential customers.

Again, gemstone durability (specifically, stability) is important in determining how and where some items can be shown to best advantage. Several stones are sensitive to both heat and light (see chart). For example, opals are subject to dehydration, which may result in cracking and crazing. Consequently, opals are best displayed in inside cases away from the case lights and direct sunlight, both of which can generate considerable heat.

Stones that fade easily in light (e.g., most kunzite) should not be displayed in windows exposed to sunlight or in brightly lit cases. Some amethyst, too, is subject to fading when exposed to strong, direct light for a long period.

CARE TIPS

Professionals should be as concerned with the care of the stone after it is sold as they are while it is in their possession. Consequently, any durability problems that affect decisions with regard to setting, repair, cleaning, and display should be communicated to the purchaser in the form of care tips.

Pearls and opals are two of the better-known gems that benefit from special care. Both are subject to dehydration and are best stored away from prolonged exposure to heat. Pearls should also be protected from damaging chemicals that might attack the nacre and from rough-textured fabrics that might abrade the nacre. Make-up (which may cause discoloration), perfume (which may attack the nacre), and hair spray (which may coat the pearls and lead to dehydration) should always be applied and allowed to dry before the pearls are put on. Pearls should not be worn next to the skin if acidic perspiration is a problem. They are best stored in a soft silk pouch rather than loose in a jewelry box, where they risk abrasion.

Opals are fragile stones, easily scratched, broken, or chipped. Care should be taken during wear that the opal does not receive any sharp blows, and opals should be stored away from other stones or

settings that might cause abrasion. Contrary to popular belief, soaking opals in mineral oil does not prevent cracking or crazing; it only temporarily masks existing cracks, which again become readily visible when the oil dries out.

Jewelers should advise customers who purchase a potentially light-sensitive stone (e.g., kunzite, amethyst, etc.) that it is best used for evening or occasional wear and that it should be kept out of light when it is not being worn.

CONCLUSION

Gemstones are rare products of nature and have been revered for their beauty and durability for thousands of years. Much has been learned about the commerce and culture of earlier peoples from the gems and jewelry articles found in ancient ruins. Properly cared for, most gemstones should retain their beauty for hundreds, if not thousands, of years. In fact, turquoise and lapis lazuli are constituents in one of the oldest known pieces of wrought jewelry, which dates back more than 5,000 years (Vilimkova, 1969). When one considers the history that accompanies gemstones, and the significance to future generations that our creations might have, it seems only right that we do our best to preserve the gems we wear. One of the easiest ways to do this is to understand the areas where each individual gemstone needs special consideration and to compensate through our design processes, manufacturing techniques, and care procedures.

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THE OCCURRENCE AND GEMOLOGICAL PROPERTIES OF WESSELS MINE SUGILITE

By James E. Shigley, John I. Koivula, and C. W. Fryer

Examination of jewelry-quality sugilite shows that it consists of manganese-bearing sugilite and other minerals in a polycrystalline aggregate. The material occurs in a large stratiform manganese orebody at the Wessels mine near Kuruman, South Africa. Some 12 to 15 tons of sugilite of varying quality are estimated to occur at the mine. The attractive purple color is due to the presence of about 1–3 wt.% manganese oxide. The research reported here revealed that there are actually two types of gem materials that have heretofore been called sugilite: one that is predominantly manganose sugilite with minor impurity minerals, and the other that is chalcedony mixed with (and colored by) sugilite.

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In 1979, a new gem material with a striking purple color began appearing on the gem market (figure 1). Its source is the Wessels mine in the northern part of Cape Province, Republic of South Africa. Initially there was some question as to the identity of this material, and in the gemological literature it was first referred to as *sogdianite* (Dusmatov et al., 1968; Forbes et al., 1972; Bank et al., 1978; Dillman, 1978). Subsequently, Dunn et al. (1980) showed that this new gem material is actually a compositional variety of the uncommon mineral *sugilite* (which is closely related to *sogdianite*) that contains minor amounts of manganese. The manganese is responsible for the distinctive purple color.

The mineral *sugilite* was first described by Murakami et al. (1976) from a locality in southwest Japan. There it occurs in limited amounts as small brownish yellow grains in an aegirine syenite host rock. Clark et al. (1980) reported an occurrence of the mineral as a few tiny pink crystals in manganese ore from the state of Madhya Pradesh in India. These two and the Wessels mine are the only known occurrences of *sugilite*. The appearance of the massive purple material from the Wessels mine bears no resemblance to the "type" material from Japan.

Manganose *sugilite* from the Wessels mine has been marketed under several trade names, including *Royal Lavulite* and *Royal Azel*. Within the trade, however, there has been some confusion as to the exact nature of this gem material. In contrast to single-crystal gem materials with gemological properties that generally fall within well-defined limits, this *sugilite* is both polycrystalline and polymineralic (i.e., it consists of an aggregate of tiny individual grains of *sugilite* and other minerals). The polycrystalline character and often variable mineral content of manganose *sugilite* results in a wide variety of material that might be considered gem quality, as well as in a broad range of gemological properties. The lack of



Figure 1. The jewelry shown here combines fine sugilite in a variety of applications. The necklace incorporates 166.4 ct of translucent sugilite beads; the S-shaped center pendant consists of sugilite inlaid in gold with pavé-set diamonds from which is suspended a 4.6-ct pear-shaped faceted translucent sugilite. The bracelet illustrates various shades of sugilite, here inlaid with gold. The ring features a 6-ct cabochon-cut center stone set in gold. Jewelry by Randy Polk. Photo © Harold & Erica Van Pelt.

definitive gemological data on the nature of manganiferous sugilite prompted the investigation reported in this article. Our research showed that material from the Wessels mine can range from samples that are predominantly manganiferous sugilite to those that contain major amounts of chalcedony mixed with manganiferous sugilite. Although standard gemological tests can indicate that both minerals are present in a single sample, they cannot determine the relative proportions.

Using information from a recently published field study of the Wessels mine (Dixon, 1985), and also from written communications with a mine geologist, we will provide a brief description of the occurrence of manganiferous sugilite. This is followed by a gemological characterization of this material (and of the chalcedony mixed with sug-

ilite) and a summary of the diagnostic features by which it can be identified. Although the correct varietal name for the sugilite from the Wessels mine is purple manganiferous sugilite, to be consistent with trade use we will refer to this material simply as sugilite throughout the balance of this article.

GEOLOGY

Location and Access. The Wessels mine is located some 80 km northwest of Kuruman, and is accessible by automobile (figure 2). This area of South Africa is part of the Kalahari Desert. Within this region, the relatively flat topography is interrupted by a few gently rolling hills and by occasional stream or river channels. Most of the terrain is covered by sand. Mean elevations are approx-

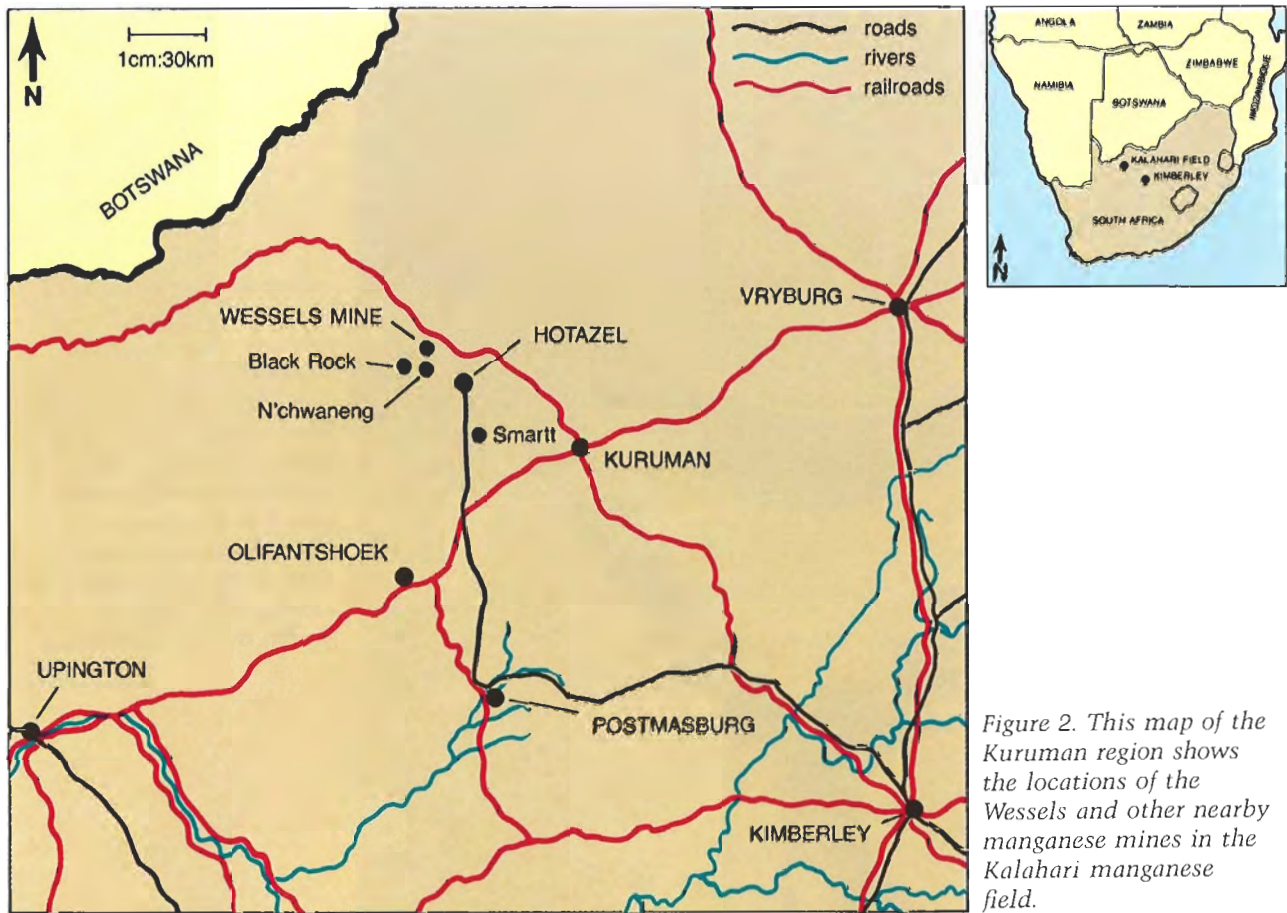


Figure 2. This map of the Kuruman region shows the locations of the Wessels and other nearby manganese mines in the Kalahari manganese field.

imately 1000 m above sea level, with isolated rock outcrops rising an additional 20 to 30 m above the land surface. Annual rainfall averages 20 to 25 cm. The local climate is characterized by distinct seasonal temperatures—from below 0°C (32°F) during winter to above 38°C (100°F) in summer—and by large daily temperature variations. Vegetation, typical of the elevated topography and semi-arid climate, consists of small trees, low scrub bushes, and various grasses.

Nature of the Manganese Deposit. Manganian sugilite occurs in small quantities with other manganese minerals at the Wessels mine, one of a number of surface and underground mines that exploits a series of important manganese deposits in the northern Cape Province. These deposits, known collectively as the Kalahari manganese field, extend over a distance of some 140 km from Black Rock to Postmasburg. With estimated reserves of eight billion tons of ore, these are among the largest and richest manganese deposits in the world (Roy, 1976; Button, 1976).

The manganese fields near Kuruman were

discovered early in this century (see details in Boardman, 1964). By the late 1920s, geologists had located a series of major manganese orebodies along two parallel, north-south trending belts beginning at Postmasburg. Some of these deposits, such as at Hotazel, are mined at the surface by open-pit methods. In most places, however, the manganese ore occurs below the desert sand, and is only seen in channels cut by streams or in rock samples brought up during well excavation or subsurface drilling. The Wessels mine, owned and operated by South African Manganese Mines Ltd. (SAMANCOR) of Johannesburg, is one of the largest underground mines in the Kuruman area and has been in operation since 1973.

Regional Geology of the Kalahari Manganese Field. At the Wessels mine, the manganese ore occurs in a stratiform orebody (for further information, see Roy, 1976, and Hutchinson, 1983). Such stratiform manganese deposits are found in India, Brazil, Ghana, and the Soviet Union, but the ones in South Africa are among the largest and economically most important.

The regional geology of the area around the Wessels mine has been described by J. E. de Villiers (1960, 1983), Boardman (1964), Button (1976), and P. R. de Villiers (1967, 1970). The manganese ore occurs at several horizons within a sequence of sedimentary rocks that is over 10,000 m thick. The ore layers are quite rich, some with a manganese content in excess of 50% (Wilson and Dunn, 1978). The ore consists of braunite, hausmannite, manganite, pyrolusite, rhodochrosite, and other manganese-bearing minerals (Frankel, 1958). It is dark brown to black and occurs in massive layers. Although not especially thick (5–25 m), some individual layers of ore are remarkably continuous and have been traced more than 50 km.

According to Söhnge (1977), the layers of manganese ore and the enclosing sediments were deposited in a sedimentary basin between 2.6 and 2 billion years ago. The manganese was derived either from weathering of the surrounding land or from hydrothermal solutions that moved through the sediments during local episodes of volcanic activity. Favorable conditions led to the deposition of various manganese minerals at certain layers in the sequence of sedimentary rocks.

The Occurrence of Sugilite at the Wessels Mine.

Compared to the production of manganese, only small amounts of sugilite are found at the Wessels mine. Because of its minor economic importance relative to the manganese ore, sugilite has not received great attention from mine officials. The few reports published on sugilite since its discovery in 1973 lack specific information on the occurrence; the best description is by Dixon (1985). The information presented below is taken from that article as well as from written communications with Dr. D. N. Bird, a SAMANCOR geologist.

Sugilite is found in massive form in layers or seams within certain zones in the manganese ore (figure 3). When several sugilite layers occur together, the group can reach 15 cm thick. The layers of sugilite mineralization are not continuous, but rather they extend laterally as far as 15 m. The sugilite is also found as irregular-shaped patches or as massive material that fills the spaces between brecciated blocks of manganese ore. In the original description, Dunn et al. (1980) mentioned that the sugilite and its associated minerals—chiefly braunite and acmite pyroxene—are intimately intergrown on a fine scale. According to Dixon



Figure 3. At the Wessels mine, sugilite can occur in massive or layered form. This representative sample (6 × 5 × 1 cm) shows the layered appearance often seen in the material. The thickness of individual sugilite layers varies greatly, and can reach up to several centimeters across. The thin layers in this sample are almost pure manganoan sugilite. The sugilite occurs with black braunite and a light gray rock containing pectolite and possibly acmite. Photo © Tino Hammid.

(1985), associated minerals also include andradite, wollastonite, pectolite, vesuvianite, glaucophane, and quartz. Dixon describes this group of minerals as forming a skarn within the layered manganese ore. A skarn is a mineralized ore deposit that results from the chemical interaction of circulating hydrothermal solutions with the sedimentary host rocks through which they pass. Original minerals in the host rock are metasomatically replaced by new minerals, which then often form a sequence of mineralized zones related to the direction of flow of the hydrothermal solutions. At the Wessels mine, sugilite apparently formed by such a process at some point following the original deposition of the manganese-bearing sediments.

Manganoan sugilite has been mined intermit-



Figure 4. In the underground workings of the Wessels mine, miners probe with metal poles for layers of sugilite within the massive manganese ore. Photo by John Pittorino.

Figure 5. A miner working underground in the Wessels mine displays a chunk of sugilite that has just been taken from the mine well. Photo by John Pittorino.



tently. The original discovery resulted from an accidental encounter with a sugilite-rich area during normal mining operations. When sugilite is found (figures 4 and 5), the miners remove it from the host rock using hand tools, haul it to the surface, separate it from the more abundant manganese ore, and stockpile it for eventual sale. At the mine, the quality of the sugilite varies greatly, with no particular quality being restricted to certain parts of the underground workings. Dr. Bird (pers. comm., 1985) reported that sugilite has not been observed in any of the other manganese mines operated by SAMANCOR, and has not been identified in any of the neighboring mines in the Kalahari manganese field. No exact figures are available on the total reserves of sugilite at the Wessels mine, but R. D. Dixon (pers. comm., 1985) has unofficially estimated that there are 12 to 15 tons of sugilite of varying quality present. He based this estimate on his field studies and on the occurrence and production of the sugilite mined thus far. Of the projected reserves, no estimate is available as to how much is gemologically important or actually recoverable. However, blocks of massive jewelry-quality sugilite weighing up to several kilograms have been found.

CHARACTERIZATION OF WESSELS MINE SUGILITE

For our study we examined a number of massive samples as well as 25 cabochon-cut and faceted pieces of varying quality. It was during our examination that we discovered that two types of material actually come from the Wessels mine: (1)

samples that are predominantly sugilite; and (2) samples that are less pure, and that contain varying amounts of chalcedony mixed with (and colored by) sugilite. Samples from the latter group exhibit gemological properties of both minerals, and should be identified as a rock composed of both; standard gemological testing of these samples will only indicate if some significant amount of chalcedony is present. The following paragraphs summarize the properties of relatively pure manganian sugilite (see box). The properties of the samples composed of chalcedony mixed with sugilite are also reported in the text when they differ significantly from those of manganian sugilite. In the discussion that follows, samples containing both chalcedony and sugilite are identified as such; the term *sugilite* is used only to refer to samples that are predominantly manganian sugilite.

Appearance. The most striking feature of the purer samples of sugilite is the purple color. As described using GIA's color terminology, the material generally has a purple or bluish purple hue with a variable tone (6–8) and saturation (2–4). A representative ColorMaster reading for the best-quality material is C-04/00/66. In incandescent light, the material takes on a more reddish appearance. Samples containing chalcedony that are lower in sugilite content retain the same purple hue but are less saturated in color and are lighter in tone.

A small amount of sugilite from the Wessels mine has a distinct reddish purple or dark pink color that corresponds to a ColorMaster reading of C-43/35/100 (figure 6). We found this material to differ in chemistry and in absorption spectrum from the more common purple sugilite, as described later in this article. This reddish purple color variety of sugilite is reported to be quite rare at the mine and, to our knowledge, has not appeared on the gem market.

