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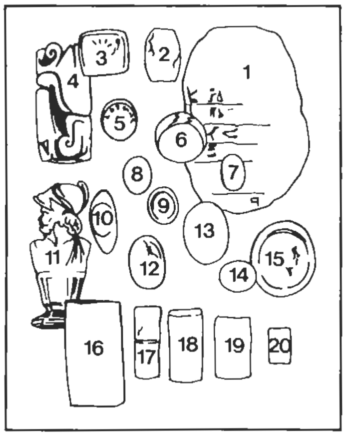

ABOUT THE COVER: Engraved gems are almost as old as civilization itself. Fred Gray provides an introduction to their complex history in this issue. Illustrated on the cover are some of the engraved stones used from as early as 3000 B.C. to as recently as the 19th century: (1) Egyptian scarab of Amenhotep III, 1400 B.C.; (2) Hittite turquoise seal, 1500 B.C.; (3) Gnostic seal with inscription, 4th century A.D.; (4) pre-Columbian clay cylinder seal from Esmeralda, Equador; (5) Sassanid inscribed seal of green jasper, 6th century A.D.; (6) Sassanid inscribed seal of carnelian, 6th century A.D.; (7) lapis lazuli scarab, 1300 B.C.; (8) Phoenician jasper seal, 900 B.C.; (9) Roman carnelian seal with gold band, 1st century A.D.; (10) Roman seal ring, bronze, 1st–3rd century B.C.; (11) Austrian rock-crystal seal, 19th century; (12) sardonyx cameo with bird, Roman, 1st–3rd century A.D.; (13) Roman jasper seal with cupid, 1st–2nd century A.D.; (14) chalcedony seal with cherub, 7th century B.C.; (15) Roman seal ring, gold and carnelian, 1st century A.D.; (16) Sumerian cuneiform tablet, 1500–1200 B.C.; (17) steatite cylinder seal, 3000–2500 B.C.; (18) Assyrian cylinder seal, chalcedony, 200 B.C.; (19) green jasper cylinder seal, 2100–1900 B.C.; (20) Babylonian hematite cylinder seal, 1900–1300 B.C.
The stones are courtesy of Barakat, Rodeo Collection, Beverly Hills, CA.
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ENGRAVED GEMS: A HISTORICAL PERSPECTIVE

By Fred L. Gray

Such innocuous events as the creation of the pre-gummed envelope and the modern postal system contributed to the demise of the engraved gem seal. During the thousands of years that the seal served as man's most important mark of identification, however, gem engraving reigned as one of his most significant art forms. This article traces the history of engraved gems from primitive amulets through cylinder seals, scarabs, scaraboids, and ringstones, to the more recently introduced cameos. Also discussed is the engraving process itself, how to evaluate an engraved gem, and more recent developments in the materials and methods used to engrave gems.

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For virtually thousands of years in the early days of Western civilization, the words *gem* and *engraved gem* were virtually synonymous. The earliest engraved gems evolved from amulets on which gods as well as everyday images such as animals were carved. As these carved charms came to symbolize the owner or wearer as an individual, they developed into seals with which he might mark his property or, as civilization became more sophisticated, he might use as tools in barter and trade. These seals became the personal mark, or "signature," of their owners. As such, they were often worn on the clothing of the bearer, attached to a thong around his wrist or neck or, in later years, mounted in a ring. With time, the ornamental value of the seal began to equal its utilitarian value. Eventually, a form of engraving gems for purely ornamental value emerged—and from the Hellenistic period of ancient Greece to the present, cameos have played an important role in the engraver's art.

The purpose of this article is to provide a historical overview of engraved gems, including an introduction to the different types as well as the techniques and materials used to produce them. Although particular attention is given to the early history of gem engraving, especially the role of seals, we will also take a brief look at the current status of engraved gems and important considerations in their evaluation.

INTAGLIO AND CAMEO

Gem engraving is a miniaturistic art form whereby designs are cut into or on the surface of a gem. The outstanding feature of this type of carving is the small scale of the art: gem engraving is done most often on a surface less than one inch (2.5 cm) in diameter. Also known as glyptic (from the Greek word *glyptos,* meaning carved) art, gem engraving is often distinguished by the great attention to detail accomplished on such a small surface.

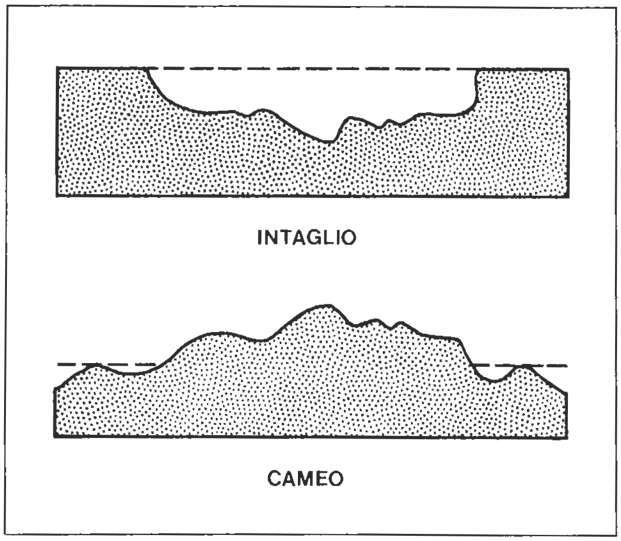


Figure 1. The intaglio (used primarily for seals) and cameo are the oldest forms of engraved gems.

For the most part, engraved gems can be divided into two distinct types: intaglio and cameo (see figure 1). An intaglio is made by grinding away material below the surface of the gem, leaving an inverse image. Detail is achieved by varying the depth of the engraving. A cameo is the opposite of an intaglio: that is, the subject is sculpted above the surface of the gem, appearing in relief on stones usually of two or more different-colored layers. Most cameos utilize several layers of material to increase the definition of the carving. Another type of engraved gem occasionally encountered is the chevet (also called chevee or cuvette), in which a raised figure rests in a background sunk below the surface. Because the chevet is a relatively modern development, it will not be discussed further here.

THE ENGRAVING PROCESS

The earliest gemstone engraving was accomplished simply by drawing a piece of hard stone or metal against a softer material to produce grooves. The results may have been adequate, but the finished pieces lacked subtlety in design and were often very crude. This simple technique was eventually followed by the use of a drill to form crude round depressions. The earliest drill was a simple hand-held device driven by a bow that was moved back and forth (figure 2). The drill shaft was made of wood, to which a small piece of flint was attached as a bit (Sutherland, 1965; King, 1885). The vertical drill, which was very difficult to hold steady, was eventually replaced by a horizontal version, which allowed better control of the work in progress by freeing the hands to manipulate the gem.

Fine-grained rock (serpentine, soapstone, etc.) was often used for the earliest engraved seals because of ease of carving (see cover). We do not know when metal points replaced the stone points on the drill (although King, 1882, suggests that it may have been as early as 2000 B.C.), but we do know that metal points used in conjunction with emery or another hard powder (added as the drill revolved to do the actual abrading) enabled the cutting of harder materials such as jasper and carnelian (again, see cover). Varieties of chalcedony were overwhelmingly favored because of their availability, the predictability of their lapidary behavior, and their great strength, which helped assure the carver that he would not break the piece before he was through (John Sinkankas, personal communication, 1983).

When the early glyptic artists replaced their drill bits of stone with metal tools and cutting wheels, they had essentially the same equipment that engravers use today (Gerhard Becker, personal communication, 1983). For convenience and to increase the speed of the drill, contemporary craftsmen use machine instead of man power. Another modern development is the replacement of emery by far faster-cutting diamond powder.

The actual engraving process is exacting and laborious. Because of the small scale involved, it is one of the most difficult of the sculpting arts. For an intaglio, where the design is to be sunk below the top of the gem, the surface is usually given its final polish at the outset, and the design drawn on that surface. The engraving begins with larger cutting tools: wheels, and ball- and oval-shaped bits. In the later stages, tools as small as the head of a pin are used for the detail work. Lastly, the actual engraving may be polished or textured, depending on the detailing desired (Renton, 1896).

It is interesting to note that magnification is not commonly used during the engraving process. The slurry of polishing compound obscures the carving in progress. The hands and cutting tools also make direct observation of the work difficult. The cutter must rely mainly on the feel of the carving to execute the design. To check his prog-

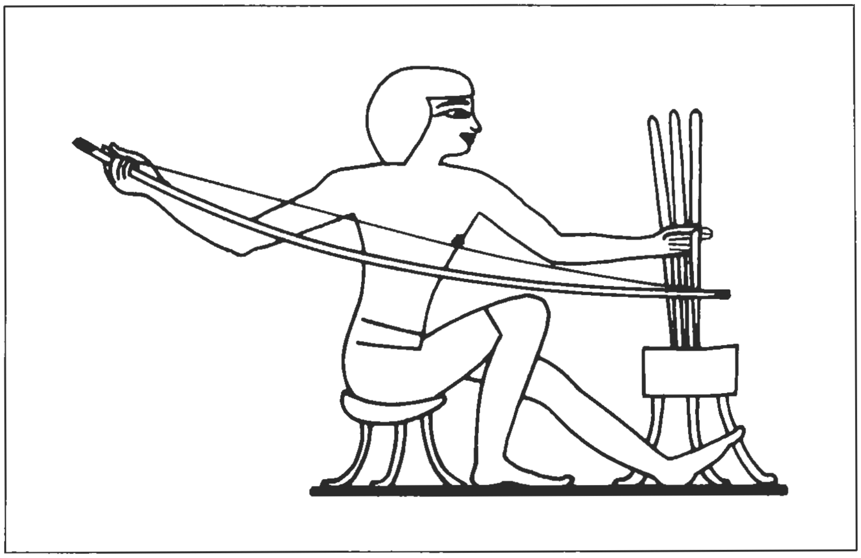


Figure 2. This Egyptian drawing shows an early technique for drilling holes in stone which involved the bow drill. The bow caused the drill bit to revolve, thereby boring a hole into the stone. Modern historians surmise that this same equipment was also probably used to engrave gems.

ress, however, the craftsman constantly presses the stone into clay and examines the design in positive with a loupe. We have little information to suggest that magnification of any form was used by ancient engravers, although a current theory holds that these early craftsmen commonly were myopic, thereby naturally possessing better vision at a close range (Michael Stubin, personal communication, 1982).

THE HISTORY OF ENGRAVED GEMS

The Introduction of the Seal. The history of stone engraving is as old as organized societies, having originated when the first congregations of man developed socially and economically to a point where there was a need for sealing property. Worm-eaten wood pressed into clay was one of the earliest means, as the random pattern of these bits made each seal unique (King, 1885).

The engraving of harder materials specifically to serve as individual seals was the next logical step. An important factor in this progression was that prehistoric man had used and worn crudely carved amulets, decorated with the animals and religous figures so central to his world. As the concept of personal property—and later those of trade, taxes, banking, and the like—required the use of a personal mark, the evolution of these amulets into seals was a natural development (Sutherland, 1965). For convenience, the seals were often worn on the owner's clothing or at the neck or wrist. With time, their function became ornamental—as jewelry—as well as utilitarian and religious. The widespread acceptance of seals is undoubtedly due to the fact that they satisfied so many needs for newly civilized man.

The earliest seals were probably introduced between 6500 and 6000 B.C. in the neolithic cities of Mesopotamia (Sutherland, 1965). These primitive seals are extremely varied in shape and material. Most were made from fired clay, but locally available soft stones were also used. Such seals were shaped into cones, rectangular tablets, bean-like forms, and the like: Vast numbers of these have been found, usually with religious motifs or with simple geometric designs.

Cylinder Seals and Scarabs. The first important group of engraved seals were the cylinder seals (see figure 3 and the cover), which made their appearance in the river valleys of southern Mesopotamia around 3300 B.C. (Wiseman, 1956), or approximately the same time that writing was first employed as a means of communication. Cylinder seals were used to sign documents, to seal goods for barter or tax purposes, and as trademarks on objects such as pottery. Their shapes made them ideally suited for rolling around the openings of jars, bottles, sacks, and other containers to discourage tampering. Locally obtained materials such as hematite, serpentine, jasper, and chalcedony were most commonly used to make cylinder seals, but the highly prized lapis lazuli was occasionally obtained via trade (Wiseman, 1956).

The Egyptians also used the cylinder seal, but they eventually created a seal that was both of greater religious significance and served their needs better: the scarab (figure 4). Whereas the cylinder was ideally suited for sealing large ob-

Figure 3. The cylinder seal represents the first important group of seals used by man. An inverse image was engraved on a cylindrical piece of stone so that it could be rolled out along wet clay, wax, or other impressionable substance to produce a positive image. This Assyrian cylinder seal, made of chalcedony, dates from approximately 2000 B.C. It measures 34 mm long × 17 mm in diameter. Like most cylinder seals, it has a hole going through the middle lengthwise to accommodate a string or thong for wearing by its owner. Photo ©1983 Harold and Erica Van Pelt.

jects, the scarab was more appropriate for stamping paper documents made from the papyrus indigenous to Egypt.

The scarab seal took its convex shape from the scarab beetle, which symbolized the sun god and eternity in ancient Egypt. On the flat bottom side, the artisan engraved hieroglyphic characters which served as the bearer's mark (see the large white stone on the cover). Most early scarab seals were made of soft materials such as faience, a glazed earthenware pottery. In later periods, hard stones such as carnelian, rock crystal, and amethyst were more often employed. According to Ball (1950), Egypt was the world's greatest producer of gems from approximately 3200 to 200 B.C.

The Classical Age: Scaraboid, Ringstone, and Cameo. Seals were produced and used most intensively during the classical period of ancient Greece and Rome (approximately 500 B.C. to 400 A.D.). By this time, the role of engraved stone seals was firmly established; virtually every important culture had adopted them. Although most seals were very rudimentary, not infrequently they were engraved with great technical skill. The classical artisans of Greece and Rome carried engraving (now a distinct profession) to a level higher than ever seen previously. Their designs were imaginative, and their technical skills in working with hard stone equal to the demands of their creativity.

Although the earlier cultures of the Minoans and Mycenaeans knew how to work the harder, more durable materials such as quartz and chalcedony, the destruction of these cultures before 1100 B.C. meant the demise of their technical knowledge as well. It was not until the seventh century B.C. that the Greeks learned from the Phoenicians how to use abrasives on hard stone. From these great "merchants of the Mediterranean" they also acquired the form of the scarab, which the Phoenicians had adopted previously from the Egyptians. To this basic shape they added motifs inspired by both events and figures in their daily lives and by the many colorful legends surrounding the gods they worshipped, making their seals look distinctively Greek.