The textural appearance and coloration of both sugilite and those samples intermixed with chalcedony can range from quite uniform to mottled, veined, or layered depending on the homogeneity of the material (figures 7 and 8). When observed with a microscope, all samples (even those with a uniform color) were found to consist of interlocking grains of sugilite and other impurity minerals of differing size, shape, and optical orientation (figure 9). This polycrystalline nature can become so pronounced as to give some pieces a

PROPERTIES OF WESSELS MINE SUGILITE

- Color:** bluish purple to purple to reddish purple
- Textural appearance:** uniform color to veined or mottled
- Toughness:** good to excellent
- Cleavage:** none observed
- Transparency:** opaque to translucent
- Luster:** vitreous to resinous
- Refractive index:** about 1.607
- Specific gravity:** 2.74 to 2.80, average 2.76
- Hardness:** 5½ to 6½
- Absorption spectrum:** bands at 411, 419, 445 and 495 nm; 419-nm band most intense; band strength related to the intensity of the purple color; broad regions of absorption below 430 and from 500 to 600 nm
- Color stability:** stable to normal heat and light conditions of wear
- Ultraviolet fluorescence:** inert to long-wave and short-wave ultraviolet radiation
- Chemical composition:**
(K,Na) (Na,Fe³⁺,Mn³⁺)₂ (Li₂Fe³⁺)Si₁₂O₃₀
- Crystal system:** hexagonal

polygonal appearance. Others, with a relatively uniform color, have an orbicular texture in which faint, grayish purple, 1–2 mm round areas can be seen. Narrow reddish brown veinlets up to 2 mm across cut through some samples in random directions.

Sugilite can fracture along irregular surfaces, but the material used for jewelry is generally quite tough and durable. Cleavage was not apparent in the samples we examined. The material varies from opaque to translucent. There apparently is no relationship between the degree of transparency and the sugilite and chalcedony content. The luster on a broken surface is vitreous or resinous.

Refractive Index. Dunn et al. (1980) reported the refractive indices of manganian sugilite from the Wessels mine to be $\epsilon = 1.605$ and $\omega = 1.611$. It was

during R.I. testing that we first noted the two distinct types of gem material. Sixteen of the 25 samples gave a nonvarying spot or flat-facet reading of 1.607, as expected for sugilite (Fryer et al., 1981). One of the faceted stones, however, gave a distinct reading of 1.544 that corresponds to the refractive index of quartz or chalcedony. The remaining eight samples showed two separate readings of 1.544 and 1.607. When the magnifying lens was removed from the refractometer, and flat-facet readings were taken at various locations on one of these eight samples, a number of locations on different mineral grains easily gave either or sometimes both of these refractive indices.

These results indicate that the gem material commonly called "sugilite" in the trade actually ranges from relatively pure manganoan sugilite to samples that contain progressively greater amounts of chalcedony. Samples exhibiting the two refractive indices should not be described as sugilite but rather as a rock consisting of a mixture of sugilite and chalcedony. There is no way to determine if chalcedony is the major constituent of a particular sample by standard gemological testing procedures.

Birefringence. As is common with other massive, polycrystalline gem materials used for lapidary purposes, none of the samples tested on the refractometer displayed discernible birefringence. The

double readings of 1.544 and 1.607 are distinct and separate refractive indices for the two different minerals found intermixed in some samples, and they should not be mistaken for birefringence.

Pleochroism. The samples examined are polycrystalline, and display no pleochroism because of the random orientation of their microscopic constituents.

Specific Gravity. To test for specific gravity, we selected six samples from the group of 25. This set covered the range of colors of sugilite and included a lighter-colored sample that also contained chalcedony (as indicated by the 1.544 refractive index). Testing of this group should demonstrate a simple means of distinguishing material that is predominantly sugilite from pieces that are chalcedony mixed with sugilite because of the lower specific gravity of chalcedony (2.58–2.62, as compared to 2.79 for sugilite).

The samples were tested first in a methylene iodide–benzyl benzoate solution of known 2.67 specific gravity. The sugilite samples sank readily in the liquid; their specific gravity was estimated to be approximately 2.75 to 2.80. The single lighter-colored sample containing chalcedony sank slowly in the liquid; its specific gravity was estimated to be approximately 2.70.

Using a Voland double-pan balance and three repeated measurements, we obtained a hydrostatic



Figure 6. Comparison of purple and reddish purple samples of massive sugilite from the Wessels mine. The specimens are 2 cm high. Photo © Tino Hammid.



Figure 7. This selection of cabochons of manganovan sugilite, ranging from 2.53 to 9.08 ct, illustrates the range of color and textural appearance of the material. Photo © Harold & Erica Van Pelt.

value of 2.69 for the lighter-colored sample, and values of 2.74–2.78 (2.76 average) for the remaining five samples. It appears, then, that measurement of specific gravity does indeed provide a rough indication of how much chalcedony a sample of this material might contain, with samples with lower specific gravities containing more chalcedony.

Absorption Spectra. When examined with a “hand-held” type of spectroscope and reflected light, the sugilite samples were found to exhibit one or more of the following features: a weak band at about 411 nm, a strong band at about 419 nm, a weak band at about 445 nm, and a weak band at approximately 495 nm. The strong band at 419 nm could be seen in all samples, but the weaker ones were not always visible. In addition, broad regions of absorption below 430 nm and from 500 to 600 nm were noted (see spectrum illustrated in Fryer et al., 1981). The strength of these spectral features increases in intensity as the color of the sugilite becomes darker. The narrow bands were much less obvious in the reddish purple color variety of sugilite, but the broad absorption region from 500 to 600 nm was still visible. In a sample of the chalcedony mixed with sugilite, no narrow bands were observed, but, again, a broad region of absorption from 500 to 600 nm was weakly visible.



Figure 8. Although this material was originally thought to be sugilite, gemological tests indicated that it is actually a mixture of chalcedony and sugilite. The carving is 4 cm in diameter and weighs 51 ct. Photo by Scott Briggs.

Absorption curves on this material were obtained with a Pye-Unicam UV/VIS spectrophotometer, and compared with the absorption spectra of other manganese- and iron-bearing min-

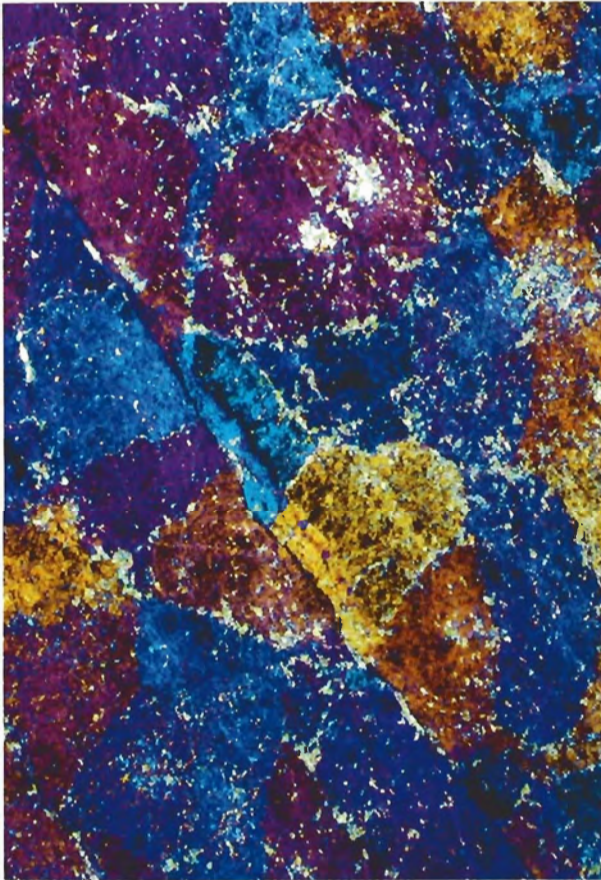
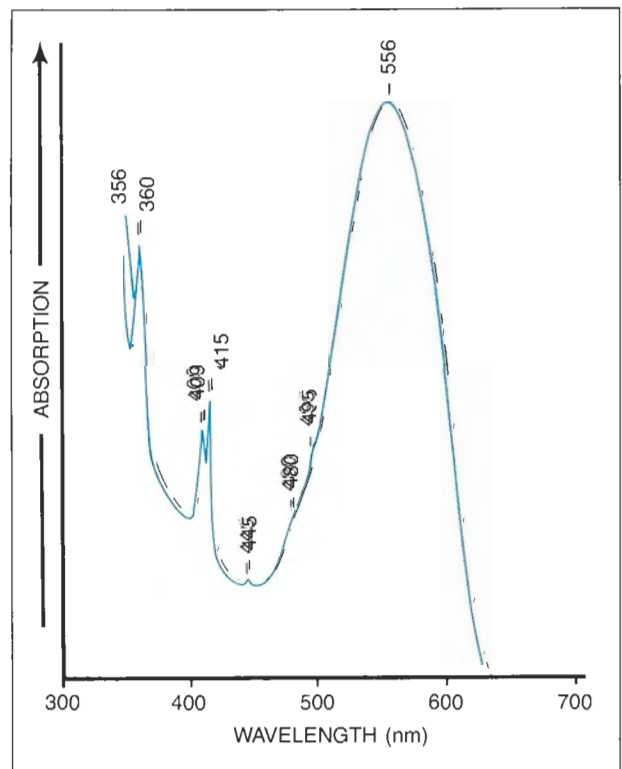


Figure 9. In this thin section viewed with polarized light, individual grains of sugilite, each exhibiting a different interference color, are seen in a polygonal arrangement that relates to the polycrystalline character of the material. The grains are approximately 0.1 mm in diameter. The tiny black inclusions are impurities. The presence of sugilite and other minerals in such a granular aggregate leads to the polymineralic nature of this material; magnified 50 \times . Photomicrograph by John Koivula.

erals. The results (see figure 10) indicate that the color of the purple sugilite can be attributed to both manganese (as Mn³⁺) and iron (as Fe³⁺). The color of the material proved to be stable when subjected to heat (100°C) and light (exposure to direct sunlight for several hours) conditions that might be experienced during routine jewelry use. In addition, none of the samples was found to have been treated with any color-enhancing dyes. The same remarks on color stability can be made for the samples containing both chalcedony and sugilite.

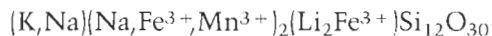
Hardness. The samples we tested vary in hardness between 5 $\frac{1}{2}$ and 6 $\frac{1}{2}$, and most commonly between 6 and 6 $\frac{1}{2}$, on the Mohs scale. Those specimens that gave a 1.544 R.I., indicating a significant chalcedony content, also tended to test consistently at the higher, 6–6 $\frac{1}{2}$, end of the hardness range. Other factors that appear to affect the hardness are texture and the thickness of the sugilite layers. These hardness values correspond to those reported by Dunn et al. (1980) for manganese sugilite. No directional variation in hardness was noted during testing. Both sugilite and the chalcedony with sugilite are sufficiently durable for use in various jewelry applications.

Figure 10. The spectrophotometer absorption curve of a polycrystalline sample of purple manganese sugilite. Within the visible region, the absorption peaks indicated correspond to the narrow absorption lines seen in a "hand-held" type of spectroscope. The large peak centered at about 556 nm corresponds to the broad region of absorption from 500 to 600 nm seen in the hand spectroscope. The curve was obtained with a Pye Unicam PU8800 UV/VIS spectrophotometer with a 1-nm bandwidth and a 1-nm/sec scan speed. The path length through the sample was approximately 1.56 mm.



Ultraviolet Fluorescence. All of the 25 samples were inert to long-wave (366 nm) ultraviolet radiation. When exposed to short-wave ultraviolet radiation, six of the samples showed a slight reaction while the remaining 19 were inert. Of the six, four fluoresced an extremely weak, dull, chalky orange. The remaining two exhibited weak to moderate orange fluorescence on a few tiny randomly arranged spots. Some of these spots were pinpointed and then examined with the microscope, but no distinct mineral grains responsible for the fluorescence could be resolved. It was noted, however, that those samples that reacted to short-wave ultraviolet radiation were also among those that had both the 1.607 and 1.544 refractive indices. Thus, such a fluorescence reaction seems likely to be due to the presence of chalcedony in the sample. Manganoan sugilite is inert to ultraviolet radiation.

Chemical and X-ray Diffraction Data. Chemical composition data on manganoan sugilite have been published by Dunn et al. (1980), Clark et al. (1980), Olivier et al. (1983), and Dixon (1985). They reported that the material contains about 1–3 wt.% manganese oxide. The chemical formula of manganoan sugilite can be written as follows:



The X-ray diffraction pattern we obtained for a sample of manganoan sugilite from the Wessels mine (GIA 14561) is consistent with X-ray data reported for the type sugilite from Japan (1986 JCPDS Mineral Powder Diffraction File 29-824). Least-squares refinement of 68 measured reflections obtained from this specimen yielded unit-cell dimensions of $a = 10.020(3) \text{ \AA}$ and $c = 14.085(11) \text{ \AA}$. The close correspondence of these values to those of the type sugilite from Japan ($a = 10.007 \text{ \AA}$, $c = 14.000 \text{ \AA}$) suggests that the presence of manganese has little influence on the crystal structure. The reddish purple color variety of sugilite gave a similar X-ray diffraction pattern.

X-ray diffraction patterns obtained from some of the more grayish purple material confirmed the presence of important amounts of quartz (in the form of the cryptocrystalline variety chalcedony). Patterns for some of the other minerals in those pieces of rock containing sugilite with prominent gray layers revealed (black) braunite, (grayish) pectolite and, to a lesser extent, (white) barite. The reddish brown veinlets cutting some samples were

found to be a color variety of sugilite of presumably different chemical composition.

Gemological Uses. Since its discovery, sugilite (and the samples now known to contain chalcedony as well) has been used in an increasing variety of jewelry and decorative applications. The material can be categorized into various quality grades on the basis of color (hue and saturation), texture (uniformity or zonation of color, presence of veining, banding, or fractures), hardness, translucency, and size (thickness of the sugilite layers). Most of the sugilite is cut in cabochon form (figure 7). Commonly, thin layers are used for inlay in both jewelry and decorative objects (see, e.g., Elliott, 1986; see also figure 1). Larger massive pieces make excellent carving material (figures 11 and 12). A few translucent pieces of manganoan sugilite have been faceted (again, see figure 1). Individuals who have worked with this material report that good samples, selected to be free of fractures and other defects, cut and polish in a manner

Figure 11. Sugilite has become a popular carving material, as this blue heron illustrates. The bird, 19 cm high, was carved by Herbert D. Klein Co., Idar-Oberstein. The beak is jasper and the legs are 14K gold. Photo © Harold & Erica Van Pelt.





Figure 12. This piece of sugilite was carved in a dragon motif by Hing Wa Lee, Los Angeles, CA. The carving measures 52 × 35 × 7.5 mm. Courtesy of Sylvia and Ralph Coello; photo © Tino Hammid.

normal for a gem material of this hardness. In many ways, during cutting, carving, and polishing, sugilite behaves similar to jade (both jadeite and nephrite) and, to a lesser extent, to lapis-lazuli (although sugilite is reported to be slightly harder on the saw and polishing wheel). The fact that sugilite does not fracture or cleave easily, and is not heat sensitive, is important when considering its potential usefulness as a gem material.

SEPARATION FROM OTHER MATERIALS

Only a few other opaque or translucent purple gem materials could be confused by sight alone with sugilite (figure 13). However, they are easily separated by standard gemological testing.

Whether dyed or naturally colored, purple or lavender jadeite has a distinctive 1.66 spot refractive index reading. Massive violet to purple dumortierite, though rarely encountered as a gem material, also has a refractive index range that is much higher (1.678 to 1.689) than that of sugilite.

Charoite is easily separated from sugilite on the basis of sight alone because of its distinctive interlocking, fibrous texture. Additionally, charoite's 1.55 refractive index is much lower than that of sugilite (although it is close to that of the chalcedony-sugilite mixture).

The refractive indices of chalcedony and massive amethyst are so low in comparison to sugilite's 1.607 reading that no misidentification should result. As noted earlier, though, the grayish purple material from the Wessels mine that we found to be chalcedony mixed with sugilite will give the refractive indices of both minerals. This material, which should be identified as a rock composed of chalcedony and sugilite, is also weakly fluorescent to short-wave ultraviolet radiation. In contrast to the absorption spectrum of sugilite, there are no sharp lines in the absorption spectrum of either the sugilite-colored chalcedony or amethystine chalcedony (Shigley and Koivula, 1985). However, both can have spectra with a region of absorption from 500 to 600 nm.

Although the above-mentioned gem materials

Figure 13. A cabochon of manganoan sugilite (14.12 ct) is surrounded by cabochons of possibly similar-appearing gem materials. Clockwise from the top, these are lavender jadeite (25.07 ct), charoite (10.26 ct), two pieces of amethystine chalcedony (9.51, 8.34 ct), dyed jadeite (8.60 ct), and amethyst (9.69 ct). Photo by Robert Weldon.



also differ dramatically from sugilite in their specific gravities, this testing method is not always practical because the gems must be removed from their mountings for testing. In virtually all cases, the refractive index, together with sugilite's unique absorption spectrum, should be sufficient to separate it from any other known violet-to-purple, opaque-to-translucent gem material.

CONCLUSIONS

Purple manganean sugilite has been found in commercial quantities at only one location, the Wessels mine near Kuruman in South Africa. With a hardness of 5½ to 6½, the finest qualities of manganean sugilite are ideally suited for use in all forms of jewelry. As a polycrystalline gem material, it is generally tough and resistant to fracturing. Sugilite is also color stable to both light and

heat in normal wearing conditions. We know of no sugilite that has been treated in any way to improve its appearance. Sugilite can be readily separated from similar-appearing materials.

Some material from the Wessels mine was found to contain important amounts of chalcedony. These differ from the purer manganean sugilite in their gemological properties. Although the chalcedony-bearing samples have a slightly greater hardness (6 to 6½), they are less saturated in color. We do not know how much of this latter material may appear in the market, but few samples of it relative to those of sugilite have been submitted for identification to the GIA Gem Trade Laboratory (R. Kane, pers. comm., 1987). Nonetheless, samples containing chalcedony can easily be distinguished from sugilite on the basis of the gemological properties summarized here.

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NOTES • AND • NEW TECHNIQUES

THREE NOTABLE FANCY-COLOR DIAMONDS: PURPLISH RED, PURPLE-PINK, AND REDDISH PURPLE

By Robert E. Kane

Three fancy-color diamonds were recently sold at auction by Christie's, the largest—a 0.95-ct purplish red—for \$880,000. These diamonds are notable for their unusual colors, of which the purplish red is the rarest. This article provides a comprehensive description of the visual appearance and gemological properties of these three diamonds.

On April 28, 1987, at Christie's in New York, a 0.95-ct fancy purplish red round brilliant-cut diamond was sold for \$880,000. This extraordinary sale set a new world record per-carat price, at auction, for any gem: \$926,000. The previous world record per-carat price for a diamond sold at auction was \$127,000, for a 7.27-ct pink stone (Christie's, May 14, 1980). Also sold at the recent auction were a 0.54-ct fancy reddish purple diamond (\$65,880; \$122,000 per carat) and a 0.59-ct purple-pink diamond (\$135,000; \$229,000 per carat).

The three fancy-color diamonds (figure 1) were put up for auction by the heirs of a Montana collector, who reportedly bought the 0.95-ct stone in 1956 for \$13,500 (Arnold Baron, pers. comm., 1987). According to Mr. Baron, the "0.95-ct round red diamond" was "found in a Brazilian collection of fancies" he had purchased in the 1950s; the other two diamonds described here were also part of the same "Polychrome" collection. These stones were assembled by a Brazilian cutter from rough purchased at various mines in Brazil.

In August 1986, these three diamonds were

submitted by Christie's to GIA's Gem Trade Laboratory, Inc., in Los Angeles for origin-of-color reports. Christie's also gave the laboratory and the GIA Research Department the opportunity to study and photograph them. The purpose of this article is to document the gemological characteristics of these three extremely rare fancy-color diamonds (see table 1).

COLOR

The three fancy-color diamonds were quite saturated in hue, and dark enough in tone to surpass easily the "fancy light/fancy" color grade distinction, and were all given the "fancy" grade. The following grades were assigned to these three round brilliants:

- 0.95 ct—Fancy purplish red
- 0.59 ct—Fancy purple-pink
- 0.54 ct—Fancy reddish purple

Although intense pink diamonds are rare (Hofer, 1985), a color description that includes "red" is even more rare, especially where red is the primary hue, such as purplish red. Rarest of all is pure red with no secondary hue. For the few descriptions in the literature of such stones, see

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All photomicrographs are by the author.

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Figure 1. These three round brilliants are among the rarest of fancy-color diamonds. They are, from top to bottom: a 0.95-ct purplish red, a 0.59-ct purple-pink, and a 0.54-ct reddish purple diamond. Courtesy of Christie's; photo © Tino Hammid.

Kunz (1925 and 1928), Shepherd (1934), Ball (1935), and Gaal (1977). In the almost 30 years of records of Gem Trade Laboratory reports available, there is no mention of a diamond with "red" as the only descriptive term.

SPECTRAL ANALYSES

The visible-light absorption spectra (400 to 700 nm) of the three fancy-color diamonds were examined using a "hand-held" type spectroscope, first at room temperature and then at low temperature (around $-65^{\circ}\text{F}/-54^{\circ}\text{C}$), cooled by an aerosol refrigerant. At room temperature, the 0.95-ct purplish red diamond exhibited a moderate to strong 415.5-nm line, which is very common in diamonds, including some in the pink to red and purple color

range (figure 2). This absorption became extremely intense when the diamond was cooled. No 415.5-nm line was observed in the 0.59-ct and 0.54-ct diamonds at room temperature. However, the 0.59-ct diamond showed an extremely weak, and the 0.54-ct a weak, 415.5-nm line when they both were cooled. All three diamonds showed almost total absorption below 410 nm, both at room temperature and when cooled.

The 0.95-ct purplish red diamond also exhibited a broad, diffuse band of moderate intensity from approximately 530 to 590 nm, and a weak band from approximately 495 to 510 nm. Unlike the 415.5-nm line, these absorption features were much weaker at low temperature than at room temperature. The two smaller diamonds exhibited

TABLE 1. The gemological properties of three notable fancy-color diamonds.

Properties	0.95-ct Diamond	0.59-ct Diamond	0.54-ct Diamond
Color	Fancy purplish red	Fancy purple-pink	Fancy reddish purple
Absorption spectrum ^a (400–700 nm)	Moderate to strong 415.5-nm line; weak band at 495–510 nm; broad, diffuse band of moderate intensity at approx. 530–590 nm	Very weak band at 495–510 nm; weak, broad, diffuse band at approx. 530–590 nm ^b	Very weak band at 495–510 nm; weak, broad band at approx. 530–590 nm ^b
Transmission luminescence	Weak to moderate whitish blue	Strong blue	Very weak chalky blue-white
Long-wave U.V. radiation	Distinctly zoned, weak chalky pink and chalky bluish white fluorescence	Patchy, slightly chalky, moderate blue fluorescence	Opaque, chalky, moderate bluish white fluorescence
Short-wave U.V. radiation	Essentially the same fluorescent colors as long-wave but intensity very weak	Essentially the same fluorescent colors as long-wave but intensity very weak	Essentially the same fluorescent colors as long-wave but intensity weak
X-rays	Moderate chalky bluish white	Moderate chalky bluish white	Moderate chalky bluish white

^aAs observed at room temperature through a GIA GEM Instruments spectroscopy unit with a Beck prism spectroscope.

^bWhen cooled with an aerosol refrigerant, the 0.59-ct stone showed an extremely weak, and the 0.54-ct stone a weak, 415.5-nm line.

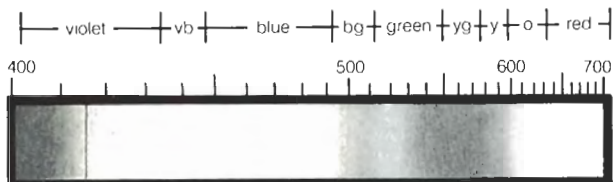


Figure 2. The absorption spectrum of the 0.95-ct purplish red diamond as viewed at room temperature on a GIA Gem Instruments spectroscopy unit with a Beck prism spectroscope.

the same temperature-dependent behavior, but the absorption in the same areas was much weaker.

TRANSMISSION LUMINESCENCE

When the diamonds were placed over a strong light source from the opening of the iris diaphragm on the spectroscopy unit, all three displayed a luminescence often seen in various fancy-color diamonds, which is frequently referred to as “transmission.” This phenomenon is most evident when the diamond is placed table-down over the concentrated beam of light. If the luminescence is strong enough, it will be visible even in sunlight (or any

artificial light), as was the case with the 0.59-ct purple-pink diamond.

The 0.95-ct purplish red diamond displayed a weak to moderate whitish blue luminescence, the 0.59-ct purple-pink diamond transmitted a strong blue (figure 3), and the 0.54-ct reddish purple

Figure 3. Transmission luminescence was readily visible in the 0.59-ct purple-pink diamond.





Figure 4. All three diamonds—from left to right here, the 0.59-ct, 0.95-ct, and 0.54-ct stones—fluoresced to long-wave ultraviolet radiation. Photo by Shane McClure.

diamond exhibited a very weak chalky blue-white uneven luminescence of moderate intensity. When this last diamond was positioned table-down toward the edges of the concentrated beam of illumination, a slight, dull green, “oily” appearance was also observed.

REACTION TO ULTRAVIOLET RADIATION AND X-RAYS

The three diamonds were exposed to long-wave (366 nm) and short-wave (254 nm) ultraviolet radiation in a completely darkened room. When exposed to long-wave U.V. radiation, the 0.59-ct purple-pink diamond fluoresced a patchy, slightly chalky, moderate blue; the 0.95-ct purplish red diamond fluoresced a distinctly zoned, weak chalky pink and chalky bluish white; and the 0.54-ct reddish purple diamond fluoresced an opaque, chalky, moderate bluish white (figure 4). The three diamonds reacted essentially the same to short-wave U.V. radiation, except that the intensity was very weak for the 0.95-ct and 0.59-ct diamonds, and weak for the 0.54-ct diamond. None of the stones showed phosphorescence.

When exposed to X-rays for a few seconds, all three diamonds fluoresced a fairly even chalky bluish white of moderate intensity. Again, no phosphorescence was observed.

OBSERVATIONS WITH THE MICROSCOPE

When examined with polarized light in a binocular gemological microscope (see Kane, 1982, for a description of this technique), all three diamonds showed second-order (bright and vivid) inter-

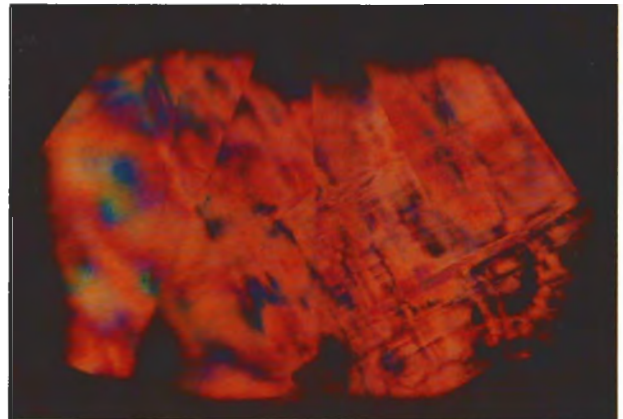


Figure 5. When the 0.95-ct purplish red diamond was examined at 25× magnification with polarized light, strong linear banded (as well as mottled) strain patterns were evident in some areas. Cross-hatching of the linear banded strain patterns forms a “tatami” pattern.

ference colors. The 0.95-ct purplish red diamond showed strong linear banded strain patterns, as well as strong mottled strain patterns (figure 5). The strong linear banded strain patterns intersected in two directions in some areas to form a cross-hatched pattern. Such a pattern is frequently referred to as the “tatami” type of birefringence pattern because of its resemblance to the Japanese woven mat of that name (Orlov, 1977; for illustrations, see Kane, 1982). The mottled birefringence areas are irregular patterns that appear to undulate as the diamond is moved within the field of view, or as one Polaroid is rotated.

The 0.59-ct purple-pink diamond exhibited strong, well-defined, linear banded strain patterns, which correspond directly to the prominent color

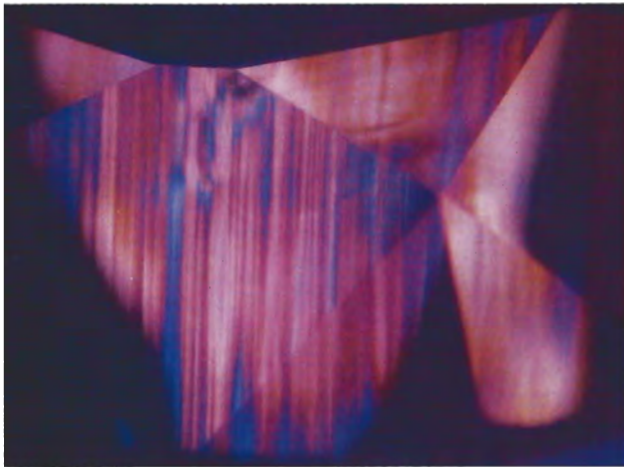
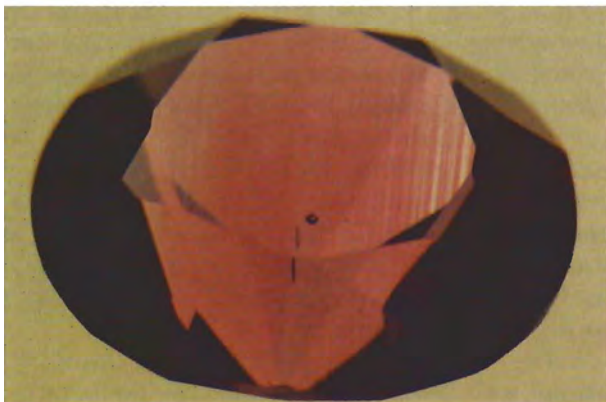


Figure 6. In the 0.59-ct purple-pink diamond, the strong linear banded strain patterns observed with polarized light (left, magnified 30 \times) correspond directly to the color zoning and graining evident with darkfield illumination (right, magnified 25 \times).

zoning and color graining visible with darkfield illumination (figure 6). In addition, localized strain patterns around two crystal inclusions (probably olivine) were observed. The 0.54-ct reddish purple diamond also exhibited "tatami" birefringent strain patterns when viewed under crossed polars. Also present throughout this diamond were strong mottled and localized strain patterns, which are undoubtedly related in part to the numerous inclusions of various types in this diamond.

When viewed with darkfield illumination, all

Figure 7. The closely spaced red and pink graining and color zoning seen in the 0.59-ct purple-pink diamond (here immersed in methylene iodide) were evident in the other two fancy-color diamonds as well. Diffused light; magnified 15 \times .



three diamonds were found to contain significant quantities of easily visible graining. Although the specific causes of color in diamonds in this color range are not entirely understood, current explanations involve defects in the atomic structure that result from gliding (the slight movement of atoms along the octahedral direction) as a result of plastic deformation (Orlov, 1977). This is readily apparent through the microscope as graining and color zonations within the graining (which can vary from weak to quite prominent). The three diamonds examined in this study exhibit closely spaced red and pink graining and color zoning (see figure 7). Considered in conjunction with the author's experience with numerous pink and purple diamonds of somewhat low tonal values (much lighter in color than the diamonds discussed here), this suggests that the tightness of the spacing and intensity of color in the graining is directly correlated to the intensity of the "face-up" color of such diamonds.

The "tatami" pattern was also easily visible as color graining in the 0.54-ct diamond in darkfield illumination, with the grain planes intersecting at approximately 45°. The two directions of color graining were also present in the 0.95-ct purplish red and the 0.59-ct purple-pink diamonds, but were very subtle and somewhat difficult to observe. In these two diamonds, one direction of graining was significantly stronger than the other.

In addition to the graining features discussed



Figure 8. A deep cavity is evident in the table of the 0.95-ct diamond. When viewed from the pavilion, parallel angular growth steps can be seen. Darkfield illumination, magnified 35 \times .



Figure 9. A second cavity in the 0.95-ct diamond begins at the girdle plane. Note the frosted appearance in reflected oblique illumination. Magnified 25 \times .

above, all three diamonds contain other inclusions. The 0.95-ct stone contains a large, deep cavity in the table (figure 8), with numerous parallel angular growth steps that are most evident when viewed from the pavilion. A second cavity—long, narrow, and irregularly shaped—begins at the girdle plane and extends onto the crown to the star facet. It is interesting to note that the highly irregular surface of this second cavity was transparent and glossy in darkfield illumination, in contrast to the white frosted appearance seen with reflected oblique illumination (figure 9). The slightly iridescent fracture seen extending inward from the girdle is aligned precisely with one of the tightly spaced

graining planes easily visible through the pavilion. There are three naturals: one is a deep V-shape with sharp angular parallel growth steps, while the other two have a subtle irregular glossy texture reminiscent of alluvial diamond rough. The 0.95-ct diamond also contains both randomly oriented and intersecting groups of small, black, acicular crystals.

The two smaller diamonds were found to contain naturals, fractures, and clouds of pinpoint inclusions (probably olivine). The 0.59-ct stone contains two crystal inclusions (also probably olivine). The 0.54-ct stone contains several small, and some very large, graphite inclusions.

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THE SEPARATION OF NATURAL FROM SYNTHETIC EMERALDS BY INFRARED SPECTROSCOPY

By Carol M. Stockton

Infrared spectroscopy provides a means to distinguish natural from synthetic emeralds in the range 2000–5000 cm⁻¹, as determined by a study of spectra obtained from 37 natural, 19 hydrothermal synthetic, and 38 flux synthetic emeralds from a variety of sources. The technique is nondestructive and, with Fourier transform instrumentation, extremely rapid in comparison to most laboratory methods. It is especially useful for identifying stones that contain no distinguishing inclusions.

Various manufacturers continue to produce and introduce synthetic emeralds (figure 1). Although inclusions usually enable gemologists to distinguish natural from synthetic emeralds, flawless stones may be extremely difficult to identify by conventional gemological means. Laboratory methods (e.g., microprobe, X-ray fluorescence) that involve equipment that is generally too expensive for practical ownership by most gemologists can then be applied as a last resort. More than one of these has proved useful in separating synthetic from natural emeralds (Griffiths and Nassau, 1980; Kuhlmann, 1983; Schrader, 1983; Troup and Hutton, 1983; Stockton, 1984), but the methods are generally time-consuming. By contrast, Fourier transform infrared (FTIR) spectrometry, especially when accompanied by an automated micro-beam chamber, provides rapid, completely non-destructive results in less than five minutes (Fritsch and Stockton, 1987).

MATERIALS AND METHODS

It was thus relatively simple to obtain the infrared spectra of 37 natural and 57 synthetic (19 hydrothermal and 38 flux) emeralds, most of which are from the GIA reference collection. The natural emeralds came from a variety of localities: all those reported in Stockton (1984) as well as specimens recently acquired from Afghanistan, Pakistan, and new localities in northern Brazil and southern Tanzania (see table 1). The synthetics also include those in the previous study and samples from Russia (both flux and hydrothermal),

Swarovski in Austria and Ustan in the U.S. (both noncommercial), and Lennix (France).

Unpolarized spectra were acquired in the range 400–5000 cm⁻¹ with a Nicolet 60SX FTIR spectrometer. However, complete absorption occurs below about 2200 cm⁻¹, so the spectra reported here are shown only for the range 2000–5000 cm⁻¹.

THE SEPARATION OF NATURAL FROM SYNTHETIC EMERALDS

As can be seen in figure 2, flux synthetic emeralds can readily be distinguished from their natural and hydrothermal synthetic counterparts. The most obvious difference is the absence in the flux stones of the strong absorption between 3400 and 4000 cm⁻¹. This strong absorption has been identified as being associated with water (Wood and Nassau,

TABLE 1. Origin and number of samples of natural and synthetic emeralds tested by Fourier transform infrared spectroscopy.

Origin	No. of samples
Natural	
Afghanistan	1
Brazil	12
Colombia	17
Norway	1
Peru	1
Sandawana	2
South Africa	1
Tanzania	1
USSR	1
Flux-grown synthetic	
Chatham	7
Gilson	5
Inamori	2
Lennix	2
USSR	4
Ustan	3
Unknown	15
Hydrothermal synthetic	
Biron	5
Linde	2
Regency	2
Swarovski	1
USSR	3
Unknown	6



Figure 1. Among the more recent synthetic emeralds introduced are the Biron hydrothermal (top, 0.54 ct) and the Inamori flux (bottom, 0.56 ct) products. Photo © Tino Hammid.