As the Greeks gradually lost interest in the scarab, because it was not relevant to Greek religious symbolism, a new form of seal—the scaraboid—appeared. It was also oval in outline, but the scarab back was replaced by a simple unornamented dome (figure 5). The seal engraving was still placed on the flat bottom side which was worn toward the body.

The scaraboid, like the Greek scarab, was made almost exclusively of chalcedony, a natural choice because of its durability, availability, and attractiveness. Another important advantage is that sealing wax does not stick to this cryptocrystalline mineral. The varieties carnelian and sard were used for the earlier scarabs because their darker color showed off the engraving of the beetle to great advantage. For the new scaraboid, lighter material was more often desired, particularly a beautiful blue variety that has more recently been given the French name "sapphirine" (Boardman, 1968).

In the third century B.C., Alexander the Great expanded the Greek empire into the gem-rich Eastern countries. The result was a flood of new gem materials into Greece and later into Rome. Garnets, amethyst, topaz, beryl, agates, and other stones were now also available for engraving (Boardman, 1968). Amethyst and garnet became particular favorites and were often used for the finer pieces. Interestingly, glass was also highly valued (Boardman and Vollenweider, 1978).

The Hellenistic period, which spanned the years between the death of Alexander the Great (323 B.C.) and the conquest of Greece by the Romans (146–39 B.C.), produced several important innovations with regard to the glyptic arts. The first of these was the evolution of the scaraboid into the ringstone. With the ringstone, the seal was mounted so that the engraving showed at all times and was fixed in its setting (figure 6). The finger ring was soon widely adopted as the ideal mounting for personal signets. Equally important was the acquisition of the diamond point (i.e., minute splinters of crushed diamond mounted in an iron tool) from India (King, 1885). Possessing a hard, sharp edge, this tool was ideally suited to engraving the fine lines needed to realistically represent hair and the delicate folds of clothing so admired by the objective eye of the Hellenistic Greeks and later the Romans (Richter, 1968).

The Hellenistic period also marked the first appearance of the modern cameo. During and immediately following the reign of Alexander the Great, the practice of using a portrait as a seal was started. With the introduction of banded chalcedonies, such as sardonyx, into Greece from its conquered territories, an engraving form that was distinctly suited to portraiture—the cameo—evolved. Cameos were usually composed of two layers, a light upper layer against a darker background (figure 7), but complex pieces occasionally utilized as many as four layers of color. The earliest documented example of a true cameo—the heads of Demetrius Soter and his wife Laodice (162–150 B.C.)—was carved in three layers of sardonyx on a surface that measured only 1¼ × 1 inch (King, 1885). Although the cameo had evolved from the scarab and scaraboid, which had important utilitarian functions, this form of engraving in relief was for decorative purposes only. Usually,

Figure 4. The highly symbolic scarab beetle served as the model for the scarab seal that was commonly employed by the ancient Egyptians and was eventually adopted by other cultures.

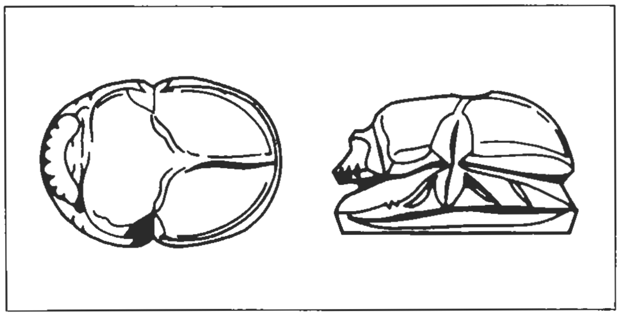
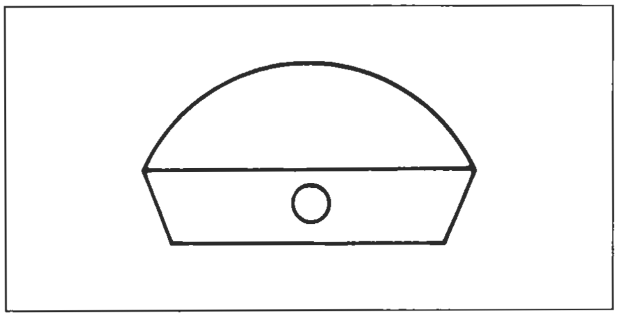


Figure 5. The simple lines of the scaraboid seal were preferred by the ancient Greeks.



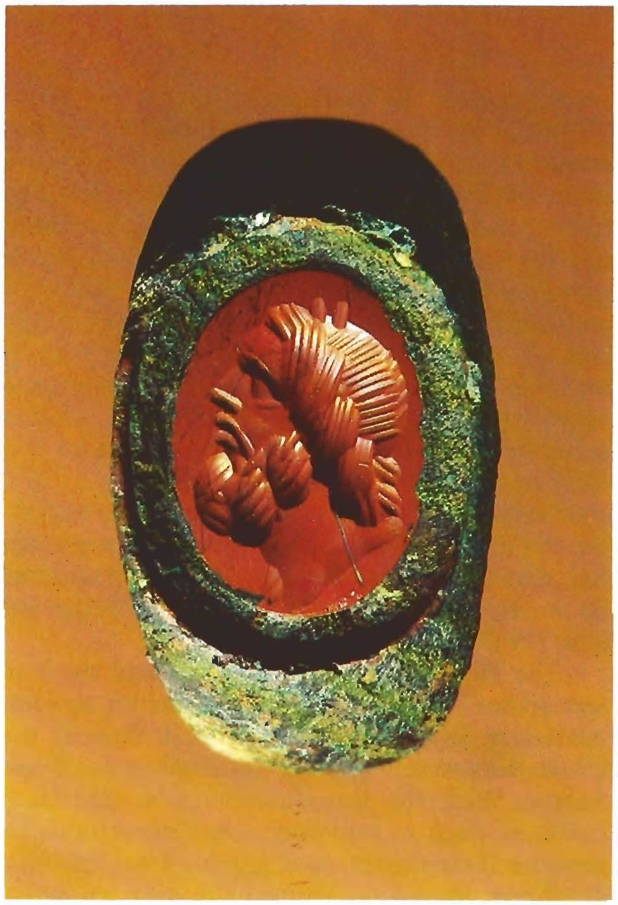


Figure 6. This Roman seal from the third century A.D. features the head of Jupiter engraved in jasper. As was the popular style during this period, the seal was mounted in a brass ring. Photo and ring courtesy of Michael Stubin.

cameos were set in jewelry, especially rings and pendants.

The Roman conquerors greatly admired anything Greek, and engraved gems were no exception. The earlier Italians, the Etruscans, used the Greek scarab almost exclusively for their seals (Boardman and Vollenweider, 1978). The later Romans replaced the scarab with the ringstone and the signet ring; they also adopted the cameo. Although they did not improve on these models, they did increase the variety of subjects. While they continued to use the Greek gods in their designs (figure 8), the Romans added their own gods, along with such subjects as chariot races, erotic poses, whimsical animals, and many other imaginative creatures and scenes.

The Romans not only were prolific producers of engraved gems, they were also enthusiastic collectors of the engraved gems of other cultures, particularly those of Greek origin. As they returned victorious from their military campaigns, the commanders would parade their spoils through the streets of Rome. These displays fueled an ostentation for jewelry. "Unless you are strewn with gems, don't even hope to pass for a wealthy man," wrote Manilius, a Roman poet (Ball, 1950). "Gems" and "engraved gems" were virtually synonymous, since the great majority of gems perceived to be of value were those that were engraved. Many gems were placed in temples as offerings to the gods and as a display of the Romans' wealth. Julius Caesar dedicated six cabinets of gems in the Temple of Venus Genetrix and Marcellus, thereby creating what some experts feel were the first public museums (Boardman, 1968b).

Figure 7. A Roman cameo dating to the first century B.C. or the first century A.D. made from chalcedony (9 × 10 mm). The subject is an almost whimsical rendition of a gorgon. Note that the detail has been engraved into the white layer of the stone, with the darker layer serving as background. Stone courtesy of Michael Stubin; photo by Mike Havstad.

The Mediterranean area is poor in gem deposits. Much of the early material, which was mostly varieties of chalcedony, was picked up by itinerant peddlers traveling in the desert regions. Egypt was probably the best early source, drawing on their turquoise and, more rarely, their emerald and peridot deposits. But with the conquest of the Eastern territories, particularly India, by Alexander the Great and the later Roman military commanders, a great profusion of new species and varieties of gems arrived into the classical world. Although carnelian and sard continued to be used predominantly for engraved seals (1300 out of 2600 classical gems in the British Museum are composed of these two varieties of chalcedony), almandine, rhodolite, and hessonite garnet, amethyst, rock crystal, sapphire, bloodstone, jasper, turquoise, and many other gem materials were also used for intaglios (see figure 9 and cover). Emerald from Egypt, Scythia, and possibly the Urals was much appreciated but only occasionally engraved because of its rarity and fragility. Nevertheless, both Alexander the Great and Cleopatra favored emerald for their engraved portraits (Ball, 1950).

After the Fall of Rome. With the dismantling of the Roman empire, so ended the greatest era for the glyptic arts. By the close of the fifth century, gem engraving had virtually passed into extinction (Sutherland, 1965). The Middle Ages contributed little; the few stones that were engraved were crudely cut with bold designs that lacked any subtlety. To satisfy the need for seals, ancient gems were often remounted in rings with the name of the bearer carved in the metal surrounding the intaglio. For example, after Charlemagne was crowned heir to the Caesars by the Pope in 800 A.D., he made the portrait of the pagan Emperor Marcus Aurelius Antoninus (88–217 A.D.) his seal. The pagan motifs were reinvested with new Christian symbolism, effectively sidestepping an obvious incongruity. Every veiled Roman lady became a Mary Magdalene in the eyes of the Christian wearer; Jupiter was renamed St. John the Evangelist (Sutherland, 1965).

Figure 8. A Roman intaglio of banded carnelian engraved to represent Athena, the Greek goddess of wisdom, holding a shield and spear. This ringstone (which measures 12 × 15 mm) was engraved in the first century B.C. Photo and seal courtesy of Michael Stubin.

The average citizen of Western Europe apparently knew and cared little about engraved gems as seals. Rather, the gems seemed to assume greatest significance for their purported magical and medicinal powers. For example, the figure of a man holding a palm branch in his hand, cut in jasper, was determined to render the wearer "powerful and acceptable to princes;" the engraving of a horse on any stone was indicated as a cure for lunacy; and a lion engraved in garnet would bring riches and honor. The wearer of an Aquarius carved in green turquoise was assured good luck in all buying and selling, "so that buyers shall seek him" (Sutherland, 1965). King (1885) cites 42 such associations. In fact, a common belief during this period was that the stones were not carved by man, but rather were engraved by some force of nature: man could not have cut such hard material (Anderson, 1981). Although seals continued to be used

Figure 9. This engraving of a sow has been made on a piece of green quartz, one of the more unusual gem materials used by the Romans. This 10 × 12.5 mm piece has been dated to the latter half of the first century A.D. Photo and seal courtesy of Michael Stubin.

regularly, most of those newly fashioned were made from metal rather than stone. With the exception of the few vestiges of Western civilization that remained to preserve knowledge of gem engraving in some fashion—particularly Alexandria and Byzantium—the art almost vanished.

A Renaissance. With the passage of time and the increasing civilization of Europe, especially the broadening of trade and barter, a renewed interest in engraved gems developed. By the 14th century, a revival of stone engraving was apparent, especially in Italy. Personal seals, displaying heraldic designs and Christian motifs in a Gothic style, predominated. These were soon followed in the 15th century by gems engraved with classical subjects. A renewed interest in anything antique by such important personages as the Medici increased the popularity of this art form (Morassi, 1964). During this age of personal patronage of art, artisans were encouraged by the various noble houses and to some extent the papacy (particularly Pope Paul II, 1417–1471) to enhance their own skills and teach others. Cameos were especially popular during the 15th and 16th centuries, since they were much more conducive to lavish display in jewelry and as *objets d'art* than the delicate intaglio. Also during the Renaissance period, with the influx of fine stones—rubies, emeralds, diamonds, and the like—the art of faceting gems to provide the brilliance and life that made them highly attractive in their own right developed. Gradually, artisans began to specialize in either the glyptic arts or gem cutting (Sutherland, 1965). The concepts of gem and engraved gem were no longer inseparable.

An important factor in the renewed popularity of cameos and other engraved gems throughout the 16th and 17th centuries was the discovery of large deposits of carnelian and agate in the Idar-Oberstein region of Germany. In conjunction with these important deposits, the famous lapidary community of Idar-Oberstein was created and nurtured.

Although the renaissance in the glyptic arts was based on classical designs, the ancient pieces themselves were not directly copied until the 18th century, during another resurgence of interest in all things classical. Napoleon Bonaparte was partially responsible for this neoclassical revival. He was especially fascinated by engraved gems and even founded a school for gem engraving. He acquired a great many important pieces as part of the plunder from his conquests. The Vatican was one of the reluctant contributors to Napoleon's collection, as this holy seat possessed an important collection based on an inheritance from King Louis XV of France (Hinks, 1975). Eventually, every self-styled intellectual, which included much of the royalty in Europe and others of note, shared Napoleon's fascination with ancient engraved gems and sought to establish their own collections. But there was just not enough supply to satisfy the demand. Fake antiques were created in great quantities to fill this gap. This prompted the observation by C.W. King (1860) that "For every antique gem of note, fully a dozen of its counterfeits are now in circulation, and often so close is the imitation as to throw doubt upon the authenticity of the original itself."

The downfall that resulted was inevitable. The leading character in this drama was Prince Poniatowski, who had inherited from his uncle, the last king of Poland, an important collection of 154 antique engraved gems that he subsequently expanded to approximately three thousand pieces. Following the prince's death in 1839, his collection was auctioned by Sotheby's in an event that drew buyers from all over the world. Shortly after the sale, however, word began to spread that most of these gems were not antique, but rather were contemporary pieces created by Italian craftsmen following antique designs. The embarrassed collectors who had purchased the gems suddenly felt themselves vulnerable, painfully aware of their general inability to safely tell the age of engraved gems.

In the wake of this scandal, the passion for collecting antique engraved gems almost died. To this day, interest in this specialized field remains at levels far below those of the 18th and 19th centuries, despite the increased expertise in dating such pieces. Even the utilitarian value of seals was diminished by the invention of the gum-sealed envelope and the development of the modern postal system during the 1800s.