1968], which is always present in natural and hydrothermal synthetic emeralds because of their growth conditions.

The infrared spectra of natural and hydrothermal synthetic emeralds are more similar to one another. However, all but two types of hydrothermal synthetics exhibit a pattern of strong absorption features between 2600 and 3000 cm^{-1} that readily distinguishes them from their natural counterparts (figure 2). Most of the absorption features seen in this range for synthetics were also seen to some degree in natural emeralds, but never all together in the magnitude and same relative strengths as in the synthetics. Moreover, some features that were observed in most hydrothermal synthetics—for example, those at about 2745, 2830, 2995, 3490, 4052, and 4375 cm^{-1} —were never detected in natural emeralds. Thus, the overwhelming majority of hydrothermal synthetic emeralds can be distinguished from natural emeralds by infrared features in this region. No

interpretation of these features has been published, and it is not within the scope of this study to determine their causes, but it is hoped that future researchers will do so.

As mentioned above, two types of hydrothermal synthetic emeralds presented greater difficulty in identification. One is a product that was grown experimentally between 1961 and 1974 by Dr. R. Haupt at Swarovski in Austria, but was never commercially released (K. Schmetzer, pers. comm. to R. Kane, 1987); one sample of this product was included in the study. The other is the Russian hydrothermal product, which is now available commercially and is, therefore, of greater

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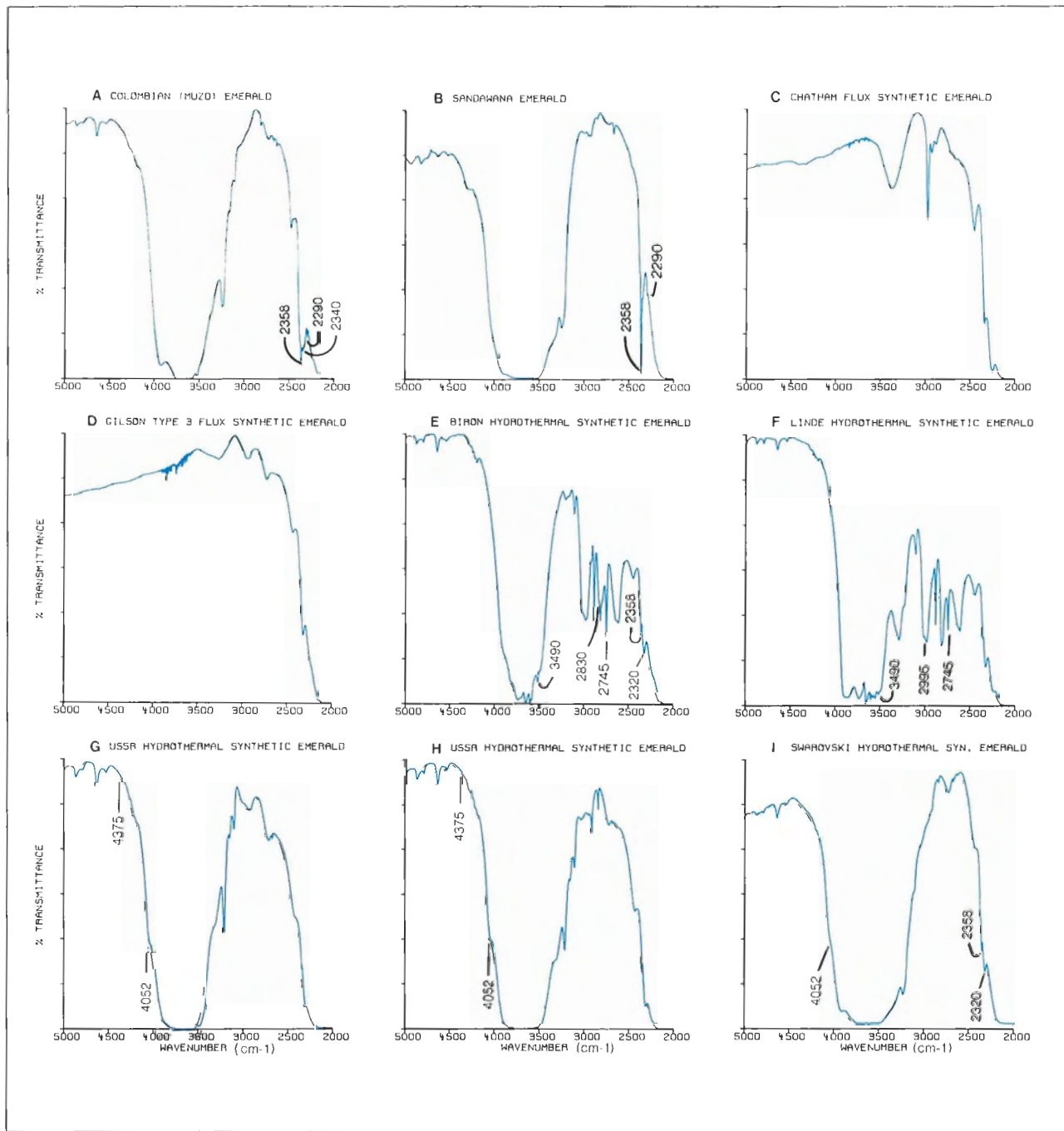


Figure 2. A representative sample of infrared spectra for two natural emeralds (a and b), two flux-grown synthetic emeralds (c and d), two hydrothermal synthetic emeralds (e and f), two Russian hydrothermal synthetic emeralds (g and h), and a Swarovski hydrothermal synthetic emerald (i). Features that can be used to distinguish natural emeralds from hydrothermal synthetics are labeled on spectra a and b. The flux synthetic emerald spectra c and d clearly lack the strong absorption at about 3400–4000 cm^{-1} that is evident in the spectra of all the natural and hydrothermal synthetic emeralds. The spectra of hydrothermal synthetic emeralds (e–i) illustrated here also exhibit features (labeled) that can be used to distinguish these synthetics from natural emeralds. The Russian and Swarovski synthetics (g, h, and i) are most similar to natural emeralds; although the diagnostic spectral features (labeled) are relatively small, they are still distinctive.

concern; three samples of this material were studied. All four of these specimens showed spectra that are deceptively similar to those of natural emeralds (figure 2). Fortunately, a close inspection revealed features that, while not obvious, are nevertheless distinctive. All three Russian stones have two of the features mentioned above, at 4052 and 4375 cm^{-1} , that were not observed in any of the specimens of natural emerald, but can be detected in most hydrothermal synthetics. In the Swarovski specimen, the 4052 cm^{-1} feature occurs, although weakly, while the 4375 cm^{-1} band could not be observed.

Features in the 2200–2400 cm^{-1} range can also be used to distinguish these troublesome hydrothermals from natural emeralds. The latter show at least two and, more commonly, three features in this region, at about 2290, 2340, and 2358 cm^{-1} . The 2290 cm^{-1} band was never observed in the synthetics, while it is usually present (in all but two of the 37 samples here) in natural emeralds. In the synthetics, the location of the "2340" band ranges from 2310 to 2329 cm^{-1} , while in natural stones it is located between 2335 and 2342 cm^{-1} , a distinction that can be made easily with a good infrared spectrometer. Moreover, in natural emeralds the 2358 cm^{-1} band,

associated with structural CO_2 (Wood and Nassau, 1968), is always stronger than the 2340 cm^{-1} feature, while in synthetics the relationship is reversed.

DISCUSSION

It should be remembered that emeralds, both natural and synthetic, are doubly refractive. As a result, their infrared spectra are affected by the orientation of the sample to the incident beam of energy. Ideally, spectra should be taken at known crystallographic orientations in order to control for these variations, but cut gemstones rarely lend themselves to such conditions. While none of the diagnostic features completely disappeared at any orientation tested, some did become quite weak and a less sensitive instrument could fail to detect the relevant features in some cases. It is, therefore, important that spectra be obtained at two or three different orientations before any conclusion is drawn as to the origins of a particular sample.

The results of this study suggest that infrared spectroscopy provides additional means to distinguish natural from synthetic emeralds. With a Fourier transform instrument, the analysis is rapid as well as nondestructive and can frequently be done even on mounted emeralds.

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THE RUTILATED TOPAZ MISNOMER

By John I. Koivula

Recently a number of faceted Brazilian topazes containing brownish yellow acicular inclusions of what has been described by some gem dealers as the mineral rutile have appeared on the market. An investigation of this material shows that these inclusions are not rutile but rather are open channels colored by limonite.

Acicular (needle-like) crystals and crystal groups of brownish yellow to red rutile are relatively common as inclusions in both rock crystal and smoky quartz, so much so that quartz containing such inclusions is usually called rutilated quartz. Over the past two years, a small number of faceted colorless topazes containing what look like brownish yellow needles of rutile have appeared on the market. Because they are so similar in appearance to rutilated quartz, these topazes (see figure 1) have been marketed under the name "rutilated topaz."

These topazes are said to come from a pegmatite in Minas Gerais, Brazil (G. Becker and D. Epstein, pers. comm.). They are faceted, usually in a free-form cut, and range in weight from approximately 2 to over 20 ct. Most of the gems are colorless, but a few are blue. Undoubtedly the latter stones have been irradiated and heated; this treatment does not, however, appear to affect the color of the inclusions.

When one of these topazes is examined with the naked eye, the most obvious characteristic is the directional nature of the individual "needles." As illustrated in figure 1, the "straw-yellow" inclusions are quite obvious when viewed through the table and crown facets of the gem. When, however, one looks through the pavilion of this same topaz (figure 2), the primary images of the inclusions virtually disappear and only secondary reflections are visible. In fact, these inclusions are so ribbon-thin that for all practical purposes they are two-dimensional. When viewed in an edge-on direction, as in figure 2, they seem to vanish.

Rutile is not known to crystallize in topaz in a ribbon-like habit that would produce such a directionally dependent effect. This raises considerable

doubt that these inclusions are rutile, and led to the present investigation into the identity of this material. Because the inclusions were too small for X-ray powder diffraction to be performed and because there was no means of chemical analysis available (such as an electron microprobe), it was decided that microscopy would be the avenue for investigation. During this investigation, a total of nine stones were studied.

MICROSCOPY

When first examined with a standard low-power stereo-zoom gemological microscope, the inclusions had the general appearance of essentially parallel, unbroken, thin, brownish yellow crystals that easily could be mistaken for rutile (figure 3). However, a more thorough examination revealed four features that, together with the nearly two-dimensional acicular habit, proved conclusively that these inclusions are not rutile.

The first of these features was a general observation that, on all of the cut stones examined, the brownish yellow inclusions always reached the surface. Not one of these inclusions was found to be contained completely within the topaz; at least one end, if not both, reached the surface of the stone. This finding suggested that the body color of the inclusions might have been derived from an outside source and was not necessarily inherent to the true nature of the inclusions themselves.

It was also observed that wherever these inclusions reached the surface, there was undercutting in the form of grooves or drag lines extending and

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All photomicrographs were taken by the author.

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Figure 1. Table-up view of this 19.77-ct Brazilian topaz shows the prominence of brownish yellow inclusions that have been mistaken for rutile. Photo © Tino Hammid.



Figure 2. The inclusions are so ribbon thin that many of them are barely visible in this pavilion view of the stone shown in figure 1. Photo © Tino Hammid.

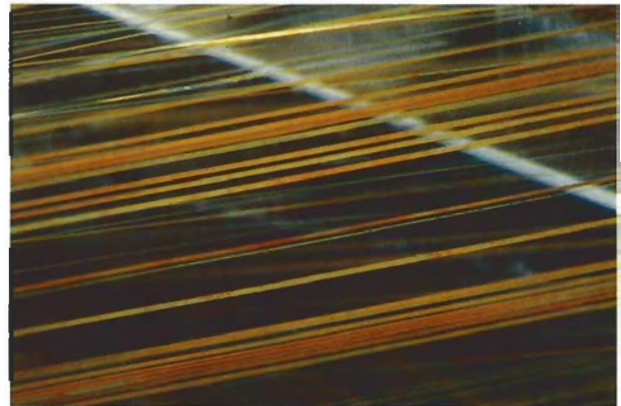


Figure 3. These inclusions in topaz could easily be mistaken for rutile. Darkfield and oblique illumination, magnified 35 \times .

tapering away from the inclusions in the direction of polishing (figure 4). These are not the types of surface markings that one expects when slightly softer solid inclusions such as rutile, captured in a harder host material such as topaz, are cut through and polished over during lapidary treatment. They are much deeper and are reminiscent of the drag lines observed when preexisting fractures of similar surface-reaching hollows are polished over perpendicular to their length. The polishing-wheel action causes the spalling off of tiny chips from the rim of the fracture which are then pulled along by

the wheel. This scores the surface of the material being polished and produces the visual evidence we see in figure 4.

Incomplete filling of the inclusions provided additional proof that they are not rutile. Acicular rutile inclusions are single crystals and as such would not contain randomly spaced gaps at uneven intervals down their length. However, dislocation-caused growth tubes or voids that extend to, and are open at, a crystal's surface might contain incomplete fillings of epigenetically derived limonitic compounds. This latter phenomenon, re-



Figure 4. These polishing drag lines on the surface of a topaz extend from the ends of the "inclusions." Shadowed oblique illumination, magnified 25 \times .



Figure 5. The incomplete filling of the inclusions provides further proof that they are not rutile. Oblique illumination, magnified 60 \times .

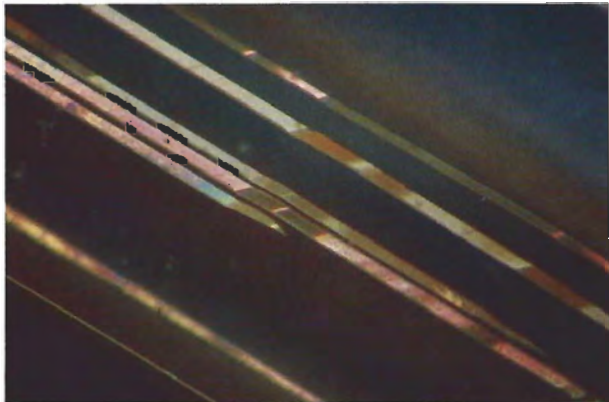
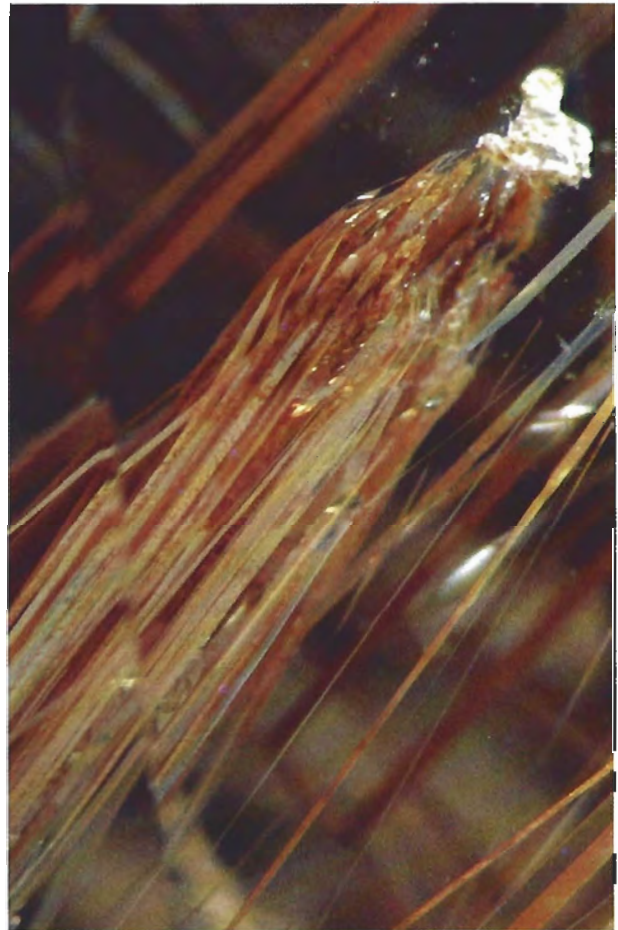


Figure 6. Thin-film iridescence from some of the unstained areas along the etch channels serves as additional support for the discontinuous nature of the inclusions. Oblique illumination, magnified 45 \times .

Figure 7. This dense, broom-like cluster of iron-stained etch channels all propagate, as a result of growth blockage and disturbance, from the same solid inclusion. Darkfield and oblique illumination, magnified 40 \times .



sulting in discontinuous coloration (figure 5), was observed on close inspection of these inclusions.

When oblique illumination was used, the fourth feature, thin-film iridescence (figure 6), was observed wherever a gap was present in an inclusion channel. This provided additional proof of uneven channel filling, which is contrary to the continuous crystallization that would be expected if the inclusions were rutile.

As a final test, the thinnest portions of several of the inclusions were examined in polarized light to see if they were doubly refractive, which would also be expected of rutile. No double refraction was observed, so the possibility of rutile was once again negated.

CHARACTERIZATION OF THE INCLUSIONS

With this visual evidence, it is safe to say that the acicular inclusions observed in these "rutilated" topazes do not consist of rutile and are in no way related to rutilization. All of the above-noted observations, together with the previously published literature (Phakey and Horney, 1976; Roedder, 1984), point to the conclusion that these needles are the direct result of growth blockage caused by the presence of solid inclusions, which may or may not be microscopically visible, within the topazes.

Once trapped, the solid inclusions interfered with the ideal structural development of the topaz host as it grew away from them. This resulted in the formation of many dislocations leading away from the solid inclusions, often all the way to the surface of the topaz crystal. Such dislocations are a known invitation to etching (Phakey and Horney, 1976). Natural etching along these dislocations followed (or could have occurred continuously as the host topaz was growing). The final step was epigenetic iron staining through capillarity of the resultant etch channels. This epigenetic iron staining, incorporating a mixture of cryptocrystalline powder-like iron hydroxides and oxides referred to as limonite, gives the inclusions their brownish

yellow color and high visibility. Observations and illustrations of similar inclusions in topaz by Dr. Edwin Roedder (1984) strongly support this characterization (compare the photomicrograph on page 25 of his book with figure 7 here).

CONCLUSION

Although these topazes have been sold as "rutilated," in reality they contain no rutile. Rather, limonitic stains filling, or partially filling, ribbon-thin etched dislocation channels in the topazes create the rutile-like effect.

A great deal of care must be taken during the faceting of these topazes because of the directional nature of the inclusions. The lapidary must orient the rough so that the inclusions will appear boldest to the eye when the finished faceted gem is in the table-up position. Referring back to figures 1 and 2 will show how important proper lapidary orientation is with this material.

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Gem Trade LAB NOTES

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Needle-like Inclusions in EPIDOTE

The Santa Monica laboratory recently examined a very dark green oval modified brilliant cut that weighed approximately 5 ct. The stone resembled deep green tourmaline in appearance, but the refractive index reading of 1.739–1.779 was much higher than that of tourmaline (1.624–1.644). It was strange that despite the high birefringence (0.040), no apparent doubling of facet junctions was visible with the microscope. However, we did notice numerous straight and some curved needle-like inclusions of unknown origin (figure 1). John Koivula, chief gemologist in GIA's Research Department and an inclusion expert, identified the needle-like inclusions as probably tremolite, an amphibole. The dichroscope revealed very distinct pleochroic colors, green and olive brown, in the stone. Because the overall color was so dark, we

Figure 1. These straight and curved (out of focus) inclusions were determined to be tremolite needles in epidote. Magnified 63×.

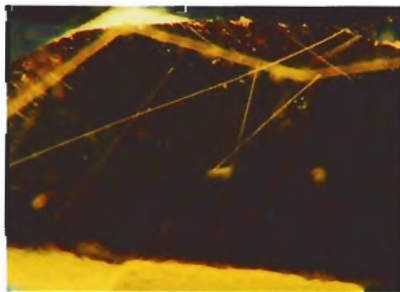


Figure 2. These 7-mm diameter, high-dome cabochons set in yellow metal earrings were found to be a new type of opal assemblage. Magnified 10×.

could not obtain an optic figure in the polariscope. Spectroscopic examination showed a quite characteristic absorption spectrum: a broad band centered at 455 nm, a faint line at 470 nm, and a cut-off area starting at 430 nm. This collection of data proved that the stone is epidote. KH

A New OPAL Assemblage

The New York laboratory recently received a striking pair of 7-mm-diameter, high-dome cabochon "opals" set in yellow metal cluster earrings (figure 2). Close examination with a loupe revealed that the "diamonds" are actually foil-backed glass. We then became suspicious of the center stones, and with, as we learned, good reason. The "opals" did

not fluoresce, but cement at the base glowed orange. When we looked through the stones as in figure 3, the "opal" appeared to be contained within a capsule. Out of the setting, the assemblage became very obvious. As evident in figure 4, the "opals" are composed of a glass "cup" filled with opal chips in clear cement. The relatively thick-walled glass container suggests a measure of durability. The trade name "Multi-Opal Triplets" has been proposed by the distributors of this product.

RC

Editor's Note: The initials at the end of each item identify the contributing editor who provided that item.

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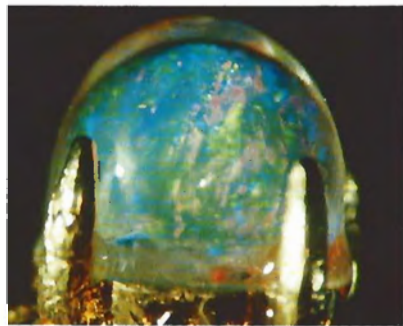


Figure 3. A close examination through the side of one of the cabochons seen in figure 2 shows the outer glass container. Magnified 10 \times .

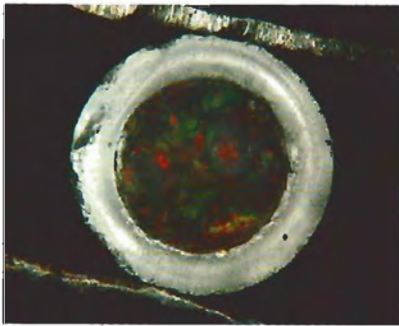


Figure 4. This view of the base of the opal assemblage seen in figure 3 clearly reveals the thick glass outer container. Magnified 10 \times .

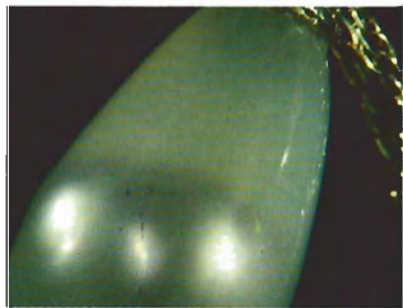


Figure 5. Distinct areas of orient and lack of orient can be seen on this 9 \times 14 mm cultured pearl. Magnified 10 \times .

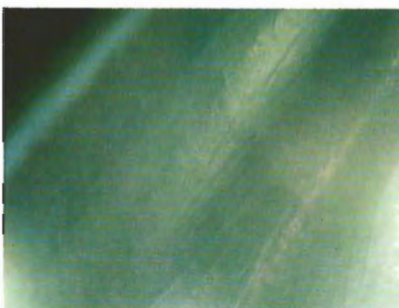


Figure 6. Abrasion striations on the cultured pearl shown in figure 5 indicate "working" of the surface. Magnified 23 \times .

PEARLS

A Cultured Pearl Puzzle

A very high quality 9 \times 14-mm cultured pearl was recently returned to the supplier by his customer, who claimed that it was inferior because it had changed in appearance since the purchase. Both the customer and the supplier agreed that this originally had been a fine drop-shaped cultured pearl. It was not misshapen, was thickly nacre, and in general displayed fine orient and luster. The New York laboratory was asked if they could determine why the top half of the pearl had apparently lost its orient and become a milky color, resembling "opal" glass (figure 5).

Although the pearl displayed evidence of "working" (notice the abra-

sion striations shown in figure 6), there is no way to determine whether this could have affected the orient, causing the eventual change in the

Figure 7. This 7-mm "fossilized pearl" was found in Utah.



top half. Neither the laboratory, nor any of the several pearl dealers asked, had ever seen this apparent loss of orient before. Nor could anyone offer a possible solution to the puzzle.

Dave Hargett

A "Fossilized Pearl" from Utah

A graduate student from Southern Utah State College sent the Santa Monica laboratory a specimen that someone at the college had identified as a fossilized pearl. The specimen was found in the Tropic Shale Formation, of Upper Cretaceous age, in Tropic, Garfield County, Utah, 10 miles east of Bryce Canyon National Park. It is yellowish brown in color and measures approximately 7 mm in diameter (figure 7). Even though the surface was rough, we were able to determine on the refractometer that the material has the high birefringence that is characteristic of all carbonates. When examined with the microscope, the bead revealed what appeared to be a concentric structure. At one point where the top layer had been removed and the underlying layer was exposed, a peculiar structure became visible. The vaguely hexagonal pattern is illustrated in figure 8. This pattern resembles in appearance the external and internal structure of pearls. K. Scarratt, of the Gem Testing Laboratory in London, also illustrated these characteristics in "Notes from

Figure 8. The structure of the "fossilized pearl" shown in figure 7 (here at 50 \times magnification) resembles that of a natural pearl.

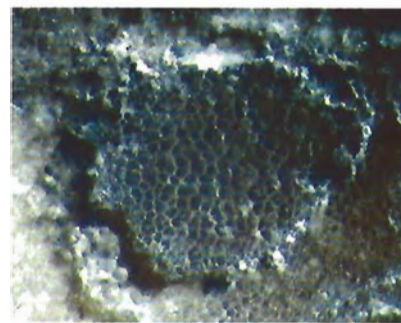




Figure 9. A 15.73-ct cat's-eye peridot.

the Laboratory-9," *Journal of Gem-mology* (1987), Vol. 20, No. 5, p. 287. Although this piece showed similarities to pearl, because there was no evidence of nacre we could identify it only as a calcareous concretion. KH

PERIDOT, Cat's-Eye

Many years ago, Webster stated that "A cat's-eye peridot is known," but provided no additional information. In his *Color Encyclopedia of Gemstones*, Arem reported that "cat's-eye and star peridots are known, but are very rare." Perhaps one reason that we encounter phenomenal peridot only very rarely is that the preferred cutting style for this gemstone is faceting rather than cabochon.

A long-time friend of GIA recently gave the Los Angeles laboratory the opportunity to examine the very interesting 15.73-ct cat's-eye peridot illustrated in figure 9. Even to the unaided eye, it was readily evident that this oval cabochon is filled with small dark brown inclusions, so much so that the overall body color of the gem is affected. Examination with the microscope revealed that these inclusions are ultra-thin and vary greatly in size and shape; some are rectangular, while others exhibit dendritic formations. John Koivula suggested that

they are most probably an iron compound closely related to ilmenite ($\text{Fe}^{+2}\text{TiO}_3$). The dendritic appearance of many of these inclusions is characteristic of both rapid crystallization and an exsolution product. Their orientation in definite crystallographic directions gives rise to the chatoyancy. At certain viewing positions an additional, weaker ray is seen, creating a star with one prominent ray and one vague ray. Oriented exsolution ilmenite together with hematite is also believed to be the cause of asterism in some star beryls. RK

QUARTZITE, Dyed Yellow

At the February 1987 Tucson Gem and Mineral Show, many dealers were offering large quantities of round drilled bead necklaces and earrings as "yellow jade." Because of the general appearance and unnatural color, it was obvious to the unaided eye that this material was not jade, but rather was another material which had been dyed yellow. We obtained representative samples for testing at the Los Angeles laboratory, including the necklace and earrings shown in figure 10.

A spot reading of 1.55 was ob-

Figure 10. These 35-mm-long earrings and 8-mm-diameter beads were originally sold as yellow jadeite but proved to be dyed yellow quartzite.



tained for the beads, and an aggregate reaction was observed with the polariscope. The material fluoresced a moderate dull chalky yellowish orange to long-wave ultraviolet radiation and a weak dull reddish orange to short-wave U.V. The specific gravity was estimated with heavy liquids to be approximately 2.65. Examination of the visible-light absorption spectrum with a "hand-held" type of spectroscope unit revealed a very dark general absorption in the violet and blue regions that gradually tapered off at around 490 nm, and dark absorption in the far red (680–700 nm). No distinct lines or bands were observed. Microscopic examination revealed a typical quartzite structure, which in part consists of a fine network of small thin fractures. Although no dye concentrations were observed in the fractures, rubbing the piece with an acetone-soaked cotton swab produced a distinct yellow stain on the cotton which proved that the material was indeed dyed.

On the basis of these findings, the material was determined to be dyed quartzite. It had apparently been misrepresented to the Tucson dealers, another example of the jeweler-gemologist's "need to know."

RK

SAPPHIRE

A Synthetic Blue Sapphire

The blue oval cut shown in figure 11, which was submitted to the New York lab for identification, is interesting for a number of reasons. The stone has an extremely deep pavilion and a shallow crown, with a total depth-to-width ratio of approximately 115%—so that it is actually deeper than it is wide. In addition, to the unaided eye it appears to be free of inclusions and has a pleasant light blue color. These facts suggested that the stone might be an old, "native cut," unheated Ceylon sapphire. However, careful examination with the microscope revealed a shadow of curved color banding near the culet and suspicious stress cracks on some



Figure 11. This 8.70 × 7.30-mm stone was determined to be a Verneuil flame-fusion synthetic sapphire.

facets. The strong chalky blue fluorescence to short-wave U.V. radiation suggests that the stone either was subjected to extreme heat in treatment or is of synthetic origin. The curved color banding together with the Plato test positively identified it as a Verneuil flame-fusion synthetic sapphire.

The stone is also an excellent example of how a very small color zone can produce a pleasant face-up color. Notice in the side view (figure 12) that the top of the stone is colorless; the small blue area near the culet, visible at this angle, is virtually the entire extent of color. Blue synthetic sapphire boules often have color only in a thin layer near the surface. Figure 12 also shows the extreme depth-to-width ratio of this stone.

Clayton W. Welch

Synthetic Yellow Sapphire

The visibility of curved color banding or striation in Verneuil flame-fusion synthetic corundum is, in general, directly related to the depth of color in the stone. Dark-colored synthetic sapphires are more apt to show color banding than light-colored (e.g., yellow) ones. Consequently, the color striations in change-of-color synthetic sapphires are usually very prominent and sometimes even eye visible. The curved striae in synthetic rubies and curved bands in blue sapphires can



Figure 12. The concentration of color in the culet area of the synthetic sapphire shown in figure 11 lends the color to the entire stone when seen face up. Note also the unusual depth-to-width ratio of this stone.

almost always be seen with the microscope, although not always easily. Yellow synthetic sapphires, however, often have no detectable banding and the Plato test is sometimes needed to separate them from "clean" natural sapphires.

The New York laboratory recently examined an unusual 15.54-ct synthetic yellow sapphire in which curved color banding was readily eye visible in both diffuse transmitted light and ordinary overhead illumination (figure 13). This vivid color

Figure 13. The curved striae in this 15.54-ct yellow flame-fusion synthetic sapphire are unusually apparent.



zoning was probably caused by accidental fluctuations in the concentration of the coloring dopant during the growth of the boule.

Clayton W. Welch

Unusual Inclusions in Heat-Treated Blue Sapphire

The New York laboratory recently examined an unusual 3.05-ct blue sapphire. The presence of discoid fractures was a very good indication that this natural sapphire had been heat treated. However, the stone also contained some misty or cloudy areas that we have not observed before in sapphire. Figure 14, taken at 45 \times , shows these inclusions well. We have no explanation as to their cause. RC

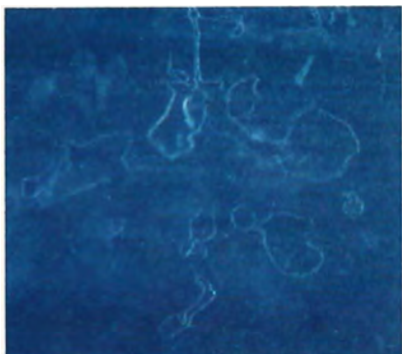


Figure 14. The Gem Trade Laboratory had never before encountered misty irregular inclusions such as those seen here in a 3.05-ct heat-treated sapphire. Magnified 45 \times .

SAPPHIRINE, A Rare Gemstone

The 0.34-ct oval mixed cut illustrated in figure 15 was recently sent to the Los Angeles laboratory for identification. When viewed with the unaided eye using overhead illumination, the stone appeared opaque and black. However, when examined in transmitted or diffused illumination, the stone was revealed to be transparent and brown-green. Testing with a refractometer and a mono-



Figure 15. The extremely dark brown-green color of this 0.34-ct sapphire makes this example of a rare gem material even more unusual.

chromatic filter light source revealed that the stone is biaxial negative with refractive index values of 1.711 and 1.718, and a corresponding birefringence of 0.007. Examination with a "hand-held" type of spectroscope unit revealed no absorption lines or bands.

The specific gravity of this stone was determined to be approximately

3.50 by comparing its sinking rate in methylene iodide (3.32 S.G.) to that of a diamond (3.52 S.G.). The stone was inert to long- and short-wave ultraviolet radiation. Strong pleochroic colors of dark bluish green, medium yellowish green, and medium orangy brown were observed with the dichroscope. Microscopic examination revealed several parallel needle-like growth tubes partially filled with a mineral substance (figure 16). These properties all indicated that this unusual stone is sapphire, a mineral that is only rarely encountered as a cut gemstone. X-ray powder diffraction analysis confirmed the identification.

Sapphire, which has the chemical formula $(Mg,Al)_8(Al,Si)_6O_{20}$, occurs in the monoclinic crystal system, and possesses a hardness of 7 $\frac{1}{2}$. Sapphire crystals are usually small and tabular and are disseminated in a rock matrix; only extremely rarely are they encountered in gem quality. Sapphire derived its name from its usual resemblance in color to blue

Figure 16. Parallel growth tubes can be seen in the sapphire shown in figure 15 at 30 \times magnification.

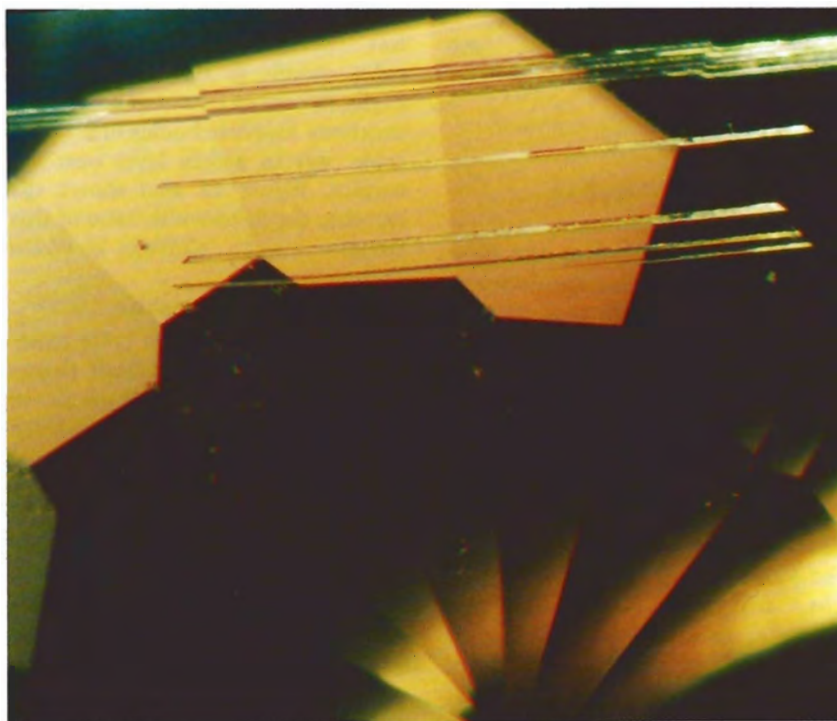




Figure 17. The intense blue color of these sapphirines is often considered the typical color for this rarely encountered gemstone (faceted stone weighs 1.01 ct).

sapphire; however, the two minerals have completely different chemical, optical, and physical properties. Although we have only seen six or seven faceted gem-quality sapphirines in the laboratories, the "normal" color is a deep blue (see figure 17). We did encounter two sapphirines of a purplish pink and a pink-purple color, one of which was described and illustrated in the Fall 1985 issue of *Gems & Gemology* (pp. 156–157).