Although many important collectors left the field and engraved seals lost the status of a major art form, the rising middle class of the nineteenth century adopted engraved gems for a different purpose—in jewelry, particularly cameos. Several factors are responsible for the renewed popularity of cameos. Large deposits of agate were discovered in Brazil, which replaced the now-depleted German resources. This new agate was also well suited for dyeing by newly discovered or rediscovered processes, thereby greatly increasing the

Figure 10. This 19th century chalcedony cameo (85 mm wide × 59 mm high) is an excellent example of the fine workmanship that could be found particularly early in this period. Like many of the pieces created during and after the Renaissance, this too carries a classical theme, "Death of Adonis." Signed "Dreher," from a private collection. Photo ©1983 Harold and Erica Van Pelt.

supply of raw material available for engraving. Although skilled artists could be found throughout Europe, Idar-Oberstein became the center for this new production of brightly colored agate cameos.

The rediscovery of shell, which was ideal for mass production because of the ease with which it could be carved and the predictability of the layering, also increased the availability of cameos. Italian artisans were already skilled at carving the local coral and lava, and their tools and techniques worked equally well on shell. Italy then as now became the center for carving cameos out of shell. The fact that England's Queen Victoria was a great patron of shell cameos assured a steady demand for many years.

But while many fine cameos were created (see figure 10), particularly during the earlier period of Victoria's reign, the mass production stimulated by increased demand eventually led to poor workmanship. Less experienced craftsman were often allowed to do most of the work on these cameos, the skilled artisan only adding the finishing touches. By the end of the 19th century, much of the interest in cameos had subsided as well.

THE CURRENT STATUS OF ENGRAVED GEMS

Engraved seals, while still popular in many Eastern nations, are little used in the modern Western world. However, interest in other forms of engraved gems has been generated by a growing pool of skilled artisans, the introduction of more sophisticated techniques, and the extension of engraving to larger objects and more unusual materials. Idar-Oberstein, in particular, has led the way both in providing the in-depth training required to master this difficult art form and in taking the art form beyond the classical styles to experiment with new designs (figure 11). In an attempt to revive the area's gem-cutting industry

Figure 11. Richard Hahn, one of the most important carvers in Idar-Oberstein today, represents the many skilled artisans who are currently expanding the scope of gem engraving.

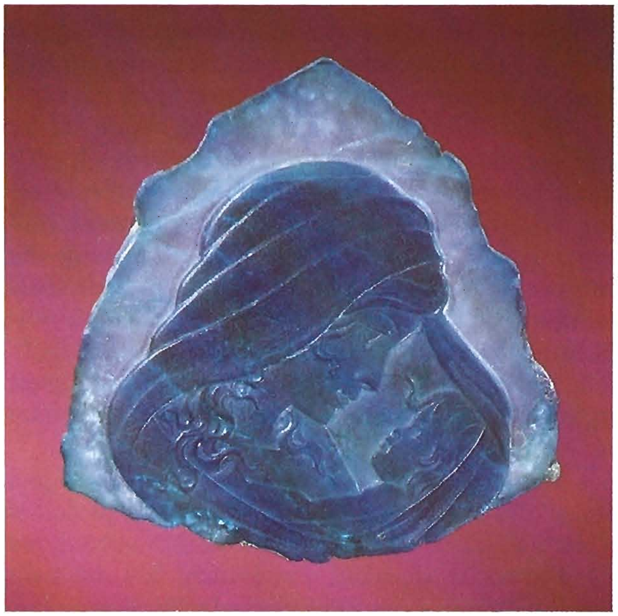
after World War II, many of Idar-Oberstein's carvers turned their attention to engraving large surfaces such as bowls, chalices, and plaques. While chalcedony remained the favored material for most of these pieces and the traditional cameos, other forms of quartz, tourmaline, and the like have been used as well to demonstrate the versatility of the engraver's art (figure 12).

Recently, a challenge to the position of hand engraving has appeared—that of ultrasonic engraving. Using ultrasonic drills, technicians can mass produce cameos and intaglios in hard stone such as chalcedony at a much faster rate than by the traditional methods. Whereas a medium-size cameo may take up to a day to complete by hand, these new techniques can shorten the time needed to less than one hour. This is accomplished by constructing a steel cameo in positive from a hand-carved cameo. From this steel positive numerous copper negatives are made; each copper negative has the ability to make one hard stone cameo by guiding the ultrasonic drills. The results are virtually identical to the original model (Manfred Wild, personal communication).

EVALUATING ENGRAVED STONES

Evaluating gem engraving is very much like evaluating any art form. Foremost in criteria is the overall design. The observer should judge whether the subjects shown are in proportion to one another and to the small field of the gem. The skillful depiction of depth and dimension is another consideration. Fine detailing and variation in surface finishes, such as a matte texture for clothing and a glossy finish for skin, create an illusion of depth that is almost three-dimensional. The piece

Figure 12. Tourmaline is one of the newer materials used for gem engraving. This scene was engraved on the blue cap of a tourmaline crystal from the Queen Mine in California (note the natural crystal edge). Cameo (7 cm × 7 cm) courtesy of Gerhard Becker; photo ©1980 Harold and Erica Van Pelt.



should also be free of accidental tool marks, which detract from the central theme or figure (Sinkankas, 1968).

While most intaglios are constructed from evenly colored stones, cameos are usually made from layered materials. The cameo artist painstakingly selects chalcedony with good contrast between layers. This task is not an easy one, and takes up much of the time of the engraver. Cassis shell provides no such selection problem, as it is consistently banded with strongly contrasting layers. Whatever substance is used, the more layers incorporated into the design, the more complex the piece is and thus the more desirable it becomes. It is also axiomatic that the harder materials are more difficult to carve, and so are more expensive to produce. Because of this, engraved beryl or corundum is highly prized.

Today's collector of engraved gems faces formidable, but not unsurmountable, challenges. A cultivated eye is developed from a study of the literature relating to gem engraving and from a more than passive contact with actual pieces. The first requirement, that of reading about the subject, is not an easy one. As interest in this field goes in cycles, so does the volume of literature. The most complete studies of engraved gems were made in the 19th and early 20th centuries. Unfortunately, most of these suffer from much misinformation, are written in German or French, and are now out of print. Fortunately, more contemporary writers/scholars such as Boardman, Vollenweider, and Richter have made excellent, if sometime esoteric, studies in English.

The most satisfying education, however, comes from actual observation. There are several excellent museum collections in the United States and Europe, including the Boston Museum of Fine Arts, the Metropolitan Museum of Art (in New York), the J. Paul Getty Museum (Malibu, California), the Oriental Institute (Philadelphia), the Burton Y. Berry Collection at the Indiana University Museum, the British Museum (London), and the Louvre and Bibliothèque Nationale (Paris). Excellent examples of more modern pieces can be found in the Deutsches Edelsteinmuseum in Idar-Oberstein, Germany. Dealers who specialize in estate jewelry also often have cameos and intaglios of all periods.

CONCLUSION

The engraving of gems for use as seals, or as objects of adornment, is one of the oldest of man's art forms. Because of the hardness of most of the materials used, many engraved gems have endured through thousands of years of recorded history, and survived as glimpses of civilizations of which few other tangible vestiges remain. Their lasting charm has kept interest in engraved gems alive through cultures down to our own.

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GEM ANDRADITE GARNETS

By Carol M. Stockton and D. Vincent Manson

Andradite, the rarest of the five well-known gem garnet species, is examined and characterized with respect to refractive index, specific gravity, absorption spectrum, color, and chemical composition. These properties are measured and specifically tabulated for 21 gem andradites (20 green and one yellow). From the narrow ranges of refractive index (1.880–1.883), specific gravity (3.80–3.88), and chemical composition (less than 3% of components other than andradite in any of the specimens examined) that were observed, it is apparent that the gem-quality andradites are chemically distinct from other types of gem garnets and that these stones are easy to distinguish by means of color coupled with refractive index.

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As part of our continuing study of gem garnets, the species andradite should present few difficulties in characterization and identification. Three varieties have been recognized by gemologists: melanite, topazolite, and demantoid. Melanite, which is black, will not be discussed here because it is opaque and has historically, to our knowledge, been used as a gem only for mourning jewelry. Topazolite, a term that has been challenged as being too similar to that of the gem species topaz, is a greenish yellow to yellow-brown andradite that only occasionally occurs in crystals large enough to be faceted. Demantoid, the yellowish green to green variety (figure 1), is the most important of the three for the jeweler-gemologist and is the principal focus of the study reported here.

Pure andradite ($Ca_3Fe_2Si_3O_{12}$) has a refractive index of 1.886 (McConnell, 1964) and a specific gravity of 3.859 (Skinner, 1956). Gemological references cite ranges as narrow as 1.888 to 1.889 for refractive index and 3.82 to 3.85 for specific gravity (Webster, 1975) and as broad as 1.855 to 1.895 and 3.81 to 3.87, respectively (Liddicoat, 1981). Demantoid has been observed to exhibit a visible light spectrum that has a very strong absorption band centered around 443 nm, which may appear as a cutoff, and, in the case of finer green stones, two bands around 622 nm and 640 nm as well as a pair of bands between 693 and 701 nm (Anderson and Payne, 1955). Liddicoat (1981) and Webster (1975) both support these observations. Anderson and Payne attributed the 443 nm band to Fe^{3+} and the remaining four bands to Cr^{3+}.

Two distinct characteristics of demantoid are usually used as visual indicators in identification. One is the very strong dispersion (0.057), which can be observed in almost any cut stone. The other is the frequent presence of "horsetail" inclusions (figure 2) of byssolite fibers (Gübelin, 1974). These inclusions are so unique and characteristic that demantoid is frequently cut so as to position them directly beneath the table of a stone where they are unmistakably visible.

DATA COLLECTION

Because of the rarity of gem-quality andradites, we were able to compile a collection of only 21 samples: one brownish yellow stone and 20 green ones, of which 10 were from a single parcel. We attempted to add variety by borrowing stones, but only one specimen (#L-1) among those available to us was of a type not already represented by stones from GIA's reference collection. Moreover, reliable information on the origins of gems is exceedingly scarce (as compared, for instance, to collectible mineral specimens); among the stones studied here, only the locality of the brownish yellow specimen from California is known for certain.

Each stone was measured for refractive index, specific gravity, absorption spectrum, color, and chemical composition. The instruments and techniques employed for data collection were the same as those used in the previous portions of the garnet study and described in detail in our initial paper in this series (Manson and Stockton, 1981). However, because the microprobe system we use for quantitative chemical analyses reports all iron as Fe^{2+} while the iron in andradites is present principally as Fe^{3+}, mathematical conversion was necessary to correct the appropriate percentages. Any error in the determination of Fe^{2+} by the microprobe is compounded by this calculation, so we performed chemical analyses four times for each stone and averaged the results in an effort to increase the accuracy of the original figures. The data are summarized in table 1.

DISCUSSION OF DATA

Physical and Optical Properties. The ranges of refractive index and specific gravity that we obtained for our 21 andradites are quite narrow in comparison to other types of garnets: 1.880–1.883 and 3.80–3.88, respectively. The refractive indices that we observed fall within the range cited by Liddicoat (1981) and below that of Webster (1975), as discussed above. The specific gravities for our specimens define a somewhat broader range than those proposed by the aforementioned sources. The often highly included nature of even gem-quality andradite would be sufficient to account for considerable variability in this property.

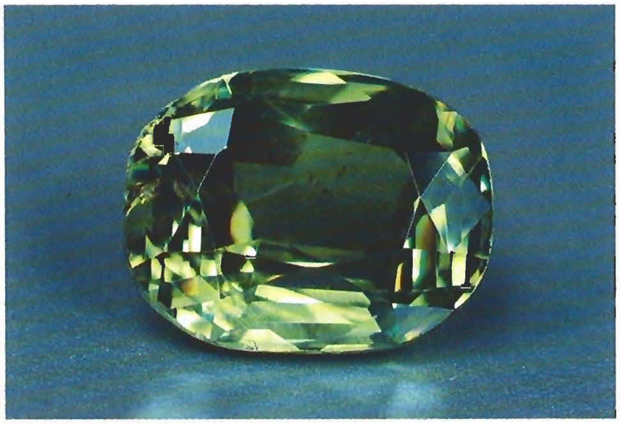
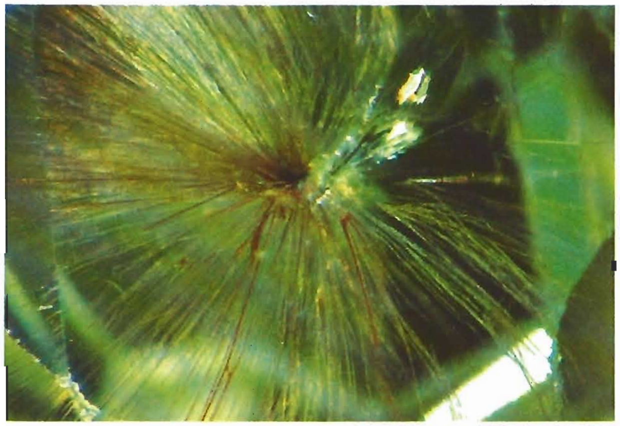


Figure 1. Andradite garnet, gem variety demantoid (GIA no. L-1).

Chemistry. It is evident from table 1 that there is very little variability in chemical composition among the andradites that we examined, especially when compared to other types of garnets. Moreover, this lack of deviation is reflected in the very narrow ranges observed for refractive indices and specific gravities. Greater compositional variation does occur in non-gem-quality andradites (Deer et al., 1963) to the extent that they appear to continuously grade into grossular. However, to our knowledge no gem-quality garnets with these intermediate compositions have been observed.

An examination of the totals in table 1 for oxide and end-member compositions reveals that our method of calculating garnet end members does not account for the oxides in andradites as well as it has for other types of garnets (Manson and Stockton, 1981). Comparison of figure 3 with

Figure 2. "Horsetail"-type inclusion in a demantoid andradite. Magnified 50×.



the histogram in our first article on garnets (figure 2, op. cit.) will clearly confirm this difference. The deficiency appears to be in cations that occupy the octahedral site (represented by Y in the garnet formula $X_3Y_2Z_3O_{12}$) leaving an excess of cations for the dodecahedral (X) and tetrahedral (Z) sites, especially calcium and silicon. This may be due to the possibility that andradite does not behave according to the ideal garnet formula employed by our end-member calculation scheme. Another likely explanation, especially evident in the large-scale conversion of FeO to Fe_2O_3 necessary for andradites, involves the presence of different oxidation states that cannot be distinguished with the microprobe (Huggins et al., 1977; Burns, 1981). In addition, there may be minor water content—fairly common in andradites (Deer et al., 1963)—that also cannot be detected with the microprobe.