The sapphirine described here and illustrated in figure 15 is the first brown-green one we have encountered. Our client reported that this stone was found at the ruby deposits in Bo Rai, Thailand. RK

SERPENTINE, Dyed Yellow and Reddish Orange

Also at the February 1987 Tucson Gem and Mineral Show, dealers from Beijing were displaying and selling various gems and minerals from China, as well as gems, carvings, and jewelry made of materials from other geographic localities but fashioned in the People's Republic of China.

Among the many attractive and interesting objects displayed were carved and pierced 25-mm round beads of dyed serpentine. We purchased a few beads for testing at the Los Angeles laboratory.

To determine the depth of the dye penetration and for further testing, we cut one bead in half and polished a flat surface (see figure 18).

Figure 18. Dyed serpentine bead cut in half. The left side shows shallow dye penetration, while the right side shows the carved surface.



A 1.565 refractive index reading was obtained on the flat surface, and a vague spot reading of 1.56 was observed for the carved portion of the bead. Exposure of the undyed portion to long-wave ultraviolet radiation revealed a moderate dull gray-green fluorescence; to short-wave U.V. radiation this portion fluoresced a weak dull purplish red. Exposure of the dyed areas to long-wave ultraviolet radiation revealed a variable, strong chalky yellow to moderate orange-red fluorescence; to short-wave U.V., these areas fluoresced a patchy weak orange-red. When we examined the visible-light spectrum with a "hand-held" type of spectroscopy unit, we observed no absorption lines or bands. Dye was easily removed from the bead when it was gently rubbed with an acetone-soaked cotton swab. Using hardness points, we estimated the hardness to be approximately 4¹/₂ on the Mohs scale. RK

TOPAZ, Bicolor

The Los Angeles laboratory recently received for identification the attractive 7.08-ct bicolored (purplish pink and orangy yellow) pear-shaped modified brilliant shown in figure 19. Subsequent testing revealed that the



Figure 19. This 7.08-ct topaz is an excellent example of a true bicolor.

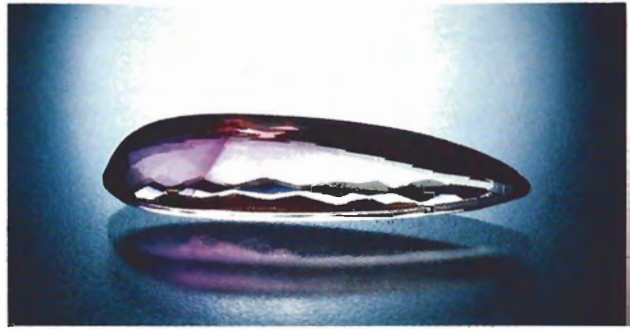


Figure 20. A sharp line separates the color zones in the bicolored topaz seen in figure 19.

stone is topaz. Two distinct colors are often seen in some topaz, particularly "imperial," which generally is the result of strong pleochroism and the orientation in cutting. The stone that we examined is a fine example of a true bicolor topaz. A sharp line of demarcation with a twinning plane divides the purplish pink and the orangy yellow zones (see figure 20).

Both colored portions of the stone had refractive indices of 1.630 and 1.639. Exposure to long-wave ultraviolet radiation revealed a weak red fluorescence for the pink portion and a moderate red for the orangy yellow section. Exposure to short-

wave ultraviolet radiation showed a weak chalky green fluorescence for the orangy yellow portion, but the pink area was inert. These different fluorescence reactions are as expected for the two different colors of topaz. When the stone was examined with a "hand-held" type of spectroscope, no bands or lines were observed in either portion; however, both the purplish pink and the orangy yellow areas exhibited a vague absorption in the far red end of the visible spectrum (around 700 nm). Microscopic examination revealed inclusions typical of topaz (two-phase inclusions, small crystals, an-

gular and straight growth features), although the orangy yellow portion was more included than the purplish pink section. RK

FIGURE CREDITS

Figure 1 was taken by Chuck Fryer; David Hargett is responsible for figures 2-6; Scott Briggs took figure 7. The photo used in figure 8 was supplied by John Koivula. Figures 9, 10, and 18 are © Tino Hammid. Figures 11-14 are the work of Clayton Welch. Shane McClure produced figures 15, 17, 19, and 20. The photomicrograph in figure 16 is by Robert E. Kane.

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Editorial Forum

WANT TO BUY A "HOT DIAMOND"?

The stone in figure 1 was brought to me by a lady who complained that the ring in which it was mounted caused her finger to turn red and break out. The stone had been sold to her as a 6.60-ct "black diamond," but it is readily apparent on sight to a gemologist that this stone is not a diamond. Since the mounting was of iridium-platinum, which is not known to cause hypo-allergenic reactions, I focused on the gemstone for further testing.

The stone was removed from its mounting and was found to weigh more than the 6.60 ct reported to its owner. A specific gravity of 5.272 was determined hydrostatically. The stone is opaque, metallic in luster, and revealed a refractive index over the 1.81 limit of the refractometer. With the owner's permission, I performed hardness and streak tests that eliminated all the high-S.G. (over 5.2) materials usually cut as gems, such as hematite, zincite, scheelite, and cassiterite.

Testing was then done with a Geiger counter, which showed a remarkably high 500 counts per minute at a distance of 5 cm! Shielding with 0.0012 in. of aluminum foil reduced the counts only to 490 cpm, which indicates the radiation was primarily gamma. Exposure to dental X-ray film for 48 hours produced the result in figure 2.

The specimen was forwarded to GIA Research for

Figure 1. A radioactive $11.58 \times 8.51 \times 4.39$ -mm stone, sold as a "black diamond." Photo by Robert Weldon.

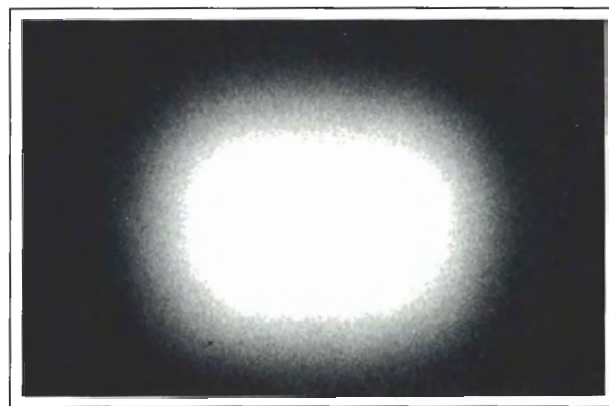
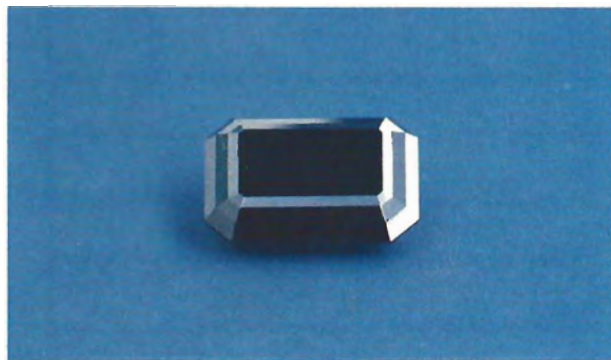


Figure 2. Exposure of the stone in figure 1 to dental X-ray film for 48 hours illustrates its radioactivity.

further study. X-ray diffraction analysis performed by Chuck Fryer revealed a completely amorphous structure, probably caused by radioactive decomposition. Using Pregl-Feigl spot test chemical analysis, I then confirmed that the material contains a high concentration of uranium; it strongly resembles pitchblende from Great Bear Lake, Canada.

The wearer has relinquished ownership of her "black diamond" rather than display it from a lead container to avoid further radiation burns. This instance may go to prove that some faceters will probably facet *anything*.

John Fuhrbach, G.G., F.G.A.
JONZ
Amarillo, Texas

15 × MEANS 15 TIMES AS LARGE

The recently published *Photoatlas of Inclusions in Gemstones*, by E. J. Gübelin and J. I. Koivula, as well as the contributions of authors to this journal, have elevated photomicrography to an art form. Unfortunately, in the process, science has suffered a setback.

"It is highly important to keep careful records of the magnification of photomicrographs. With such records, the actual size of any article shown in a picture may be determined with some degree of precision by measuring

the image with a millimeter scale. Two photomicrographs of different magnification can then be compared intelligently." (C. P. Shilaber, *Photomicrography in Theory and Practice*, John Wiley & Sons, New York, 1944.)

For a number of years, this journal has published photomicrographs which are both confusing and misleading. A representative example (Winter 1986, p. 239) shows an 8-mm bead with the caption stating "Magnified 15 \times ." If this were correct, the image of that bead should have a diameter of 120 mm. Instead, it is only 39 mm. Clearly, this object is magnified less than 5 \times .

Possibly, the explanation appears in the introductory portion of the *Photoatlas*: "The indication of magnification (e.g., 25 \times) signifies the original enlargement on the film of the object calculated from the optical elements (objective, ocular and camera distance)." This value is known as "camera magnification."

Camera magnification is a useful bit of information for the person who actually holds the film. However, it is absolutely meaningless for one viewing a printed image which has been enlarged, reduced, or cropped to an undefined degree. Since this is the position of readers, it is imperative that authors consider these factors and calculate the appropriate adjustment in magnification.

I would submit: No notation of magnification should ever appear in a photo caption in this journal unless it represents the true magnification of the printed image relative to the original object.

W. W. Hanneman, Ph.D.
Castro Valley, CA

IN REPLY

The purpose of printing photomicrographs in professional gemological publications is to convey useful information to the reader. Most gemologists are already familiar with the standard 35-mm format film used in photomicrography. So, when a caption states that a photomicrograph was taken at "45 \times ," it means that the subject was enlarged by a factor of 45 times on the film. The film size then serves as a ready mental point of reference and gives the gemologist a mindset on the size of the subject, regardless of how the publisher enlarges, crops, or otherwise plays with the final display of that image in the journal. More importantly, when we say 45 \times , we immediately let the jeweler-gemologist know that this subject would be easily resolved using a standard gemological microscope with an upper magnification limit of 45 \times or greater. With Dr. Hanneman's approach, however, if the slide was cropped by the editor and then enlarged by a factor of 10 to fill the planned space, we would have to put a final magnification of 450 \times on the photograph. Since no stereo zoom gemological microscope even approaches this range of magnification, a 450 \times factor would suggest to readers that this subject would not be visible to them when using their own microscope. Even if, say, the editor enlarged a

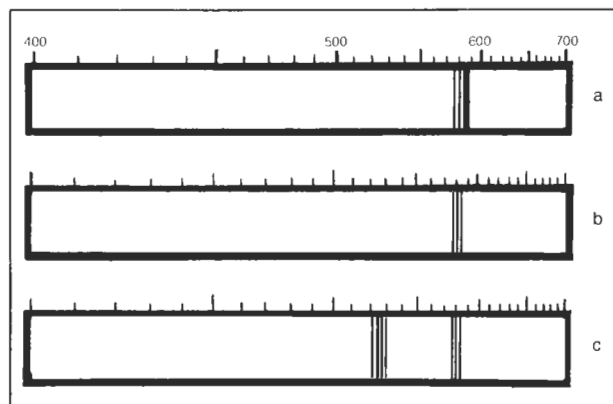
10 \times photomicrograph only three times, the use of 30 \times in the figure caption would imply that this is the image the reader would see at 30 \times magnification, which is not true. All the editor has done is increase the size of the image without gaining or increasing detail. In reality, the scene could be significantly different, with the item in question totally distorted.

The Shilaber quote mentions that microscopic images are commonly measured in millimeters (or micrometers). The fields in which this is done, such as in the biological sciences and petrology, use highly sophisticated "research" microscopes with specially built attachments and accessories for conveniently obtaining precise measurements. Such accessories are not readily available for any of the gemological microscopes manufactured today. From my own experience in the use of precise measuring devices in petrology and chemical microscopy, I can understand some of Dr. Hanneman's arguments. But each of the sciences has its own set of standard practices, and these may or may not apply to others. It is true that we could place a standard scale bar of a specified length in each photomicrograph as is done in some of the other sciences. However, gemology is more than just a science, it is also an art. As gemologists, we deal with beauty on a daily basis; it is perhaps the greatest appeal of our profession. And as long as there is no significant problem generated by the method of magnification designation as it is currently practiced in virtually all publications in the field, this writer sees no reason to detract from the artistic quality of the image by incorporating a size scale.

John I. Koivula, Contributing Editor
Gems & Gemology

ERRATUM

The article "Colombage-Ara Scheelite" (*Gems & Gemology*, Fall 1986) contains an error that was brought to our attention by Mr. Raymond Giroux of Dollard des Ormeaux, Quebec, Canada. In figure 2 (p. 168) the 500-nm and 600-nm markers were incorrectly placed. The figure should appear as below.



THE DIAMOND YEARBOOK 1986-1987

By Jean-François Moyersoén, 120 pp.,
illus., publ. by UBIGE S.P.R.L.,
Brussels, 1987. US\$99.00*

This resource text covers diamond's performance as an investment commodity over the last 18 years. It depicts the rise, fall, and incipient rise again of diamond prices, and provides abundant reference material on diamond sources worldwide. Chapters also cover buying graded diamonds, the demographics of demand, auctions, and (in a particularly enlightening presentation) De Beers.

Moyersoén has produced a nicely organized book. The pertinent items from the table of contents are repeated at the front of each chapter along with a fully titled list of illustrations. The author is straightforward in conveying his points with a minimum of text and a lavish number of charts and color graphs. Conclusions, where warranted, are clearly stated at the end of each chapter. The beautiful illustrations help speed the reader's progress through the book's 120 pages. High-quality paper and printing help to justify the \$99.00 price.

For all of these good points, there are also some problematic areas. Minor semantic faults include editing errors such as "unvaluable" and "a serious unbalance," etc. More serious (and potentially misleading) errors of fact occur as the author describes GIA diamond grading, and the following corrections should be noted. First, clarity is judged with a 10× corrected magnifier—not necessarily a loupe (p. 12). Second, while "loupe-clean" is the top clarity grade in some European systems and "flawless" is GIA's top grade, the two should not be equated. Third, the VS clarity grades stand for *very slightly included*—not "very small inclusions" (size is not the only issue!). Fourth, on page 13, the term *brilliance* is badly misdefined to include dispersion (the GIA definition comes closest to the European term *life* but is restricted to *white* light). Fifth, Moyersoén has also misstated the

BOOK REVIEWS

Elise B. Misiorowski, Editor

GIA Gem Trade Laboratories' rounding procedure, rounding upward when the third decimal is a 9 has been the rule for a number of years. Last, GIA's plotting symbols were revised as part of the 1986 changes in the diamond program; they should be printed in color to make them understandable.

Moyersoén also cites a possible trend to price 0.99-ct diamonds at just 1% less than 1.00-ct stones (and so on); this *seems* logical to the uninitiated, but almost all diamond experts would dismiss it as wishful thinking. Finally, the several cartoons could be funnier and the three or four advertisements should be removed in the next edition.

Despite these factors, *The Diamond Yearbook* is loaded with interesting facts and beautiful graphic depictions. It is a useful, current addition to the jewelry literature.

JAMES R. LUCEY, G.G.
Manager of Education Projects
GIA, Santa Monica

GARNET

By John D. Rouse, Edited by Peter G. Read, 134 pp., illus., publ. by Butterworth and Co., 1986. US\$29.95*

Garnet is, at best, a difficult gem to categorize. Even after years of research and discussion, gemologists and mineralogists continue to disagree about nomenclature and classification of the several members of the garnet group. In *Garnet*, from the Butterworth series on gems, Rouse endeavors to unravel the myriad of tangled references to garnet made throughout history and to make sense of the chemical variations that separate one garnet from another. Unfortunately, although Rouse begins by promising us a gemological

detective story, the story bogs down in a mire of clues and Rouse leaves the reader wondering whether garnets are heroes or villains in the world of gemstones.

In chapter one, the author examines garnets in their historical context, beginning with ancient writings. Although Rouse has obviously studied gem history extensively, the chapter tends to be confusing. For example, the use of ancient place names no longer found in modern atlases causes the reader to wonder just where all this mining, fashioning, and trading actually took place. A great deal of attention is devoted to the derivation of the words used to describe garnet, yet there is no mention of the amuletic and mystical properties attributed to garnets. With the fall of Rome, the history of garnet seems to falter; only eight paragraphs describe the time period between the end of the Roman Empire and the 18th century. "The magic is gone, and the charm is lost," the author writes of the dawn of mineralogy—without having imparted either the magic or the charm to the reader.

The second chapter gives a technical overview of garnets: their chemical composition, crystallography, general properties, and color. Some of the difficulties of garnet classification are also discussed. This is followed by six chapters on the individual gem garnet species: pyrope, almandite, the intermediate categories (such as rhodolite and malaya), spessartite, grossular, and andradite and the rare garnets.

Each of these chapters contains a short section on the history and nomenclature of the particular species, a description of its usual colors, its chemical, optical, and physical properties, and its inclusions. Common sizes, prices, and phenomena are touched on as well. The properties are summarized at the end of each chapter, and there are lengthy bibliographies. However, although a great deal of information is presented, the material is organized differently in each of the chapters and is thus difficult to locate readily.

Thirty-one attractive color

plates illustrate the beauty of garnets and their identifying inclusions. There are also numerous tables, graphs, maps, and other black-and-white illustrations.

The Butterworth series fills a definite need in the gemological literature by providing individual gem

compendiums for reference. Rouse has done a heroic job of sifting through the garnet literature, but, although he quotes exhaustively from published works, he does not synthesize his research into a usable whole. He also seems unclear about his audience: A beginner will be put

off by the technical, formal presentation; a gemologist, looking for fast, practical information during the course of gemstone testing, will find other references more useful.

SHARON E. THOMPSON, G.G.
Editor, Colored Stone Magazine

CONGRATULATIONS!

The following readers received a perfect score (100%) on the first annual *Gems & Gemology* Challenge, which appeared in the Spring 1987 issue:

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Answers to the *Gems & Gemology* Challenge (see pp. 50 and 51 of the Spring 1987 issue for the questions) are as follows: (1) A, (2) A, (3) C, (4) D, (5) C, (6) C, (7) D, (8) C, (9) B, (10) D, (11) C, (12) B, (13) B, (14) B, (15) D, (16) B, (17) B, (18) B, (19) B, (20) D, (21) B, (22) B, (23) A, (24) D, (25) C.