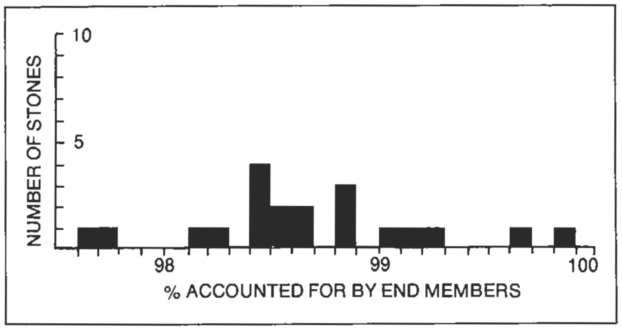


Figure 3. Histogram illustrating the percentages of oxides in the 21 andradites that are accounted for by end members.

It is interesting to note the low accountability that occurred with the one brownish yellow stone (#11648) that we examined.

TABLE 1. Physical, optical, and chemical data for 21 andradites from various localities.[a]

Physical, optical, and chemical properties	Italy								
	(2491)	(2952B)	(13132)	(6672C)	(6672D)	(13234)	(13254)	(6672A)	(13163A)
Refractive index	1.881	1.881	1.883	1.880	1.880	1.881	1.881	1.881	1.880
Specific gravity	3.85	3.88	3.86	3.85	3.88	3.85	3.88	3.85	3.86
ColorMaster coordinates	A-18/34/01	A-24/65/05	A-19/54/05	B-45/85/03	A-15/30/01	B-36/72/02	B-46/100/05	A-25/65/05	A-17/52/03
CIE x/y coordinates	0.446/0.482	0.338/0.478	0.373/0.470	0.454/0.484	0.437/0.486	0.443/0.499	0.433/0.487	0.393/0.475	0.382/0.502
GIA color terminology[b]	YG 3/4	yG 2/2	syG 2/2	YG 4/4	YG 3/3	YG 4/4	YG 3/3	yG 2/2	yG 3/3
Oxide composition[c]									
SiO_2	35.33	35.83	35.70	35.39	35.27	35.61	35.47	35.43	35.59
Al_2O_3	0.10	0	0	0	0	0	0	0	0
Fe_2O_3[d]	30.56	30.97	31.35	31.09	30.68	31.01	31.07	31.26	31.12
Cr_2O_3	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	0.10
Ti_2O_3[d]	0.09	0.03	<0.02	0.05	0.09	<0.02	<0.02	<0.02	<0.02
M_gO	0.24	<0.05	<0.05	<0.05	0.07	0.12	0.11	0.07	0.07
CaO	33.66	33.45	33.49	33.44	33.28	33.48	33.41	33.58	33.35
MnO	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total	100.08	100.43	100.71	100.12	99.50	100.34	100.18	100.45	100.30
End-member composition[e]									
Schorlomite	0.36	0.11	<0.07	0.18	0.32	<0.07	<0.07	0.07	<0.07
Andradite	97.24	98.56	99.67	98.93	97.71	98.58	98.79	99.46	98.93
Uvarovite	<0.16	<0.16	<0.16	<0.16	0.20	<0.16	<0.16	<0.16	0.33
Total	97.76	98.83	99.90	98.23	98.25	98.81	99.02	99.69	99.33
Spectral absorption bands (nm)	475	446	445	456	457	450	451	446	447
	565	574	571	567	571	571	573	573	574
	621	621	622	620	624	622	625	624	622
	738	738	—	—	—	—	740	740	740

[a] *The GIA catalogue number for each stone is indicated in parentheses.*

[b] *Color terminology refers to "hue tone/saturation." The symbols are interpreted as follows:*

Hue: s = slightly Tone: 2 = very light Saturation: 2 = slightly grayish hue
o = orangy 3 = light 3 = very slightly grayish hue
y = yellowish 4 = medium light 4 = hue
Y = yellow
G = green

Another point of interest is that some of the stones apparently are not homogeneous in composition, especially with regard to chromium. The Cr_2O_3 content of one stone was determined in four separate analyses to be 0.18, 0.26, 0.13, and 0.05 weight percent. For comparison, the four analyses of another stone revealed 0.08, 0.06, 0.07, and 0.06 weight percentages of Cr_2O_3.

Color. The range of colors of gem andradite is fairly narrow and, with the exception of the rare and very desirable vivid green, is well represented by the stones we examined (figure 4). Consequently, the distribution of the color coordinates for these stones in the CIE color graph occupies a very small region (figure 5) in comparison to the broad color variability seen in most types of garnets. We did not observe color zoning in any of our stones, even in those with chemical analyses that suggested nonhomogeneous distribution of potentially color-influencing elements. Nor could we correlate the small amounts of Cr_2O_3 measured in these stones with variations in hue, since the quantities in many of the stones approached the limits of detection of the microprobe. In most cases, therefore, our figures for chromium incorporate a relatively high level of uncertainty.

Manganese and titanium have also been associated with color origin in andradites. The exact role of the latter has been the subject of considerable debate among mineralogists (Howie and Woolley, 1968; Moore and White, 1972; Manning and Harris, 1970; Huggins et al., 1977). The low levels of titanium present in the stones we analyzed could not be measured with sufficient accuracy to contribute toward clarifying the signifi-

USSR										San Benito Co., Calif.	Unknown
(13163B)	(13163C)	(13163D)	(13163E)	(13163F)	(13163G)	(13163H)	(13163I)	(13163J)	(13103)	(11648)	(L-1)
1.880	1.880	1.881	1.881	1.880	1.882	1.882	1.881	1.883	1.880	1.881	1.881
3.87	3.84	3.88	3.84	3.83	3.86	3.87	3.83	3.83	3.81	3.80	3.87
A-20/50/03	A-17/50/02	A-18/52/04	A-19/58/04	A-20/57/05	A-17/52/02	A-20/57/03	A-21/52/04	A-24/65/05	A-28/64/05	B-83/96/01	A-18/56/02
0.401/0.487	0.392/0.517	0.381/0.482	0.378/0.490	0.377/0.473	0.385/0.517	0.391/0.495	0.392/0.469	0.388/0.478	0.407/0.465	0.528/0.444	0.388/0.520
YG 3/3	yG 3/3	yG 3/2	syG 3/3	syG 3/2	yG 3/4	yG 3/3	YG 3/2	yG 2/2	YG 2/2	soY 3/4	yG 3/4
35.46	35.66	35.53	35.51	35.63	35.62	35.87	35.72	35.72	35.27	35.56	35.40
0	0	0	0	0	0	0	0	0	0	0	0
30.74	30.93	30.87	31.13	30.83	31.02	31.22	31.10	31.08	31.14	30.52	30.99
0.16	<0.05	0.18	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
<0.02	0.04	0.03	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
<0.05	<0.05	0.06	<0.05	0.07	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	0.09
33.37	33.38	33.46	33.50	33.38	33.38	33.42	33.62	33.52	33.51	33.29	33.55
<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	<0.05
99.85	100.16	100.18	100.31	100.03	100.24	100.68	100.61	100.49	100.09	99.56	100.17
<0.07	0.14	0.11	<0.07	<0.07	0.11	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
97.73	98.44	98.25	98.96	98.01	98.60	99.25	98.86	98.79	99.00	97.02	98.50
0.53	<0.16	0.59	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	0.23
98.33	98.74	98.95	99.19	98.24	98.87	99.48	99.09	99.02	99.90	99.23	98.80
446	449	444	446	447	448	447	446	448	446	497	447
576	—	572	573	572	573	573	573	570	572	—	571
619	622	624	622	621	620	623	624	632	623	616	626
740	—	737	—	738	738	743	738	—	740	738	—

[c] For a discussion of accuracy, see Appendix. Oxide figures are given as weight percentages.
[d] All FeO and TiO_2 were converted to Fe_2O_3 and Ti_2O_3 in accordance with the requirements of stoichiometry.
[e] $Mn_3V_2Si_3O_{12}$, knorringite, spessartine, grossular, and almandine were also considered by our end-member calculation program, but were all eliminated in the process due to the absence of the necessary oxides.

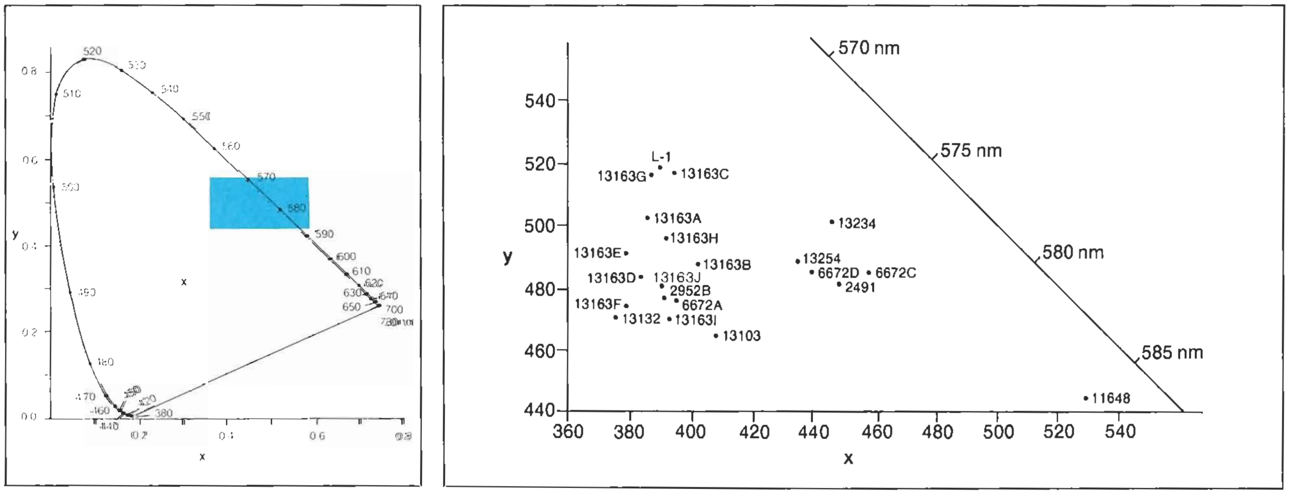
Figure 4. A selection of stones from the collection of andradite garnets used in this study which illustrates the ranges of colors of the stones examined. (From left to right, GIA nos. 11648, 2491, L-1, 13254, and 2952B.)

cance of titanium in andradites, but the possible effect of this element must not be ruled out. The presence of manganese in andradites has been documented in association with dark yellowish or reddish hues (Vermaas, 1952). Minor MnO content was detected in the one yellow-brown andradite that we analyzed, but this information is not sufficient to support any conclusions about the effects of manganese on the color of andradites.

Finally, the effects of different valence states and site occupancies of iron must be considered as a possible cause of color variation. There is evidence in the literature (Huggins et al., 1977; Schwartz et al., 1980; Burns, 1981) that iron, especially in the presence of titanium as in garnets of the andradite-schorlomite series, can be present in both divalent and trivalent states and can occupy sites other than those normally associated with those states. While these studies do not yet correlate such a distribution of iron with specific color effects, they do identify that absorption of visible light and associated variations in color result from such relationships (Marfunin, 1979; Burns, 1981).

Spectrum. With the spectrophotometer, three absorption bands could usually be discerned in the visible light range: at approximately 446 nm, 573 nm, and 620 nm (figure 6). The latter two bands may overlap considerably and at times appear as a single broad absorption, especially in the yellowish green to yellow-brown stones. In this form, they are centered around 600 nm and are referred

Figure 5. Left, the CIE chromaticity diagram with an indication of the region (shaded area) reproduced at right; x indicates the coordinates for colorless or neutral gray. Right, the yellow-green to yellow region of the CIE chromaticity diagram with positions for the 21 andradites plotted according to their x-y color coordinates.



to in the mineralogical literature as associated with the presence of Fe^{3+} in the octahedral site (Slack and Chrenko, 1971; Moore and White, 1972). These references assign the same significance to the 446 nm band. Only one source (Amthauer, 1976) refers to a single band near 621 nm and attributes it to Cr^{3+}, but no source has cited the 573 band separately. These bands may also reflect the presence of Cr^{3+}, which appears in grossulars as bands around 427 nm and 611 nm (Amthauer, 1976), but the overlap of such Cr^{3+} bands with those of Fe^{3+} in andradite would make it difficult to separate their respective influences on color. In addition, we observed a well-defined band in the near-infrared region, around 740 nm, in over half of the andradites. As yet, we have found no reference to this band in either the mineralogical or gemological literature, nor any correlation with chemical composition in the stones in which it was observed.

With the hand spectroscope, the absorption spectrum reveals a strong band at 430 to 445 nm, which at time appears as a cutoff at 445 nm, and a vague, broad band centered at approximately 590 nm (figure 7). The latter, it should be noted, is not mentioned in the gemological sources we cited in the introduction to this article. We were unable to confirm the paired bands associated with rich green color and/or Cr^{3+} mentioned by these same sources (Anderson and Payne, 1953–1957; see also those cited in the introduction to this article), since they were not present in the spectra of any of the stones we examined, probably because none of our specimens were of the finest green color associated with demantoids. We would welcome the opportunity to examine such material if it were made available to us.

Figure 6. Representative spectral curve of a demantoid (no. 131633) as observed with the spectrophotometer. Principal absorption and transmission features are labeled with their specific wavelengths. All or most of these features were observed in all the demantoids examined.

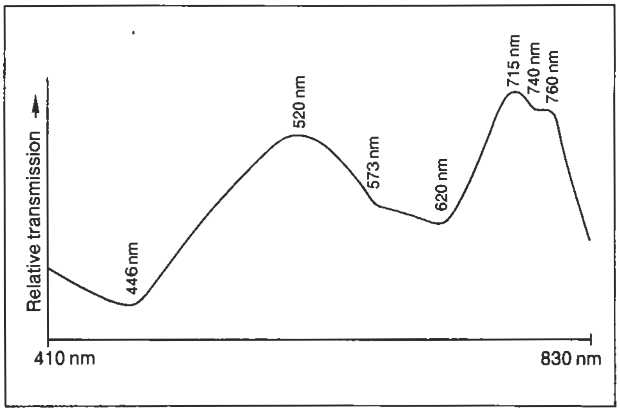
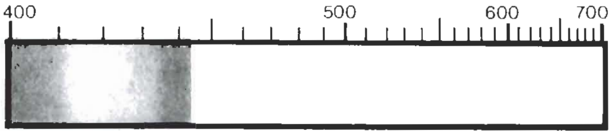


Figure 7. The same absorption spectrum illustrated in figure 6 as it is seen with the hand spectroscope. The absorption features in the blue region often appear as complete absorption below approximately 440 nm to 445 nm.



CONCLUSIONS

As in our previous studies on garnets, the definition of varieties according to characteristic spectra and corresponding color-causing elements has proved to be complex. We were able to detect no correlation between color, spectral absorption bands, and the amount of Cr_2O_3 present in the stones we examined. However, we have no reason to question the existence of absorption bands associated with high Cr_2O_3 content in more intensely green demantoids. The influences of titanium and manganese on the variability of color among gem andradites are still very questionable. While Fe^{3+} in the octahedral site is responsible for the yellow-green color of most gem andradites, iron in other valence states and in other sites in the garnet structure may also contribute to variation.

The high proportion of the andradite component in gem andradites provides ease in clearly defining the gem species associated with this end member of the garnet group. It is characterized by very little variability in chemical composition and in optical and physical properties in comparison with other types of garnets. Members of the gem andradite species can be easily distinguished by means of their high refractive index (1.880–1.883) in conjunction with color. No other type of gem garnet that has a refractive index over 1.80 occurs in green to yellow-brown hues. The precise definition of the gem varieties of andradite will be discussed in our concluding article on the gem garnets as a whole.

APPENDIX

The accuracy of our chemical data is affected principally by the amount of chemical inhomogeneity in our samples and by the variability and bias inherent in the techniques employed in chemical analysis. Aside from the problem of inhomogeneity, the accuracy of our microprobe data can be assessed through an examination of the variation among selected analyses of a well-known standard material, the McGetchin garnet (McGetchin, 1968), which we analyze each time we place a set of specimens in the instrument. Table 2 provides ranges, averages, and standard deviations for 25 microprobe analyses of the McGetchin garnet collected over a two-year period in conjunction with the analyses of the specimens described in this article.

TABLE 2. Ranges, averages, and standard deviations for 25 microprobe analyses of the McGetchin garnet over a two-year period.

Oxide	Range of wt %	Average of wt %	Standard deviation (%)
SiO_2	40.45–42.30	41.45	± 1.06
TiO_2	0.12– 0.20	0.16	±13.79
Al_2O_3	21.62–22.94	22.35	± 1.59
Cr_2O_3	1.32– 1.44	1.38	±18.16
V_2O_3	0– 0.08	0.03	±88.33
MgO	19.60–20.42	20.04	± 1.16
CaO	4.47– 4.69	4.63	± 1.12
MnO	0.29– 0.50	0.37	±18.94
FeO	8.99– 9.55	9.23	± 1.48

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THE RUBIES OF BURMA: A REVIEW OF THE MOGOK STONE TRACT

By Peter C. Keller

For centuries, the Mogok Stone Tract of Burma has provided the world with its finest rubies. The mining district is situated about 700 km north of the capital city of Rangoon, with the rubies found principally in alluvial deposits weathering out of a crystalline limestone or marble. This article reviews the history of this famous locality, the geology of the area, and the mining methods that have predominated. Also covered is the gemology of these stones, including those inclusions that are characteristic of Burmese origin, and a discussion of famous rubies from Mogok.

It is impossible to consider the "classic" or historically most important gem deposits of the world without including the Mogok Stone Tract in Upper Burma. Mogok has been associated with the world's finest rubies for over four centuries, but not until the British assumed control of Burma in 1886 was Mogok's potential for producing beautiful, deep crimson ("pigeon's blood") rubies truly realized (figure 1). Although Mogok is known particularly for these fine rubies, quantities of fine sapphires, spinels, and peridot are also found in the Mogok Stone Tract. Sapphires are most abundant in the nearby Kathe, Kyatpyin, and Gwebin deposits; peridot is limited to the area of Bernardmyo some 10 km NNW of the village of Mogok. Also found in gem quality in the Mogok area are apatite, scapolite, moonstone, zircon, garnet, iolite, and amethyst.

Historical records indicate that the Mogok Stone Tract has been worked since at least 1597 A.D., when the King of Burma secured the mines from the local Shan (Mongoloid) ruler. After the British annexation of Upper Burma in 1886, the mines were leased to a British firm, which organized Burma Ruby Mines, Ltd. Although the British firm used modern methods to work the mines, it found that their profitability was sporadic at best. Burma Ruby Mines worked the area until the early 1930s, when Mogok reverted back to native mining and the methods used for hundreds of years before the arrival of the British.

Today, little information comes out of Burma regarding the Mogok Stone Tract. Since 1962, when the communist regime took power and subsequently nationalized all industry including gem mining, no foreigner has been allowed to visit Mogok. During this period, supplies of rubies from Burma have diminished drastically. Although some stones are sold at annual auctions in Rangoon, the few quality stones that emerge are smuggled out through Thailand.

The purpose of this article is to describe what is known

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of this "premier" ruby deposit. Because it is impossible for foreigners to visit Mogok, the research for this article consists of a thorough review of the literature as well as interviews with people who had visited Mogok prior to 1962. The photos, which come from some of these same gem dealers, are particularly rare. The literature is rich in information on Mogok, usually based on a visit to the area by some Western gem dealer. The first such report was that of Pierre d'Amato (1833), who described the local mining methods in the Mogok area. Since then many articles have been written, principally on the mining activities (Wynne, 1897; Morgan, 1904; Gordon, 1888; Scott, 1936). However, since the 1965 article by Gübelin, who also produced a superb two-hour documentary film on the area, nothing of importance has been contributed to the modern literature.

LOCATION AND ACCESS

The Mogok Stone Tract is located in the Kathe district of Upper Burma between latitudes 22° 50'45" N to 23° 5'15" N and longitudes 96° 19' E to 96° 35' E, or approximately 700 km north of the Burmese capital of Rangoon. Mogok (figure 2) is about 150 km NE of Mandalay, and is located at an elevation of about 1,200 m (4,000 feet). It is the major population center in the area, with 6,000 inhabitants reported in 1960 (Meen, 1962). The tract is about 1,040 square kilometers in extent and includes the townships of Thabeikkyin and Mogok.

The general area of the tract is very mountainous, forming the western borders of the Shan Plateau. Most of the mining takes place in the alluvia of floors and flanks of the Mogok, Kyatpyin, Kathe, and Luda valleys. Mogok Valley is the most important, consisting of a narrow alluvial plain, 5 km long running NE-SW, and about 1 km wide.

All reports of travel to Mogok, when it was permitted, indicate that access to the mining area was very difficult. According to Ehrmann (1957), there were two principal travel alternatives. The first started with three days by train from Rangoon to Mandalay, followed by two days of boat travel up the Irrawaddy River to Thabeikkyin, where one could hire a car for the final 95 tortuous kilometers. The second, and far easier, means was a four- to six-hour flight from Rangoon to Momeik via Union of Burma Airways, and then about 40 km by jeep from Momeik to Mogok.

Because the current Burmese government limits foreign visitors to a 24-hour visa, any travel into the interior is virtually impossible. In addition, the Mogok area is under military control and visits by foreigners are forbidden (Nordland, 1982).

HISTORY AND PRODUCTION

According to Webster (1975), the earliest historical record of Mogok shows that the mines were taken over by the King of Burma in 1597 from the local ruling Shan, in exchange for the town of Mong Mit (Momeik) some 40 km away. The descendants of the king worked the mines intermittently. In 1780, King Bodawgyi operated the mines using slave labor. Shortly thereafter, the king placed control of the Mogok mines in the hands of governors (So's) who allowed mining on payment of a tax. Valuable stones remained the property of the king, however, with no compensation to the miner. This period was one of great oppression, and many miners left the region. The area never really recovered, and by the 1870s conditions were so intolerable that King Thebaw began negotiating with outside companies to work the deposits. He eventually leased mining rights to the Burmah (sic) And Bombay Trading Company, but arbitrarily canceled their lease on the ruby mines in 1882 (*Mineral Resources*, 1886). This action, along with certain provocations to the British-controlled lumber industry, led the British to invade Upper Burma in 1886 with an army of 30,000 men (*Mineral Resources*, 1886). The British annexed Upper Burma to the colony of India that same year. In October 1887, the Upper Burma Ruby Regulations were promulgated, creating the so-called "stone tracts." In November of that year, the Mogok Stone Tract was established (Chhibber, 1934a and b). In 1889, the British government, through the Secretary of State for India, awarded control of the Mogok mines to Edwin Streeter, the eminent Bond Street (London) jeweler, who organized Burma Ruby Mines, Ltd. The initial 1889 lease of the mining rights to the 10 × 20 mile (15 × 30 km) tract was for a seven-year period at an annual rent of £26,666 plus 16.66% of the net profits (Adams, 1926).

When Burma Ruby Mines, Ltd., moved into Mogok they faced severe difficulties, not the least of which was that they found the richest deposits to be under the village of Mogok itself. Before mining could begin, they had to move the entire village to its present location. In the years that followed, they also had to build roads, bridges, buildings, five

Figure 1. The eight unusually large rubies in this exquisite necklace well illustrate the "pigeon's blood" color so distinctive of fine Burmese stones. The rubies total 66.51 ct, and are surrounded by 96.99 ct of diamonds. Photo by Herbert Giles; courtesy of Harry Winston, Inc. (Editor's note added post-printing: We regret that given the limitations of the four-color process we could not accurately capture the deep color of the original stones.)

washing mills, and a 400-kw hydroelectric plant. In addition, the company was plagued by the age-old problem of miners "highgrading" and smuggling a large percentage of the gem production (Brown, 1933). The Indian government protected the local miners, stating that Burma Ruby Mines could not disturb established native miners in their work, nor remove them except by purchase of their claims. Otherwise, the British company held a monopoly on the mining rights of the Mogok Stone Tract (Adams, 1926; Calhoun, 1929).

In 1896, the original seven-year lease was renewed and extended for 14 years with a fixed rental fee of £13,333 plus 30% of the net profit per year. The mining of rubies in Mogok was at an all-time high. Five large washing mills processed thousands of tons of earth each day. The area eventually became so prosperous that more mills were erected 12 km from Mogok, near Kyatpyin. All mining was open pit, using large hydraulic monitors, or "cannons," under high pressure to wash the gem gravels through a series of sluice-boxes (Webster, 1975).

The area prospered under the control of Burma Ruby Mines until 1908, when large numbers of synthetic rubies entered the world gem market. This caused immediate panic among ruby buyers worldwide, and sales of rubies declined dramatically. Although the Mogok operations continued all through World War I, in 1925 Burma Ruby Mines went into voluntary liquidation (Brown, 1933). The company had six years remaining on its lease, however, and struggled on until 1931, when it surrendered the lease to the government (Halford-Watkins, 1932).

Keely (1982), one of the managers of the mine, gives some additional insight into the decline of modern mining in the Mogok area. He points out that exceptionally heavy rainfall in 1929 caused severe flooding, which destroyed all of the electric pumps as well as the drainage tunnels used to keep the mines from being inundated. The large lake formed by the flooding still remains today (again, see figure 2). Several attempts were made to repair the flood damage, but with no success. Furthermore, as the modern techniques were no longer considered economic, the native miners and their centuries-old mining methods took over Mogok once again. All lease restrictions with respect to applications for licenses were removed, and the government simply collected 10 rupees per month from each miner to cover the cost of a license that the miner "was to wear on the seat of his pants" (Halford-Watkins, 1932). Native mining continued actively except during the period May 1942 to March 1945, when the Japanese occupied Burma and the Mogok tract became part of the battleground of the 14th U.S. Army and the Japanese. After World War II, native mining prospered until the nationalization of the mines by the communist regime in 1963.

When the Burmese government nationalized all industries in 1963, it forbade all private businesses, including gem mining and selling. Today, the diminished gem mining is monitored by the army, and gems can be sold legally only at the annual auction held in Rangoon by the Petrol and Mineral Development Corporation (PMDC). These auctions have not been highly successful because of the generally poor quality of the stones offered. The total sales figures from the annual gem emporium, as published by the *Minerals Yearbook*, gives some idea of modern production. In 1969, the Fifth Annual Gem Emporium yielded $2,400,000. This figure rose dramatically in 1973 to $5,800,000, the last year for which statistics are available, but it is important to note that this sum represents mostly income from sales of jade and pearls, with very few rubies having been offered.

Early production records are difficult to find and are generally incomplete. According to Iyer (1953), in a table of production statistics for the Burma Ruby Mines, Ltd., 1,300,000 ct of ruby were recovered during the period 1924–1939. As usual with gem production statistics, it is impossible to know how much additional material was recovered by highgraders and operators of private claims.

According to Nordland (1982), the Mogok area is off-limits to foreigners, and closed even to Burmese without special permission. A division of Burmese troops now oversees the government-owned mines.

GEOLOGY

Several detailed accounts of the geology of the Mogok Stone Tract have been published. The earliest is the large and comprehensive work of Brown and Judd (1896), who conducted their study on behalf of the Burma Ruby Mines, Ltd., and the Secretary of State for India. La Touche, perhaps best known for his work on the Kashmir sapphire mines, included the Mogok area in his *Memoir of the Northern Shan States* (La Touche, 1913). Other

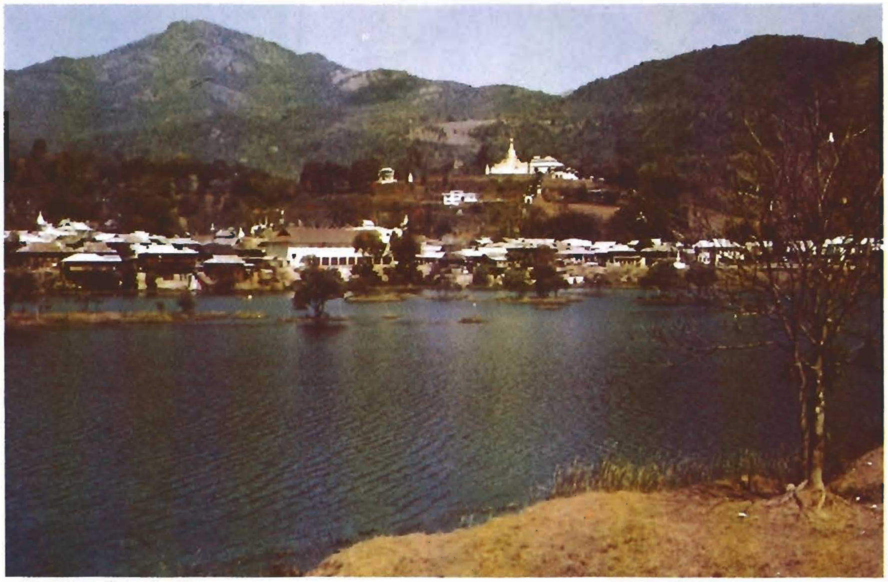


Figure 2. A view of the town of Mogok from across the artificial lake that resulted from the flooding of the extensive works of the Burma Ruby Mines, Ltd.

early geologic studies include Bleeck (1908), Fermor (1930, 1931, 1932, 1934, and 1935), and Heron (1936 and 1937). Chhibber (1934a) includes a description of the gem gravels in his work on the geology of Burma.

Systematic mapping of the Mogok Stone Tract on a scale of 4 inches = 1 mile was started in 1929 and published by Brown (1933). Much more extensive mapping, however, was continued by Iyer (1953). This work is by far the most complete on the Mogok area, and resulted in a superb map of the deposit (as adopted for figure 3).