The response to the Challenge was excellent, and literally hundreds received a passing grade on the exam. For those of you who were reluctant to try this time (and those who did), we will offer another opportunity (covering the 1987 issues) in the Spring 1988 issue.

GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

The amethyst-citrine dichromatism in quartz and its origin V. S. Balitsky and O. V. Balitskaya, *Physics and Chemistry of Minerals*, Vol. 13, 1986, pp. 415–421.

The occurrence of bicolored amethyst-citrine quartz crystals, both natural and synthetic, is discussed as a function of growth conditions. For synthetic quartz grown on rhombohedral seeds, this dichromatism is shown to be related to the growth rates of the major and

minor rhombohedral faces. This result is extended to natural quartz, which also grows on rhombohedral faces. Different thermal stabilities were found for various growth solutions; these are thought to arise from different charge compensators in the potential amethyst color centers. EF

The influence of chemical composition on the ω index of refraction of apatite. E. J. Young, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 12, December 1986, pp. 529–540.

The omega refractive index of apatite is influenced by the presence of minor impurities. Starting with the omega index of pure fluorapatite (1.6325), and drawing from 14 recently published chemical analyses of apatites, the author statistically determined how the presence of certain minor impurities (Cl, Fe, Mn, Ba, H₂O, CO₂, and rare-earth elements) either raises or lowers this value. The presence of all of these impurities except CO₂ was found to raise the value of the omega index, with water having the greatest relative effect. JES

Ion-microprobe analyses of Li and B in topaz from different environments. R. L. Hervig, W. T. Korte-meier, and D. M. Burt, *American Mineralogist*, Vol. 72, No. 3/4, 1987, pp. 392–396.

This section is designed to provide as complete a record as practical of the recent literature on gems and gemology. Articles are selected for abstracting solely at the discretion of the section editor and her reviewers, and space limitations may require that we include only those articles that we feel will be of greatest interest to our readership.

Inquiries for reprints of articles abstracted must be addressed to the author or publisher of the original material.

The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names. Opinions expressed in an abstract belong to the abstracter and in no way reflect the position of Gems & Gemology or GIA.

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Topaz can form in different geologic environments as an accessory mineral. This article presents ion microprobe analyses for lithium and boron, two light elements that can occur in trace amounts in topaz. The authors analyzed topaz samples from volcanic rhyolites, igneous pegmatites, hydrothermal greisens (fluorine-bearing granitic rocks), and other topaz-bearing igneous and metamorphic rocks. On the basis of these analyses, they identified a range of four orders of magnitude for lithium contents and three orders of magnitude for boron contents. Both elements are found in higher concentrations in topaz from rhyolites, but in lower amounts in topaz samples from pegmatites and hydrothermal greisens. Such differences in chemistry can be related to conditions of formation, and may be useful as a fingerprinting technique to differentiate environments of formation for topaz. *JES*

Irradiation-induced blue color in topaz. K. Schmetzer, *Naturwissenschaften*, Vol. 74, No. 136, 1987, pp. 136–137.

Blue topaz is routinely produced from colorless material by gamma-cell or electron irradiation followed by annealing, or by neutron irradiation alone. Dr. Schmetzer examined topaz treated by all these methods and identified three absorption features that were observed with polarized light, two along the a-axis (X-centers) and one along the b-axis (Y-center). Irradiated topaz displays one or two of these features according to the type of treatment received: Gamma-cell irradiation produces only one X-center (X_1), electrons generate the X_1 and the Y, and a nuclear reactor gives rise to the two X-centers (X_1 and X_2). The color centers in gamma-cell and electron-irradiated topaz are dependent on trace elements present in the original material; color zoning and saturation of color will follow the distribution and concentration of these elements, referred to as precursors. Topaz treated in a reactor, however, always colors, with the depth of color dependent only on the irradiation dose, and it does not exhibit color zoning. This coloration is caused by the production of phosphorus through the decay of radioactive silicon, a mechanism well-known in semiconductor technology. Trace chemical analyses of treated and natural blue topaz confirmed the correlation of color intensity with phosphorus content. *CMS*

Knowing the gem market. J. C. Zeitner, *Lapidary Reporter*, No. 324, November 1986, pp. 1, 3.

It is important for gem merchants to stay up-to-date in the continually changing colored-stone market. Traveling to gem-producing areas is a good way to learn about the various factors that affect supply and availability. It is also important to attend gem shows where one can compare the price and availability of a variety of gems. The Tucson Show in early February is one of the best. In addition, many books offer excellent information on

gemstones, although magazines and newsletters tend to have the most current information regarding what's new in the trade.

Another way to keep abreast with the colored-stone market is to attend seminars and short courses such as those offered by GIA. Seminars are also frequently offered at major gem shows.

Zeitner further stresses the importance of knowing how to use gemological instruments. Owning and using state-of-the-art equipment helps gem dealers buy intelligently and increase customer confidence.

Barton C. Curren

Microscopic observation of twinning microstructure in natural amethyst. K. Schmetzer, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 1, January 1987, pp. 8–15.

Schmetzer investigated microtwinning in natural amethyst using optical microscopy. For the first time, the orientation of the composition planes at the twin boundaries was directly observed optically in one sample of heat-treated amethyst. The liquid and two-phase inclusions that form the "zebra stripes" are also discussed in detail as they relate to the microtwinning. The article includes eight figures that illustrate various aspects of these features. *EF*

Ein Oktaedrischer Gahnospinell-Rohstein von Ratnapura, Sri Lanka (An octahedral gahnospinel crystal from Ratnapura, Sri Lanka). G. Franzel, V. Stähle, and F. H. Bank, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 35, No. 1/2, 1986, pp. 39–46.

The authors report the chemical and absorption data of a 4.53-ct color-change octahedral gahnospinel crystal from Sri Lanka. The chemical composition was found to be: $(Mg_{3.99} Zn_{3.66} Fe_{0.19} Mn_{0.06} Ni_{0.01} Ca_{0.01})_{7.92} (Al_{16.04} V_{0.01})_{16.05} O_{32}$.

Although the crystal came from an alluvial deposit, diagnostic growth features are still evident on the crystal faces. The absorption spectrum is similar to that of other color-change spinels previously reported, with bands attributed to Cr^{3+} and V^{3+} . Several opaque octahedral inclusions of zinc-iron-aluminum spinel differ in chemistry from the host crystal. *MG*

Ubiquitous quartz. R. W. Jones, *Rocks and Minerals*, Vol. 62, No. 1, 1987, pp. 6–13.

Ubiquitous (existing or being everywhere at the same time) is the perfect adjective to describe quartz. The main reason for the common occurrence of quartz is its ability to form under many conditions, including by secondary action in late-forming sedimentary rocks or by primary action in pegmatites (which are the sources of some of the finest specimens).

Because of the wide range of varieties and sources, quartz is popular with gem and mineral collectors alike.

This article covers the types of twinned crystals usually encountered—Japan-law, Dauphiné-law, and Brazil-law—as well as the many varieties of single-crystal quartz and cryptocrystalline quartz (chalcedony). The author then devotes the greater part of the article to the major sources worldwide for both mineral specimens and gem-quality rough—from the magnificent amethyst scepters on white quartz found in the Denny Mountain region of Washington State, to cave-sized cavities lined with amethyst in Brazil.

Easy and light reading, this article is a good review for the quartz enthusiast. *David LeRose*

DIAMONDS

Cutting on 47th street: Higher prices bring recovery. R. Shor, *Jewelers' Circular-Keystone*, Vol. 167, No. 12, December 1986, pp. 104–106.

In 1979, during the height of the gem investment boom, 1700 diamond cutters worked on New York's 47th Street. During the first half of the 1980s, though, the New York cutting industry was almost destroyed when the price of better-quality polished diamonds fell below what the Central Selling Organization was charging for comparable rough. As a result, by 1983 only 150 cutters were actively working on 47th Street. In 1986, however, the price of larger pieces of high-quality rough, the mainstay of the New York cutting industry, increased by about 30%, partially due to the lower U.S. dollar exchange rate vis-à-vis Japanese and European currencies. This, combined with the increased demand for larger, high-quality stones, has brought the New York cutting industry back to life: Approximately 600 cutters are now actively working on 47th Street, and output has tripled since 1982.

There still are problems on 47th Street, however. The C.S.O. has been keeping tight allocations on high-quality goods, and there are many complaints that desirable rough is becoming scarce. Adding to this problem, Israeli cutters are now buying larger, high-quality stones as well as the melee with which they have been associated. Some Israelis have been offering sight-holders a 10% to 15% premium for their parcels of rough.

Nevertheless, most of the New York cutters are optimistic about the future of the 47th Street cutting industry. The declining U.S. dollar has made diamonds an attractive purchase. Also, price increases to consumers have helped keep the industry afloat.

It is unlikely, though, that the number of diamond cutters will ever reach 1979 levels again. It takes approximately 16 weeks to complete an apprenticeship and, unless the prospective cutter has family in the business, the apprenticeship will cost him \$5,000 to \$20,000. Many shops will not bother to train new cutters because apprentices tend to break stones and slow productivity. Although the average cutter makes be-

tween \$30,000 and \$50,000 a year, new cutters generally cannot expect to reach this level for several years, because they are usually slow and they are paid by the piece. *Barton C. Curren*

Diamonds are forever? I. P. Wright and M. M. Grady, *Nature*, Vol. 326, No. 6115, 1987, pp. 739–740.

Wright and Grady describe the occurrences of diamonds in meteorites and discuss the controversy concerning their formation, that is, whether they were shock-produced or are the result of high static pressure in the large extraterrestrial bodies in which the meteorites formed. Information provided at a recent conference suggests a new theory: Several isotopic arguments favor an origin very similar to chemical vapor deposition (CVD), which is used today to produce diamond thin films and coatings. *EF*

Diamonds find new settings. G. Graff, *High Technology*, Vol. 7, No. 4, 1987, pp. 44–47.

Gordon Graff presents an update on diamond-coating research in the U.S. Many laboratories are exploring diverse and less expensive ways to build thin films of diamond on various substrates, especially using chemical vapor deposition (CVD). A group of research labs has already drawn several industrial companies into a consortium that helps finance the work. Their aim is to catch up with both the Russians and, most importantly, the Japanese, who are already producing diamond coatings for Sony that are used in loudspeaker tweeters.

Many key applications are reviewed, including cutting tools, protective coatings, diamond semiconductors, and high-density chips that might ultimately lead to faster, smaller circuits. *EF*

Spectroscopic studies of the H1b and H1c absorption lines in irradiated, annealed type-Ia diamonds. A. T. Collins, G. Davies, and G. S. Woods, *Journal of Physics C: Solid State Physics*, Vol. 19, 1986, pp. 3933–3944.

This article reports on further studies of the H1b and H1c infrared absorption lines in diamond that were recently reported in the gemological literature (Woods and Collins, *Journal of Gemmology*, 1986, Vol. 2, No. 2, pp. 75–82) as being useful for the identification of color enhancement by irradiation and annealing. Experiments were conducted on four irradiated type Ia diamonds, which were annealed progressively from 400°C to 1400°C, and on 15 irradiated and annealed (700°C–1200°C) type Ia diamonds.

The results revealed that H1b and H1c are zero-phonon lines, and that the ratio of H1b to H1c correlates with similar ratios for bands in the visible and infrared spectra that relate to nitrogen structure in the diamond lattice. This suggests that the H1b and H1c lines are nitrogen-related. However, the exact nature of these two lines remains to be established. These bands are impor-

tant gemologically because they appear in the spectra of irradiated and annealed type Ia diamonds at the temperature (approximately 700°C) at which the diagnostic 594.4-nm band is destroyed. Also, they are stable to at least 1400°C, above which temperature the effect on color is generally undesirable. Since the majority of color-enhanced diamonds are type Ia and, once annealed, yellow to brown in color, the characterization of these infrared features is of particular importance to gemologists, even though the technique involved requires sophisticated instrumentation. CMS

"Iron meteorite paragenesis," a new group of mineral inclusions in diamond. S. Arai, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 10, 1986, pp. 463–466.

A zincian chromite inclusion in a diamond from Sierra Leone, first discovered and described by H. O. A. Meyer and F. R. Boyd, is discussed by the author as representing neither the eclogitic nor the peridotitic suites of diamond inclusions. This zincian chromite inclusion is similar in chemistry to the zincian chromite inclusions found in some iron meteorites. Because of this similarity, the author suggests that the zincian chromite in this diamond is representative of a new group of minerals in diamonds and has named this "new" group the "iron meteorite paragenesis." It is proposed that the possible source for the inclusion may have been the early earth's oxygen-bearing molten nickel-iron proto-core.

John I. Koivula

GEM LOCALITIES

The collector's library: Minerals of the United States—update and additions. A. E. Smith, Jr., *Mineralogical Record*, Vol. 18, No. 3, 1987, pp. 211–227.

This article, actually a 16-page list of publications arranged alphabetically by state, is an update to a list that appeared in the January–February 1979 issue of the *Mineralogical Record* (Vol. 10, No. 1).

Maps and, where available, Locality Index have been added to the original categories, which include: State Mineralogy, Area Mineralogy, Mineral Resources, and Collecting Guides. Only statewide maps are listed because, as Mr. Smith points out, "If an attempt was made to list all of the area maps . . . the list would be too voluminous for this publication."

Mr. Smith has included individual books and bulletins as well as magazine articles. Although he states that most of the information for the listing was obtained during the fall of 1985, there are references to articles published in 1986 as well as in early 1987.

Patricia A. S. Gray

Finders keepers. A. Korwin, *Lapidary Journal*, Vol. 41, No. 1, April 1987, pp. 53–56.

The Cowee Valley ruby mines in North Carolina are a rockhoulder's delight, with mineral wealth and acces-

sibility. For a small fee, prospectors are welcome to hunt for sapphire, ruby, peridot, rhodolite and pyrope garnets, rutile, feldspar, moonstone, kyanite, sillimanite, mica, and quartz.

Cowee Valley is the only ruby- and sapphire-bearing district in the country that encourages public prospecting. Basically, there is not enough material to sustain a commercial mining operation. Private land owners are at liberty to sell or rent equipment—some even sell buckets of dirt outright—and are quick to help identify potential specimens.

Many hundreds of stones are found each year in the layers of mud, clay, and gravel. The chance of a reasonable find is good for the careful and diligent collector. And there is always the possibility, however remote, of striking it rich. *Anne Riswold*

Garnet Hill, White Pine County, Nevada. C. L. Hollabaugh and V. L. Purcell, *Mineralogical Record*, Vol. 18, No. 3, 1987, pp. 195–198.

Almandine-spessartine garnets occur as well-formed trapezohedral crystals at Garnet Hill, White Pine County, Nevada. This locality has been known for these crystals since the early years of this century. The garnets are deep red and average 4 mm in diameter, although crystals as large as 15 mm across have been collected. Some of these are even gem quality. The garnets are usually found in cavities (either lithophysae—which are hollow, bubble-like structures composed of concentric shells of host materials—or vesicles), but they may also occur as phenocrysts, in a gray or pink banded rhyolite. The crystals are believed to have been deposited by vapor-phase crystallization from gasses released during cooling of the rhyolite lava, or, in the case of the phenocrysts, by crystallization in the rhyolite magma. They were later brought to the surface with the magma as it erupted. *JES*

Mingora emerald deposits (Pakistan): Suture-associated gem mineralization. A. H. Kazmi, R. D. Lawrence, J. Anwar, L. W. Snee, and S. Hussain, *Economic Geology*, Vol. 81, 1986, pp. 2022–2028.

The Swat valley, in northern Pakistan, has produced emeralds for some 20 years. The emeralds come from deposits spread over an area of about 180 acres near the town of Mingora. This article describes the geology and occurrence of emeralds at this locality.

The emerald deposits at Mingora are found among a sequence of metamorphosed, schistose rocks. This region represents the collision subduction zone between India and Asia. Within this zone are found metamorphosed and highly deformed rocks of the Indian plate and the intervening oceanic sediments. Emerald mineralization is confined to the Mingora ophiolitic mélange, which consists of talc-dolomite schists. The emeralds are nonpegmatitic and are commonly associated with faults, fractures, and limonite, calcite, or

quartz veins within the schist. The emeralds are deep green in color with relatively high refractive-index (1.588–1.596) and specific-gravity (2.75–2.78) values. Emerald mineralization is structurally controlled and occurred during the shearing and late-stage alteration of the ophiolitic mélange. *JES*

INSTRUMENTS AND TECHNIQUES

Untersuchung radioaktiver Edelsteine und Mineralien (Investigation of radioactive gemstones and minerals). H. J. Mullenmeister, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 35, No. 1/2, 1986, pp. 59–63.

The author proposes a test to identify such radioactive gemstones as zircon and ekanite, as well as to separate them from uncommon minerals such as columbite, euxenite, gadolinite, monazite, and thorite, by measuring the β and γ radioactivity of each species. Two tables give impulse/minute values for various colors of ekanite and zircon. However, the author does not indicate how the results were normalized to the size (carat weight) of the stone, nor does he state how many samples of each type were tested. Further, the possibility remains that the use of a Geiger counter alone could lead to the mistaken identification of a host spinel or sapphire as zircon if an included zircon were strongly radioactive. *MG*

JEWELRY ARTS

Getting into die striking. A. Bratt, *American Jewelry Manufacturer*, Vol. 34, No. 7, July 1986, pp. 22–30.

This knowledgeable author examines the pros and cons of a jewelry manufacturer investing in a die-striking operation. He poses questions from which the manufacturer can, provided he is realistic, form his own conclusions.

Comparing the merits and costs of casting versus die striking requires a sound appraisal of product demand, available capital, and product suitability to the stamping process. Die striking can produce a great product and offer enormous savings in a steady, high-volume market. But because so much of the fashion-jewelry industry involves trends, and time to assess demand is a luxury not generally available, such an investment can be risky. In addition, labor costs in the tooling process may be prohibitively high, although Bratt explains how these costs can be reduced by initially having the tooling made on the outside and then gradually creating and staffing an in-house toolroom.

Overall, the information provided is thorough and well organized. The author compares the various methods available. He also gives examples of jewelry suitable and not so suitable to die striking.

Anne Riswold

New technologies for gold casting. J. P. Nielsen, D. P. Agarwal, and R. Carrano, *American Jewelry Manufacturer*, Vol. 35, No. 2, February 1987, pp. 38–60.