As is the case with all tropical areas, the geologic mapping of Mogok was particularly difficult. Not only must the geologist contend with dense vegetation and numerous wild animals, but he must also study rocks that are covered with a thick mantle of soil and products of deep chemical weathering. In the Mogok area, annual rainfall is more than 360 cm (140 in.).

We do know that the geology of the Mogok area is very complex, consisting primarily of high-grade metamorphic schists and gneisses; granite intrusives, including gem-bearing pegmatites; peridot-bearing ultramafic rocks; and, most importantly, ruby- and spinel-bearing metamorphic marble.

The rubies of Mogok are weathered from the marble of the area, which is in contact or interbedded with a complex series of highly folded gneissic rocks. Iyer (1953) identified 13 mappable rock units in the Mogok area. These, however, can be, and often are, grouped into (1) intrusive granitic rocks; (2) the Mogok gneiss, which consists of metamorphic schists and gneisses; (3) the Pleistocene and recent (Quaternary) alluvium; (4) ultramafic intrusives; and (5) marbles (again, see figure 3).

The Mogok gneiss is the prevalent rock unit in the region. It consists of many types of metamorphic rocks, including scapolite- and garnet-rich biotite gneisses, calc-granulites, quartzites, garnet-sillimanite–rich gneisses, and hornblende schists and gneisses. The Mogok gneiss makes up the eastern two-thirds of the area mapped by Clegg and Iyer (Iyer, 1953). The marbles, which are the host rocks of the rubies and spinels, are intimately interbedded with the Mogok gneiss. Rounded fragments of the Mogok gneiss are a major constituent of the gem gravels. Because of the heavy rainfall and tropical climate of the region, the Mogok gneiss weathers very quickly to a reddish lateritic soil, leaving only rounded boulder remnants.

The granitic intrusives in the Mogok area form most of the western third of the Stone Tract. On the detailed geologic map of Clegg and Iyer (Iyer, 1953), they consist of the Kabaing granite, an augite and hornblende granite, a syenite, and a tourmaline granite. Pegmatites containing topaz, tourmaline, and aquamarine are also included in this map unit. Many small exposures of granitic rock have been included in the unclassified crystallines of the Mogok gneiss.

Of the granitic intrusives mapped by Clegg and Iyer, the Kabaing granite is by far the most important and one of the largest rock units in the area. It is found in workings throughout the Mogok area, and much of the gravel encountered in the allu-

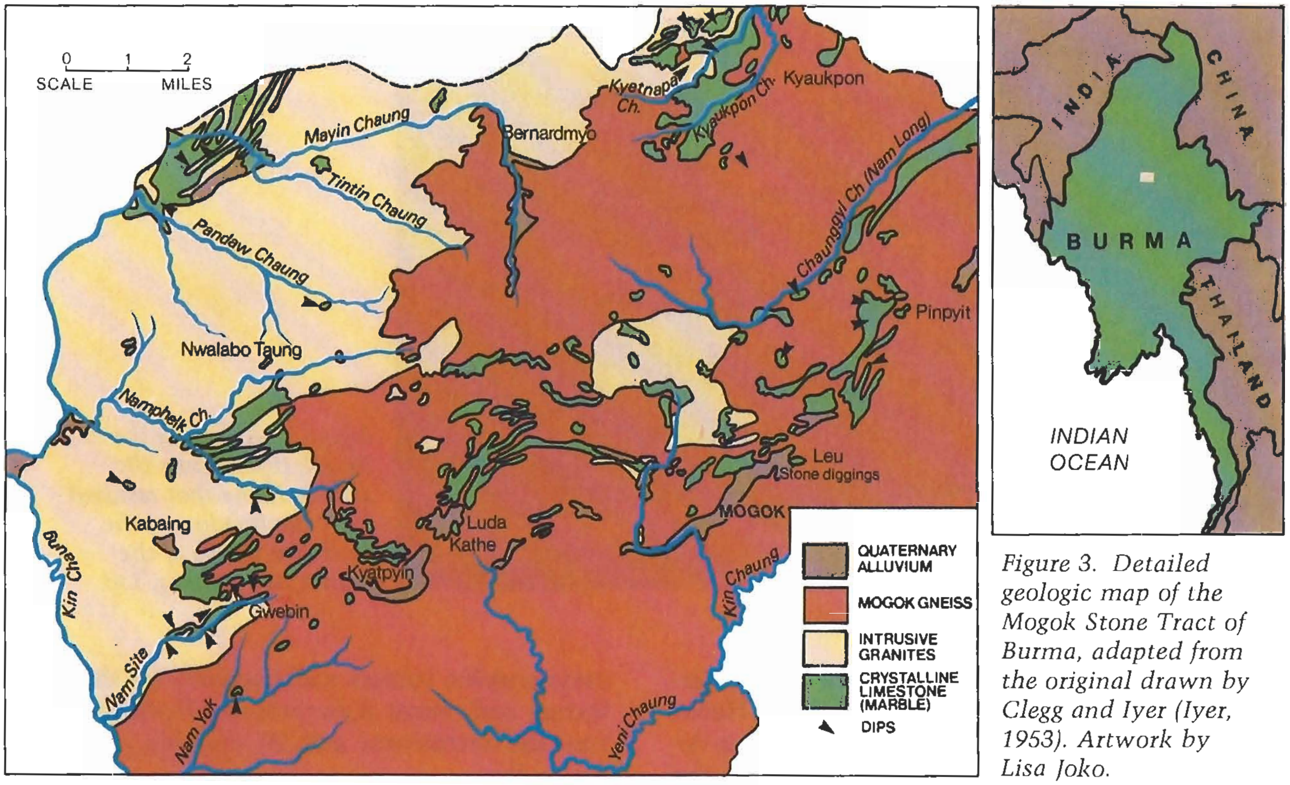


Figure 3. Detailed geologic map of the Mogok Stone Tract of Burma, adapted from the original drawn by Clegg and Iyer (Iyer, 1953). Artwork by Lisa Joko.

vium is undoubtedly derived from this granite. The Kabaing granite contains bands of marble and appears to be responsible for the contact metamorphism that formed the gem rubies and spinels of the Mogok Stone Tract.

The Kabaing granite contains numerous quartz and topaz-bearing pegmatites, with cassiterite noted in abundance in certain of these bodies. Iyer (1953) states that two topaz crystals weighing about 5 kg each were kept in the office of the Burma Geologic Survey. Such gem minerals, along with large quartz crystals, were generally sold to Chinese traders for carving.

Basic intrusives are very rare in the Mogok area, and are limited to gabbros and hornblende-pyroxene rocks, as well as to peridotites found as minor intrusive dikes and sills principally in the Bernardmyo area about 10 km north of Mogok. These rocks are of minor importance, except when they are the source of the spectacular Burmese gem peridot, which rivals that from Zabargad (St. John's Island), Egypt. The peridotite in the Bernardmyo area is a light-colored, granular rock composed almost entirely of olivine with minor pyroxene and magnetite (Iyer, 1953). In the peridot diggings, the rock is generally seen only as a series of loose, weathered boulders with serpentinization taking place along fracture surfaces. Also included as a minor map unit along with the ultramafic intrusives is a small outcrop of nepheline syenite about 12 km west of Mogok.

The marble is generally very coarsely crystallized and typically is pure white in color, although locally it may be tinged with yellow or pink. In addition to ruby and spinel, the marble contains diopside, phlogopite, forsterite, chondrodite, scapolite, sphene, garnet, and graphite. The marbles have been intruded by granitic rocks, and the effects of contact metamorphism are evidenced by the presence of feldspar and diopside in very coarse-grained portions where in contact with the granitic rocks.

La Touche (1913) included the marbles as part of the Mogok gneiss; Iyer (1953) chose to place the marbles in the "Mogok Series," restricting the Mogok gneiss to gneisses and unclassified crystalline rocks. These unclassified crystalline rocks consist of gneisses, granites, and quartz veins that, because of the thick soil horizon and dense jungle, could not be mapped as separate units.

In the valleys and on the sides of the hills, the gem-bearing gravel layer rests on a soft, decomposed rock of characteristic appearance. This gem-bearing bed consists for the most part of brown or yellow, more or less firm, clayey, and at times sandy material, known locally as *byon*

(Cecil, 1928). This layer, the residuum left by solution of the marble during weathering, contains ruby, sapphire, and other varieties of colored corundum, as well as spinel, quartz, tourmaline, feldspar grains, nodules of weathered pyrite, and other minerals of lesser importance. Rarely, a pure gem sand occurs, which consists almost entirely of minute, sparkling grains of ruby. The byon lies, as a rule, from 5 to 6 m below the surface of the valley floor, and is from 1 to 2 m in thickness, pinching off to nil. On the sides of the valley the beds of byon are as thick as 15 to 22 m. These are, of course, purely residual weathering deposits (Chhibber, 1934a).

MINING METHODS

After the departure of the British and their modern mining techniques, native mining was very active, with operations varying in size from single operators to mines employing two to three dozen workers.

The indigenous mining methods used at Mogok have been described in great detail (Simpson, 1922; Adams, 1926; Halford-Watkins, 1932; Iyer, 1953; Spaulding, 1956; Ehrmann, 1957; Meen, 1965; Gübelin, 1965). The three most common mining methods described by these authors include the *twinlon* (twin), the *hmyadwin* (hmyaw), and the *loodwin* (loo).

A twinlon, usually constructed in the dry season, consists of a small circular pit that in general is less than one meter in diameter. These pits are commonly 6 to 12 m deep, although some as deep as 30 m have been reported (Halford-Watkins, 1932). The pits are dug vertically until the gem gravel or *byon* is reached. The miners then dig laterally for about a 10- to 12-meter radius to remove the gem-bearing gravel. The pits are illuminated by means of a mirror from above. Commonly, three men are employed in a single twinlon: two men dig while the third hauls up the earth using a long bamboo crane with a basket attached (figure 4). This method is not unlike that employed at the Ban Kha Cha sapphire deposit near Chanthaburi, Thailand (Keller, 1983). Occasionally, when water is a problem, a *lebin* is constructed. A lebin consists of a square pit that is 1 to 2 m wide and reinforced with timber. Water is removed via a native-constructed bamboo pump. The recovered gem gravels are then carefully washed and sorted on the surface.

The second most common method of recovering gems at Mogok is by means of a quarry-like hmyadwin, or hmyaw. These open-pit mines are usually worked during the rainy season, since they employ hydraulic mining and require a great deal of water. A hmyadwin is dug into a hillside to a depth from 6 to 15 m. Hmyadwins are usually used continuously for 50 or 60 years because of their very complicated construction. They vary greatly in size, but the most complex is the kind that uses a series of channels to bring in water from great distances to wash the soil and gem gravels removed from open-pit mining on the hillside. The

Figure 4. A twinlon, or circular pit, from which gem-bearing gravel is removed via the basket attached to the long bamboo crane shown here.

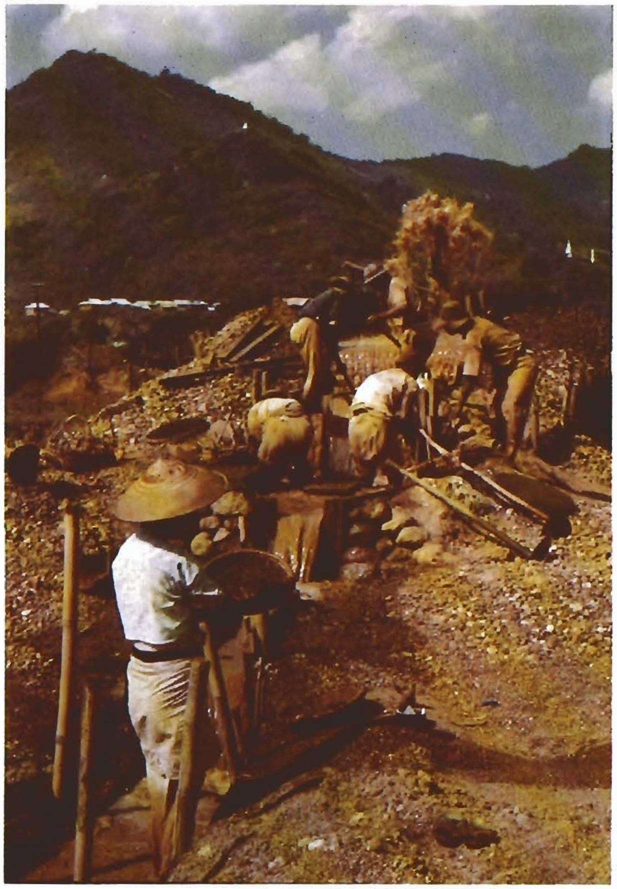


Figure 5. *A recovery and washing plant for gem gravels near Mogok.*

gravels and much lighter wastes are washed into flat circular stone pits, where the "heavies" are trapped in a series of sluices. The lighter wastes are washed into the valley below. During operation, large pebbles are picked out and discarded, and the sluices are periodically inspected for gems (figure 5).

Deep chemical weathering in the limestone areas of Mogok produces typical karst topography, resulting in numerous underground caverns which may go for hundreds of meters and contain huge chambers lined with spectacular stalactites and stalagmites. Such caverns, called loodwins or loos, may also contain some of the richest gem gravels in the Mogok Stone Tract. Unfortunately, mining in these caverns is the most dangerous of the three methods. A miner must find his way through very narrow channels in the limestone, digging in every crevice for gem gravel which he puts in a basket dragged on his foot. When the basket is full, it is brought to the surface and the gravel is washed. Because of natural concentration in the loos, such gravel may contain up to 25% ruby (Chhibber, 1934b). However, it is not uncommon for a miner to get stuck in the rocks, or lost underground. Because of this danger, as well as the depletion of accessible loos, this method has been used only rarely in recent years.

As is the practice in most of the gem-producing areas of the world, once the miner finishes processing his gravel and abandons it, it is freely available to the small independent miner (figure 6), who may reprocess it in the hope of finding overlooked

Figure 6. *As is the case in most gem-mining operations, the waste from the major mining operations is freely available to independent miners for sorting. In Burma, however, this sorting is limited to females, known locally as* kanase.