Today's evolving technologies make it possible for jewelry casters to develop new and more intricate designs. Distinguishing between jewelry and industrial casting, the authors present details of new research specifically oriented to the jewelry industry.

The information presented is designed to help the caster and manufacturer who want to design, sprue, and cast a better quality product. Complete with binary phase diagrams and alloy castability charts, and a number of equations, however, this comprehensive but complex article requires knowledge of metallurgy, ceramic science, and mechanics.

For those wishing more specific information on certain aspects of the technologies covered, a suggested reading list is provided. The technical content of this article is definitely aimed at the specialist.

Anne Riswold

JEWELRY RETAILING

Fancy cuts. *National Jeweler*, Vol. 31, No. 9, 1987, pp. 68–72.

From one-of-a-kind works of art that sell in exclusive galleries, to mass-produced simpler shapes, the market for unconventional and unusual cut gems has never been stronger. This article explores the relationship between the "art" cuts and the "standard" fancy cuts, the relative prices of these different cuts, and their place in the market. Gem dealers and designers give their opinions of the fancy, or fantasy, cut market today and where it might be headed tomorrow.

The original free-form cuts of Bernd Munsteiner have unlocked the potential of gemstones as art. Although people are willing to pay more than the actual value of the gem material for these works of art, price does limit the market for original "Munsteiners."

To satisfy customer demand for less expensive fancy cuts, some of the simpler shapes—e.g., half moons, kites, and cabochons—are being cut from commercial-quality materials. Price is a very important factor in the sale of these stones. According to Marsha Lorberfeld of New York, however, noncalibrated cuts will never truly reach a mass market.

Although fancy cuts are usually reserved for less expensive gems, James Breski & Co. of Chicago now offers fancy-cut rubies, sapphires, and emeralds. The firm's Tribrilliant and Quadrilliant cuts are based on triangular and rectangular brilliant-cut diamonds.

David LeRose

Jewelry for men. *Eclat*, No. 14, April 1987, pp. 175–177.

The author examines the trends in men's jewelry reported by several French jewelry houses, and advances some opinions on the question of why more men's

jewelry is not sold. Research has indicated that, at least in the French market, "fear of appearing vulgar, fear of appearing effeminate, and fear of negative reactions from women" contribute to the lack of a strong market for men's jewelry.

Quotes from Jacques Dereux ("The only piece of jewelry a man feels really comfortable with is one he can hide under his shirt, like the gold chain") and survey results such as "jewelry has an inherent feminine connotation harmful to men," characterize the generally negative results of the author's research. However, on the positive side, the author believes that the market potential is very strong. I. B. Goodman produces a successful "high tech" look using steel, titanium, and black chrome, as well as gold and diamonds in some pieces, that appeals to the "taste of power" many men have. New marketing techniques, such as men's "corners" in luxury jewelry shops, offer some possible approaches to increasing the sales of jewelry specifically for men.

Bill Videto

Spotlight on appraisals. J. V. Smith, Ed., *Jewelers' Circular-Keystone*, Vol. 158, No. 4, 1987, pp. 67-126.

This special report, intended to be a compact guide to the appraisal process, is written in six different sections that address various aspects of writing appraisals. The first section examines the appraisal procedures followed by seven retail jewelers. Each jeweler establishes a different fictional setting in which items are submitted for appraisal. Every aspect of the procedure is then described, starting with the reasons for the appraisal and concluding with the appraiser's notes on the methods and sources used for identification and valuation.

In the second section, AGS appraisal specialist Cos Altobelli outlines 18 important points to keep in mind when writing appraisals and dealing with a customer. These tips are offered to help appraisers protect themselves against liability while providing the best service to the customer.

The next two sections look, first, at the need for legislative action regarding appraisals and, following this, at a model law developed for the State of Texas that addresses the licensing of appraisers. Six experts who attended a JCK roundtable on the future of jewelry appraising concluded that there is an immediate need for regulation of appraisers from within the jewelry industry. The model law to license Texas appraisers was developed by Patti Geolat and C. Van Northrup, for the Texas legislature. This law would subject appraisers to penalty under the law for misrepresentation or fraud.

A section regarding watches and clocks follows (in a somewhat awkward placement) the legislative discussions. Antique pocket watches and other timepieces continue to surface, and few jewelers and appraisers understand how to analyze this market. The many price guides available on pocket watches are discussed, and a

list of the various auction houses that may be contacted on this subject is provided.

In the last section, a court case in which an appraiser was sued for issuing a false appraisal and misrepresenting gem values is presented. This section makes very evident the type of damage that can be inflicted on an appraiser when his valuation is questioned. The importance of this section lies with how the accused appraiser valued the stones and what the jury found him to be guilty of. This segment is not only interesting but also relays an important warning to those who appraise—that they may ultimately answer to the courts.

Juli L. Cook

SYNTHETICS AND SIMULANTS

Metallic inclusions in Chatham synthetic corundums.

C. R. Burch, *Journal of Gemmology*, Vol. 20, No. 5, 1987, pp. 267-269.

The author microscopically examined over one thousand carats of rough and 12 faceted flux rubies and sapphires grown by "Chatham Created Gems" of San Francisco, California. The gemological strength of this short article is found in the 12 excellent photomicrographs that vividly depict the varied morphology of the metallic inclusions, which are known to be one of the chief identifying characteristics of this material. Mr. Burch describes the various shapes as triangles, hexagons, thin plates, needles, spicules, daggers, blades, rods, bars, and pyramids. It is speculated that these inclusions are probably platinum metal derived from the growth crucible, although "crucibles composed of rhodium or iridium may sometimes be used for flux growth."

John I. Koivula

Morphologie und Zwillingsbildung bei synthetischen blauen Saphiren von Chatham

(Morphology and twinning of Chatham synthetic blue sapphires). L. Kiefert and K. Schmetzer, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 35, No. 3/4, 1986, pp. 127-138.

The authors used optical microscopy to study 20 Chatham blue sapphire rough crystals (single crystals and crystal clusters) and eight cut stones for morphology and twinning. Crystal forms are described in detail, and compared with those of various synthetic rubies. Sixty-five percent of the crystals examined were found to be twinned; in these crystals, the individuals are always associated along the same composition plane $\{11\bar{2}0\}$. The twin law is a rotation of 60° around the three-fold axis, referred to in this article as a mirror reflection across $\{10\bar{1}0\}$, a morphologically correct description. This particular composition plane seems typical of flux-grown corundum. The authors provide a number of very good sketches, as well as a few suggestions on how to recognize this twinning in a cut stone.

EF

Synthesis of rose-quartz crystal. M. Hosaka, T. Miyata, Y. Shimizu, O. Okuyama, *Journal of Crystal Growth*, Vol. 78, 1986, pp. 561–562.

Semitransparent rose quartz was synthesized using massive rose quartz as a nutrient and titanium in various forms as a dopant. The crystals came out colorless, but turned pink after heat treatment at 1200°C in the presence of iron-containing CaCO₃ powder. Growth conditions, absorption spectra, and chromogen content are provided. EF

On twinning in natural and synthetic flux-grown ruby. K. Schmetzer, *Journal of Gemmology*, Vol. 20, No. 5, 1987, pp. 294–305.

Twinning is a commonly overlooked property of natural and synthetic rubies. Two basic types of contact twins are known: rotation of 60° around the optic axis, and twinning on the rhombohedral planes {10 $\bar{1}$ 1}. The crystallographic nature of planes along which the twinned crystals are associated, as well as their abundance and distribution in the gem, varies with the origin of the stone.

The first type, with parallel optic axes, appears mostly as contact twins on the basal plane in natural rubies, and is observed along prism faces only in synthetic rubies (Chatham and Ramaura). The single contact twin on the rhombohedral face (10 $\bar{1}$ 1) is described only for natural rubies. Repeated twinning along the same plane is common in natural and synthetic (Kashan and Chatham) rubies, forming a variety of patterns. EF

MISCELLANEOUS

Gemmologisches Wissen im christlich geprägten Kulturraum zur Zeit des Früh- und Hochmittelalters (7.–12.Jh.n.Chr.) (Gemological knowledge in the Christian cultural arena at the time of the early and late Middle Ages [700–1200 A.D.]). R. J. Sobott, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 35, No. 3/4, 1986, pp. 139–159.

This article analyzes the development of gemology during the Middle Ages, specifically 700 to 1200 A.D. The gist of the article, however, is that there were few notable advancements in gemology during this time. Even though there was a very definite use of gemstones in jewelry, actual scientific compilation of gemological data was scant during this period.

Instead, knowledge of gemstones was based almost entirely on the writings of ancient Greek and Latin scholars such as Aristotle and Pliny. Rudimentary translations of these works into German often resulted in conflicting information. Furthermore, what accounts we have of gems during this period were usually written by monks and bishops whose fields of interest were religion and the manufacture of religious artifacts, not gemology.

This article provides four excellent color photographs that clearly show the religious use of gems during this period, in crosses, Bible covers, and the like. Sobott supplies ample footnotes and references, for anyone wishing to delve further into this fascinating topic.

Robert Weldon

A photographer's guide to taking mineral specimen photographs for the Mineralogical Record. W. E. Wilson, *Mineralogical Record*, Vol. 18, No. 3, 1987, pp. 229–235.

For serious amateurs as well as seasoned professionals, this article provides basic and useful information regarding mineral specimen photography. It is introspective, giving the reader insight into the "how to" of past *Mineralogical Record* photography. It is also well researched, presenting valuable answers to elusive lighting questions, as well as resolution and focus problems. Even such abstract concepts as aesthetics, specimen selection, and orientation are masterfully covered.

Although the article specifically covers close-up photography of entire specimens, photomicrography is also briefly mentioned. A small but helpful section is dedicated to photo recording and the storage problems of slide libraries. The article concludes with an excellent annotated bibliography. Robert Weldon

World gold projects. D. Hope, *Mining Magazine*, Vol. 155, No. 3, 1986, pp. 184–195.

This article provides an overall view of the major gold developments and expansion programs now under way worldwide. The steady rise in world gold production, the highest since 1971, is attributed in part to the increased demand for jewelry and to the fact that many mining companies traditionally involved with base metals are turning to gold exploration.

Beginning with South Africa, which currently dominates the world market, Ms. Hope describes the mines and projects of each important gold-producing country with regard to output, type of mining, economic considerations, and environmental problems. Although the emphasis is on the greater role that the U.S., Canada, and Australia will be playing in the gold market, there is also fairly detailed information on the potential in the Pacific (Indonesia and New Guinea), on Latin America (Brazil, Colombia, and Venezuela), on a mystery deposit in West Africa, and on the emergence of China as the "dark horse" of world gold supply, with production there expected to increase dramatically before 1990. No mention is made of Russia, probably because of the lack of reliable statistics, but the absence of any reference is odd given the fact that it is possibly the second largest gold producer in the world.

Aside from this glaring omission, this well-researched article is full of facts, figures, and mining information. Anne Riswold

GEM NEWS

DIAMONDS

Largest California diamond found. The largest diamond ever reported from the state of California was recovered by Mr. Ed Clark, a consulting geologist in northern California, on January 4 of this year. The alluvial diamond was observed in pan washings while Mr. Clark was demonstrating the art of gold panning to a friend in Trinity County. The diamond now belongs to Mr. Rudolph W. Kopf, of Grass Valley, California, who brought the stone to GIA's Santa Monica headquarters for examination.

The diamond, although not of gem quality, is impressive both because of its size (14.33 ct, 16.25 × 12.64 × 10.60 mm) and the variety of growth-dissolution features shown on the somewhat rounded surfaces. It has the appearance of a knotted grayish green semi-translucent mass of "bort," with an almost greasy adamantine luster (figure 1). The stone fluoresced a weak brownish yellow to long-wave ultraviolet radiation and a very weak reddish brown to short-wave U.V.

A diamond of this size, which apparently had not



Figure 1. This 14.33-ct rough diamond was found by Mr. Ed Clark in Trinity County, California. Photo by Scott Briggs.

Figure 2. This 1.06-ct alexandrite chrysoberyl from a new locality in Minas Gerais, Brazil, exhibits colors in incandescent (left) and fluorescent (right) illumination that are comparable to those typically seen in the color change of alexandrites from the classic locality in Russia. Courtesy of Simon Watt, Watt Gems, Los Angeles, CA. Photos © Tino Hammid.





Figure 3. The four marble Chinese tiles shown here were originally selected by Chinese artisans for the natural patterns and coloration they displayed. Tiles courtesy of Alan Winston Smith; photo © Tino Hammid.

been transported far from its source, suggests that the area where it was recovered may have economic potential. Further exploration of the region with the hope of finding additional large diamonds, perhaps of gem quality, is a distinct possibility.

COLORED STONES

Brazilian alexandrites. Alexandrite chrysoberyls "with a fabulous color change" have been found in Minas Gerais, Brazil, as reported to Pat Gray, GIA's collection curator, by Mr. John Ramsey, of Ramsey Gem Imports, San Diego, California. Faceted stones as large as 12 ct have been produced. Most of the stones have the color change typical of Brazilian alexandrites—purple to green—but some have an unusual purple to blue change. The mining area is located between Itabira and Venda Nova in the state of Minas Gerais. Mr. Ramsey states that the extent of this alluvial find is not yet known.

Two faceted alexandrites from this locality were subsequently brought to GIA by Simon Watt, of Watt Gems, Los Angeles. Both stones exhibited a color change comparable to that of Russian alexandrite (figure 2).

Large ekanite found. Mr. James D. Smith, a gemologist from Riverton, Illinois, reports that a large uncut

ekanite has been recovered from the alluvial gem deposits in Sri Lanka. Mr. D. F. Jayakody, a gemologist in Ja Ela, Sri Lanka, is presently in possession of the rough 320-ct stone. Although no description of this particular ekanite was provided, all such stones previously found in Sri Lanka are metamict and range in color from green through brown, with large stones tending to be blackish in appearance. The largest rough ekanite reported to date had a stated weight of 351 ct.

Chinese marble tiles. An unusual collection of Chinese picture tiles was recently loaned to us for study by Mr. Alan Winston Smith, a graduate gemologist from Dallas, Texas. At first these unique natural art tiles were thought to be made of nephrite jade, but subsequent nondestructive gemological testing on two randomly selected samples proved them to be marble. Mr. Smith's rectangular to almost square marble tiles average approximately 14 × 10 cm (figure 3). Dr. George E. Bushong, of the Meadows School of Fine Arts at Southern Methodist University in Dallas, advised Mr. Smith that the marble pictures came from Yunnan Province. They were used historically, and are still used today, to decorate gardens, furniture, and walls. The writing is a "mental trigger" rather than a title or message. The tiles

are selected for their natural color and patterns; the result is a series of natural abstract-art pictograms in marble.

"Conch pearl" substitute. What at first appeared to be a "conch pearl," with a flattened football shape, was loaned for examination to Dr. Emmanuel Fritsch in GIA's Research Department by Mr. William Larson of Pala International in Fallbrook, California. The pinkish orange "salmon" colored piece (figure 4), which measures approximately $21 \times 14 \times 11$ mm, was originally part of the Kunz collection, housed at the American Museum of Natural History in New York, and was found prior to 1906. A microscopic examination revealed the distinctive radial structure of coral and none of the features associated with true conch concretions. This substitution of coral for "conch pearl" makes this the first "conch pearl" imitation that GIA has ever encountered.



Figure 4. This "conch pearl" ($21 \times 14 \times 11$ mm) proved to be coral. Courtesy of Pala International. Photo by Scott Briggs.

ANNOUNCEMENTS

Jewelry of the Walters Collection and the Zucker Family Collection is featured in an exhibit titled "Objects of Adornment" that will be on display at the Walters Art Gallery May 21–October 11, 1987. Both collections specialize in historical jewelry and represent the importance of jewelry as a major art form. For more information, contact the Walters Art Gallery, 600 N. Charles St., Baltimore, MD 21201.

The Fashion Institute of Technology presents a symposium on "The Great French Jewelers," to be held Saturday, October 17, 1987, in New York. The program, a series of lectures on the fabulous jewels created by the jewelers of the Place Vendôme, features Alain Boucheron, of Boucheron; Alain Perrin, president of Cartier, International; Jean-Baptiste Chaumet, of Chaumet; and Philippe Arpels, of Van Cleef & Arpels. Other speakers include Ralph Esmerian, collector; Marie-Noel de Gary, conservator of the Musée des Arts Decoratifs; Hans Nadelhoffer, author and president of Christie's, Geneva; and Veronique Ma'Arop, of Van Cleef & Arpels. For information, contact Jean Appleton, Jewelry Design Resource (212) 760-7254.

A proposed classification for gemstone cuts. A tentative outline for a proposed system for the classification of gemstone cuts has been developed by Donald E. Udey and John Sampson White of the National Museum of Natural History (Smithsonian) in Washington, D.C.

After studying the problem of classifying gemstone cuts, they have concluded that the primary grouping for a gemstone cut should be based on the "geometry of the dominant form (or shape) as seen when the gem is viewed normal to the table." The authors realize that although this works well when dealing with common shapes such as triangles, rectangles, squares, and circles, there are still many gemstone cuts, such as free-forms or even simple emerald cuts, that cannot be readily categorized in this simple way. As an example, how much truncation of corners of a simple square step cut or a triangular step cut should be allowed before it is referred to as an octagon or a hexagon?

Now that they have prepared their tentative outline to address this problem, the authors of this "Classification of Gemstone Cuts: A First Attempt" invite any interested individuals or groups to par-

ticipate in the further refinement of their gemstone-cut classification system by contacting them at the Smithsonian.

Kenya Gemstone Dealers Association is formed. The government-licensed gem dealers in Kenya have formed the Kenya Gemstone Dealers Association ("Kengem") to promote the gemstone industry in Kenya and increase Kenyan gemstone exports internationally. Through the media, Kengem will keep local and overseas gem dealers, and associations in different countries, informed of any changes or amendments in government regulations that have an effect on the Kenyan gem trade. Kengem has also discussed with the commissioner of Mines and Geology a number of issues concerning the processing of export documents by various government departments. As a result of these discussions, modified procedures are being introduced to guarantee smooth and expeditious export of Kenyan gem materials.

For further information on Kengem, please contact: Dr. N. R. Barot, Secretary, Kenya Gemstone Dealers Association, P.O. Box 47928, Nairobi, Kenya.