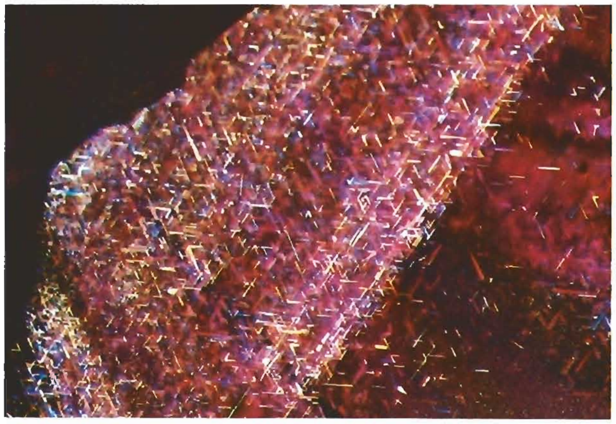


Figure 7. Exsolution crystals of rutile in a Burmese ruby. Such dense clouds of short, flattened rutile needles are commonly observed in rubies from Burma. Oblique illumination, magnified 60×. Photomicrograph by John Koivula.

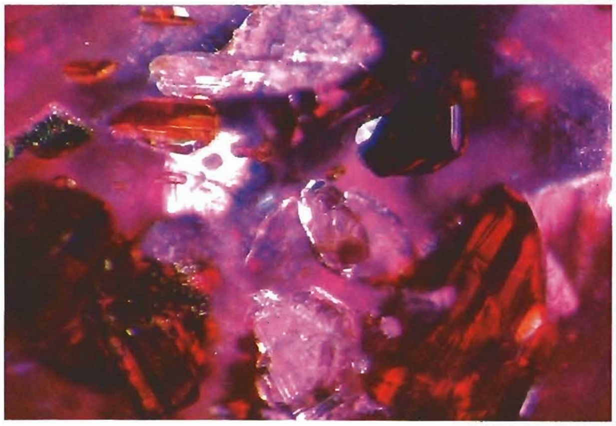


Figure 8. This characteristic inclusion scene in a Burmese ruby shows "bloody" deep red and fine, short, acicular, dust-like crystals of rutile, as well as whitish and colorless calcites, all against a color-zoned field of variable intensity. Dark-field and oblique illumination. Magnified 50×. Photomicrograph by John Koivula.

gem material. In the case of Mogok, however, only women are allowed to search for gems in such refuse. These women, called *kanase*, usually recover only enough from the debris to live on, but they have been known to recover large gems.

GEMOLOGY OF THE BURMESE RUBY

The physical and optical properties of the rubies from Mogok do not differ significantly from those listed for corundum from other sources. Anderson (1980) lists refractive indices for Burmese rubies of 1.765 and 1.773, with a birefringence of 0.008 and a specific gravity range of 3.99 to 4.00. These rubies have particularly strong dichroism, with the two colors being pale yellowish red and deep red. The Burmese material is chrome-rich, which gives rise to strong fluorescence to ultraviolet radiation and a characteristic absorption spectrum, as well as to the "pigeon's blood" color associated with Burmese stones. The absorption spectrum characteristically consists of a bright doublet in the red at 6942 Å and 6928 Å, and weaker lines in the orange at 6680 Å and 6592 Å.

Inclusions do tend to be of some use in distinguishing Burmese rubies from those of other localities. According to Webster (1980), Burmese rubies exhibit short rutile needles, parallel to each of the three parallel faces of the hexagonal prism. These needles intersect at 60° and 120°, and lie in a plane 90° from the c-axis of the crystal (figure 7). In addition, Burmese rubies may contain included crystals of rutile, spinel, or biotite. Most characteristic of rubies found in Burma are inclusions of calcite rhombs, an artifact of the marble host rock (figure 8). Both Koivula (personal communication) and Eppler (1976) have found negative crystals to be very common in Burma rubies (figure 9), and Koivula has also noted sphalerite crystals.

FAMOUS RUBIES FROM MOGOK

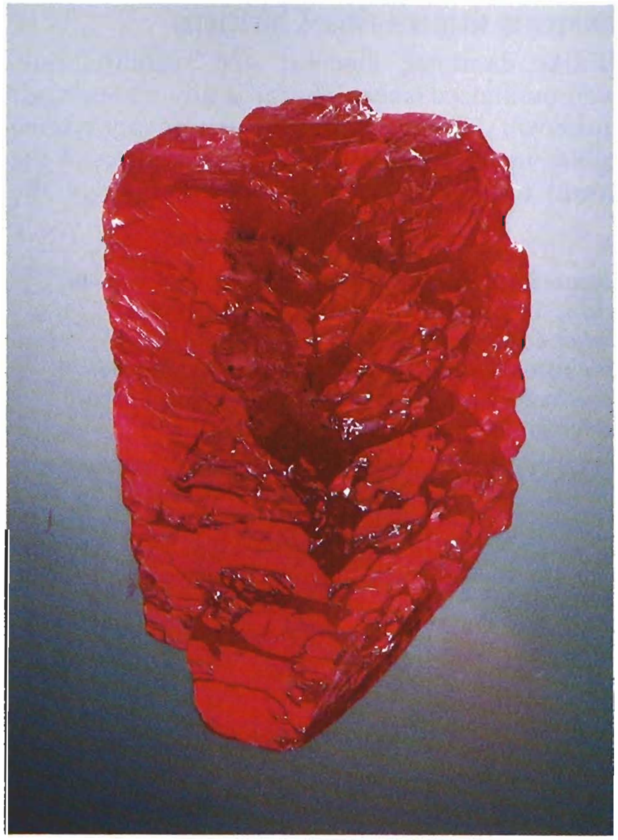
Unlike diamond, emerald, and sapphire, fine, well-publicized faceted Burmese rubies are almost unknown. There are, in fact, few if any named rubies in the museums or royal treasuries of the world today. The gemological literature of the

Figure 9. A primary negative crystal in a Burmese ruby. Such negative crystals, although somewhat common, are often mistaken for solid inclusions and therefore go unrecognized and overlooked. Shadowing, magnified 65×. Photomicrograph by John Koivula.

20th century does note a handful of stones exceeding five carats, but with the exception of two—the 43-ct Peace ruby and the approximately 40-ct Chhatrapati Manick (Clarke, 1933)—no others were significant enough to bear names, and even the whereabouts of the two named stones is unknown today.

In 1875, owing to the impoverished condition of the ruling house of Burma, two spectacular rubies were placed on the market. After cutting, these stones weighed 32.35 and 38.55 ct. Seldom have two such remarkable and perfect rubies appeared on the European market simultaneously. These two stones brought £10,000 and £20,000, respectively. At the time, many regarded this incident as only an indicator of the quality and size of the gems that the ruling houses of these Eastern empires must possess. Yet, when the British conquered and annexed Burma, they found little or no evidence of vast stores of corundum gems, although the possibility exists that all the royal gems were stolen during the conquest of the country, by both the Burmese and the English (Brown, 1934).

Figure 10. One of the finest Burmese ruby crystals ever placed on public display is this 196.1-ct etched crystal, which is now part of the permanent collection of the Los Angeles County Musum of Natural History. Photo ©1983 Harold and Erica Van Pelt.



Years later, in 1899, a 77-ct rough ruby was discovered by Burma Ruby Mines, Ltd. The most famous Burma ruby was found on Armistice Day, November 11, 1918. Two English mine supervisors spotted the stone on the washing pan and called for the mine's general manager, who subsequently named it the Peace ruby (Keely, 1982). The 43-ct crystal reportedly was purchased by a wealthy Mogok stone merchant who cut it into a 22-ct flawless stone. Unfortunately, its color tone was slightly dark and the cut gem sold for less than the dealer had paid for the crystal. Since the discovery of the Peace ruby, several stones of nearly 30 ct have been found, although none has received a special name that has been carried into the literature.

Today, fine Burmese rubies are almost nonexistent in museum collections. The British Museum of Natural History at South Kensington displays the 167-ct Edwardes ruby crystal, which was given to that museum by John Ruskin in 1887 (Spencer, 1934). The crystal is not of faceting quality, but must be considered one of the more important Burmese rubies surviving today. The Los Angeles County Museum of Natural History displays

Figure 11. This 15.97-ct cushion-cut ruby from the Mogok Stone Tract is considered to be one of the finest Burmese rubies known today. Property of Alan Caplan, New York City. Photo by Morris Lane.

the 196.1-ct Hixon ruby. This highly etched crystal is of superb color and possesses unusually complete crystal form (figure 10). Alan Caplan, a New York gem dealer, has a magnificent 15.97-ct faceted Burma ruby that many believe is one of the finest rubies of its kind. It is exceptionally free of flaws and has the classic "pigeon's blood" color (figure 11). It was displayed recently at the American Museum of Natural History in New York.

CONCLUSION

The Mogok Stone Tract is a classic example of the uncertainties inherent in the mining of colored gems. This deposit has been known to produce relatively large amounts of rubies of the finest quality. In addition, the geology of the area and the slowness of the relatively primitive mining methods suggest that the supply of Mogok rubies should be far from depleted. Yet fine Burma rubies are rarely encountered in today's gem markets and the number of rubies offered at the annual gem emporium in Rangoon appear to have dwindled to insignificance because of the political uncertainty of that area of the world. It remains to be seen whether the true potential of the Mogok area will ever be realized.

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NOTES
· AND ·
NEW TECHNIQUES

INDUCED FINGERPRINTS

By John I. Koivula

Over the past few years, numerous Verneuil-type (flame fusion) synthetic sapphires and rubies with somewhat natural-appearing induced fingerprint inclusions have surfaced in the trade. This article reports the results of a series of experiments conducted to explain the phenomenon of induced fingerprints and how they are produced in gemstones generally and in flame-fusion synthetic corundum specifically.

Since 1980, the presence of somewhat natural-looking fingerprint inclusions in flame-fusion synthetic corundums has haunted the colored stone industry. After the first report in the literature (Crowningshield, 1980) of this new treatment, a number of treatment-related articles appeared in various gemological and jewelry trade publications. These articles detailed most of the treatment processes, such as diffusion, used on rubies and sapphires, but they only briefly mentioned induced fingerprints. In two excellent articles on heat and diffusion treatment of natural and synthetic sapphires (Crowningshield and Nassau, 1981; Nassau, 1981), the mechanisms used to induce fingerprints are described as unknown. However, the statement by Nassau (1981) that "according to some unsubstantiated reports, a flux-type chemical such as sodium carbonate or borax may assist in this process" provided an important clue to the production of induced fingerprints. Another important clue is given by C. R. Beesley (1983), who stated that "an outgrowth [of heating synthetic sapphire] was to induce fractures from the surface of the material [synthetic sapphire], then force some material into the fractures which could be almost crystallized during heating. This gives the appearance of a natural fingerprint." The statement concerning the fractures induced from the surface is significant (although the comment about some material being forced into the fractures which could be *almost* crystallized during heating, is confusing at best).

To better understand and clarify the mystery surrounding "induced fingerprints," the author performed a series of "before and after" heating experiments on flame-fusion rubies that were based on observations made on natural fingerprints and those found in flux and hydrothermally grown synthetic gemstones. The results of these experiments are reported below.

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Acknowledgments: The author is most grateful to Thomas H. Chatham of Chatham Created Gems, San Francisco, who, through his cooperation in the healing experiments, proved the author's theory. Mark Mann, supervisor of the GIA Jewelry Arts Course, was very helpful in the fusion fingerprint experiment. Thanks are also extended to Chuck Fryer, GIA Santa Monica, for helpful discussions; to Robert Kane, Gem Trade Laboratory, Inc., Los Angeles, for the study-loan of two flux-healed flame-fusion synthetic rubies with induced fingerprints; to William Kerr, GIA Santa Monica, for faceting the crystal after regrowth; and to Ruth Patchick for typing this manuscript. Lisa Joko prepared the line drawings. All photographs, unless otherwise captioned, are by the author.

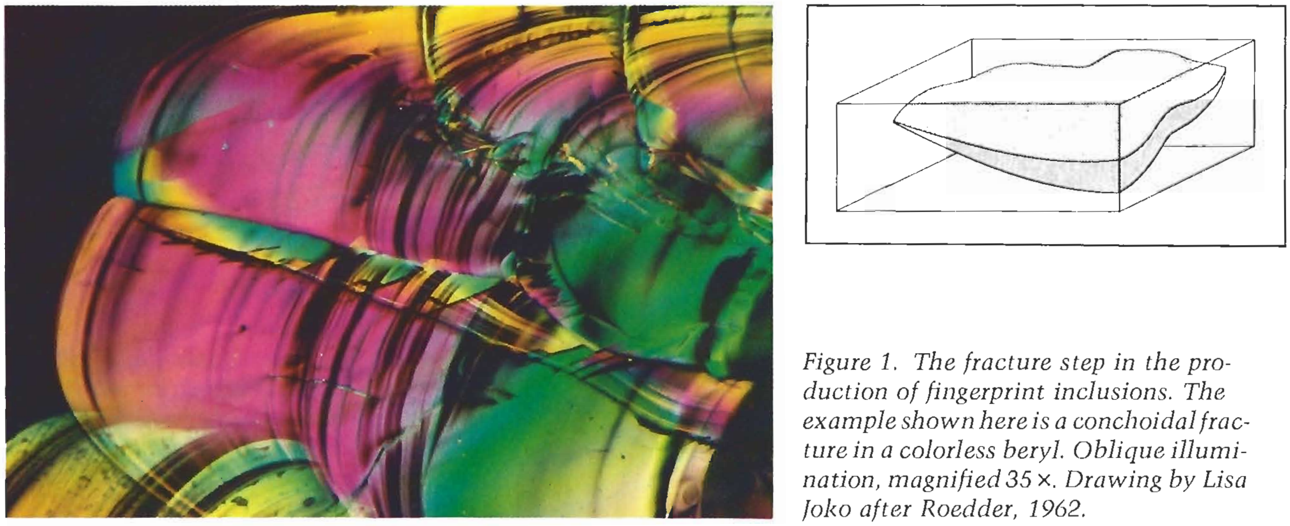


Figure 1. The fracture step in the production of fingerprint inclusions. The example shown here is a conchoidal fracture in a colorless beryl. Oblique illumination, magnified 35×. Drawing by Lisa Joko after Roedder, 1962.

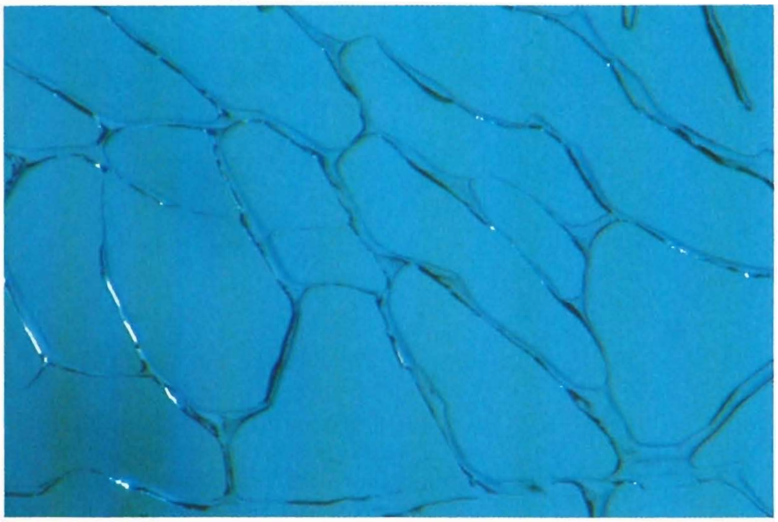
HOW DOES A FINGERPRINT INCLUSION FORM?

The most important clue to understanding induced fingerprints lies in the very name we have given them. In both natural and synthetic gemstones, fingerprint inclusions have been induced, that is, stimulated by internal and external forces acting on the crystallized host material. The mechanism behind natural fingerprints is well documented in the literature (see, for example, Eppler, 1959, 1966; and Roedder, 1962, 1982). This knowledge of how the process occurs in nature is helpful to our understanding of the synthetic production of similar inclusions.

When a crystal is fractured (figure 1), the fracture instantly becomes a vacuum, drawing in whatever surrounds it to alleviate the negative pressure. Capillarity provides further impetus in drawing fluids into the break. If the crystal is even slightly soluble in the fluids surrounding it, repair of the fracture will begin immediately. The more kinetic energy, in the form of heat, supplied during the healing process, the faster the fracture will heal. Heat is (1) generated by sources outside the crystal, such as igneous or metamorphic activity or the heat generated by pressure commonly associated with burial at depth in the earth; and (2) released by the crystal itself, as it seeks to regain crystallographic equilibrium (upset by the increase in potential energy of the fracture zone created by the additional surface area exposed) and return to a lower energy state.

Provided the fractured crystal is in a repair environment, as it starts to heal itself individual atoms or groups of atoms will leave an area of high energy on the fracture surface and redeposit on a surface of lower energy, releasing their heat of crystallization in the process. Molecule by molecule this process continues. Material is dissolved from both the convex and flat portions of the fracture walls and redeposited in the concave areas, gradually trapping small volumes of the repair fluid. Trapping occurs between recrystallized walls, pillars, and columns that have formed, like the adjoining stalagmite and stalactite pillars in a cavern, between the opposing surfaces of the fracture. These fluid islands are often interconnected by a series of fine tubes termed *communication tubes*. So many of these communication tubes may be interconnected that a fishnet-like pattern results. This intermediate stage in the healing process is shown in figure 2.

If healing continues, the communication tubes will gradually thin out in certain areas, gain volume in others, and eventually separate into numerous smaller fluid-filled cavities all lined up along the original path of the pre-existing communication tube. This process is called necking down. Necking down continues throughout the entire original fracture zone, as numerous smaller fluid inclusions are formed from a few larger ones. Ultimately we are left with a uniformly arranged grouping of small fluid-filled voids that occupy the same space as the original fracture. The resulting healed fracture has now taken on the appearance of a "fingerprint," composed of numerous dots or islands. Each of the dots that so geometrically make up the total fingerprint is in fact a separate and distinct fluid inclusion, as portrayed in figure 3. The process of forming a fingerprint inclusion in any crystalline material, synthetic or natural, should be the same. The environment of growth



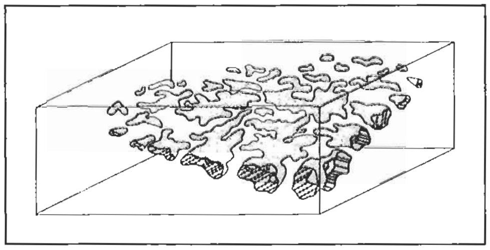


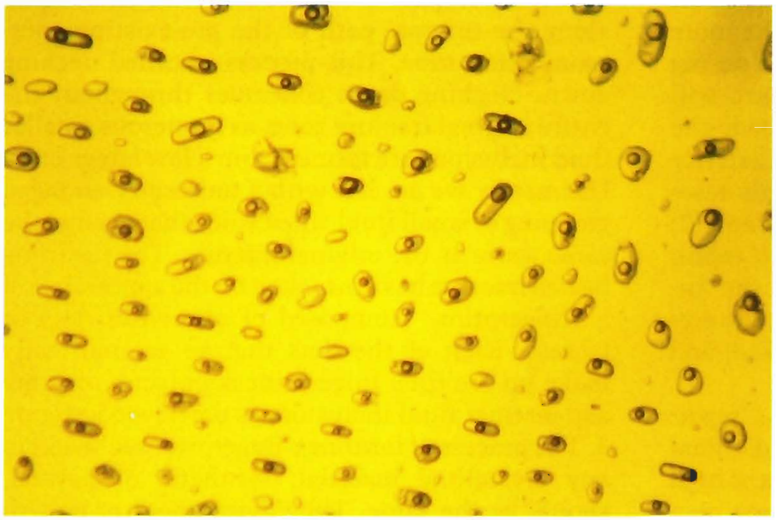
Figure 2. This aquamarine illustrates the intermediate, communication-tube-forming stage in the healing of fractures. Transmitted and oblique illumination, magnified 60×. Drawing by Lisa Joko after Roedder, 1962.

and the fluids used to transport the atoms required to heal a fracture may be different, but the step-by-step process, as shown in figures 1 through 3, does not change.

THE THEORY BEHIND THE FORMATION OF INDUCED FINGERPRINTS IN FLAME-FUSION SYNTHETICS

All gemologists have studied fingerprint inclusions in natural gemstones, as well as in flux and hydrothermally grown synthetics. But gems synthetically grown from a melt by the Verneuil flame-fusion method or by the Czochralski crystal-pulling process are not products of environments that produce crystals with healed fractures. Yet synthetic corundums cut from Verneuil and Czochralski melt crystals containing induced fingerprints have been mistakenly purchased as the more expensive flux synthetic rubies, and even as natural rubies and sapphires. Quite often parcels of corundums will be found to contain some of these synthetics with induced fingerprints. How are fingerprint inclusions placed in such synthetic crystals?

Corundum is corundum regardless of the environment in which it is grown. If we were to take a gem cut from a synthetic melt crystal and thermally shock it to produce fractures, then place it in a synthetic growth environment, such as a flux-growth bath, surrounded by a fluid in which the corundum is at least partially soluble, the induced fractures should, over a period of time, heal themselves, turning into induced fingerprint inclusions. The following experiments were carried out to test this theory.



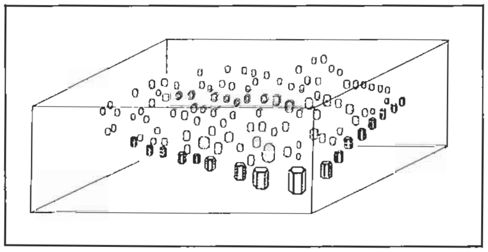


Figure 3. A golden beryl demonstrates the third and final step in fingerprint formation. Now the communication tubes have necked down to form individual fluid inclusion islands. Transmitted light, magnified 100×. Drawing by Lisa Joko after Roedder, 1962.

PRODUCTION OF INDUCED FINGERPRINTS

Verneuil material (figure 4) was selected for testing because it was more readily available than the Czochralski pulled synthetic. A flat, windowlike configuration was chosen for the experimental synthetic rubies because of the ease with which they could be studied under the microscope. Three subjects were heated and then quench-crackled in cold water, resulting in badly fractured slabs. One of these is illustrated in figure 5.

Each of the three fractured synthetic rubies was then designated for a separate experiment as follows: (1) fingerprints induced through flux healing (the most important of the three experiments), (2) fingerprints induced by secondary fusion, and (3) induced chemical dendrites.

A SIMPLE EXPERIMENT FOR INDUCING FINGERPRINT INCLUSIONS

There is a simple experiment that anyone can do to test the mechanism of fingerprint formation and actually observe the step-by-step repair process first hand. All that is needed is water, a good supply of a highly water-soluble salt such as alum or sodium chloride (common table salt), at least one transparent single crystal of the chosen salt weighing 2 ct or more that you have studied carefully under the microscope before beginning the experiment, and a source of heat such as a kitchen stove. First, prepare a boiling supersaturated solution of the salt in water. Pour only the liquid portion off, leaving the excess undissolved salt behind. While keeping the solution very hot, supercool your test crystal(s) using a freezer, an alcohol and dry ice solution, or, if you have access to a cryogenically liquefied gas such as liquid nitrogen, use that.

Once the crystal(s) are very cold and the solution is hot, plunge the crystal(s) into the solution. This will cause the crystal(s) first to fracture in the growth-nutrient-rich salt solution and then to begin healing virtually immediately. Now allow the solution to cool gradually. At first some dissolving of the crystal(s) surfaces may be noticed, but quickly the process will reverse itself and the crystal(s) will begin growing. Remove the crystal(s) from the solution periodically and study them under the microscope. Fingerprint inclusions will be observed forming where the fractures once were.

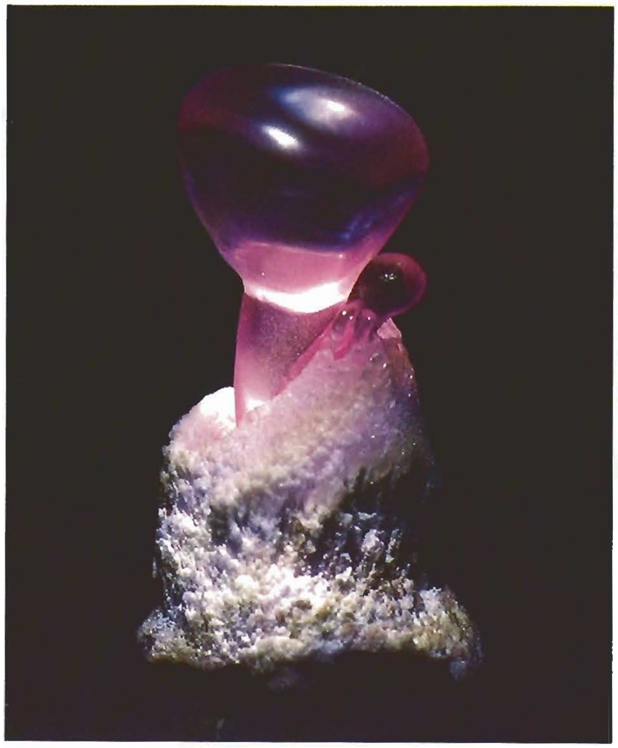


Figure 4. A flame-fusion synthetic ruby boule similar to the material used in the experiments. Photo by Mike Havstad.

Fingerprints Induced Through Flux Healing. After carefully documenting the appearance of the fractured synthetic rubies (again, see figure 5), the author mailed one of the stones to Thomas H. Chatham, president of Chatham Created Gems, in San Francisco. Mr. Chatham had volunteered to place this test subject in a flux-growth environment in an attempt to heal the fractures. A platinum wire affixed to the synthetic ruby slab provided a convenient means of transporting the test subject into and out of the growth chamber. The regrowth time was 42 days (Chatham, personal communication, 1983). The result is shown in figure 6. Note the remnants of the platinum wire at the base of the crystal.

To prepare the regrown mass for study, the author first sawed off the two ends and then had them polished so the thickness of the overgrowth could be observed (figure 7). Already it was apparent that fingerprints were present throughout the overgrown Verneuil subject. Next the crystal was

Figure 5. A quench-crackled synthetic ruby window used for flux healing (14.2 × 12.0 × 3.0 mm). Photo by Mike Havstad.

Figure 6. Verneuil synthetic ruby slab after flux regrowth for 42 days (20.7 × 16.8 × 7.6 mm). Note the platinum wire at the base. Photo by Mike Havstad.

completely faceted and the induced fingerprints were studied. Although it was no longer possible to locate the exact configuration of fractures shown in figure 5, any number of induced fingerprints were available for photomicrography. One of these is shown in figure 8 together with the curved striae characteristic of the synthetic material. The author also examined two other large Verneuil boule sections with flux ruby overgrowths prepared by Chatham Created Gems (figure 9). These were found to contain numerous flux regrowth induced fingerprints as well.

Inducing Fingerprints by Secondary Fusion. In the second experiment, to see if heat alone could induce pseudo-healing, one of the prefractured synthetic rubies was placed on a charcoal block and a jeweler's torch was used to melt and recrystallize it several times. Although the overall appearance of the melted mass was not an attractive sight, and on cooling numerous additional unwanted fractures appeared, a few somewhat fingerprint-like inclusions were observed.

Induced Chemical Dendrites. The third and last experiment resulted from observations, by the author, of a flame-fusion ruby that had fractures decorated by a crystalline chemical with a melting point just over 100°C. This low melting point made it possible to melt and recrystallize the contents of the fractures until a desirable, somewhat

Figure 7. Cross-sectional view through the end of the experimental synthetic ruby illustrated in figure 6. Note the outline of the flux ruby layer over the flame-fusion core. Some fingerprints are visible even at this low magnification. Oblique and transmitted light, magnified 5×.

Figure 8. Induced flux fingerprint produced through experimentation in a Verneuil flame-fusion synthetic ruby together with the characteristic curved striae. Shadowing, magnified 45×.

natural-appearing dendritic form was obtained.

The low melting point of this unknown chemical suggested that it might be organic in nature. Although the author had access to two organic crystalline compounds with similarly low melting points, acetanilide (melting point, 114°C; boiling point, 304°C) and resorcinol (melting point, 111°C; boiling point, 178°C) acetanilide was chosen for the experiment because of its greater melting point to boiling point spread and, therefore, less crucial temperature control.

The prefractured synthetic ruby was heated over a Bunsen burner to create a vacuum in the fractures through rarefaction. The heated ruby was then quenched in enough premelted acetanilide, contained in a test tube, to completely submerse the ruby. The acetanilide was allowed to crystallize and then was remelted and poured off. The ruby was cleaned and then studied under the microscope. One of the resulting patterns decorating the fractures is reproduced in figure 10.

WHO PRODUCES THESE SYNTHETICS WITH INDUCED FINGERPRINTS?

On the basis of the author's observations, it is likely that those synthetic rubies and sapphires that appear in the trade with induced fingerprint inclusions, such as the one shown in figure 11, are probably not healed in a well-controlled flux-growth furnace. Rather, they are probably the sometimes accidental result of clever but often crude heat treatments carried out, both in Thailand and Sri Lanka, on synthetic rubies and various colors of synthetic sapphires in the attempt to dissipate the curved color and growth zoning.

During heat treatment in these countries, it is

Figure 9. Two Verneuil flame-fusion ruby boule sections with a thin flux ruby overgrowth. Both of these samples contained numerous induced fingerprints. The largest sample is approximately 5 cm long. Photo by Mike Havstad.

Figure 10. Acetanilide chemical stain decorating a fracture plane in a Verneuil synthetic ruby. Dark-field and oblique illumination, magnified 80×.

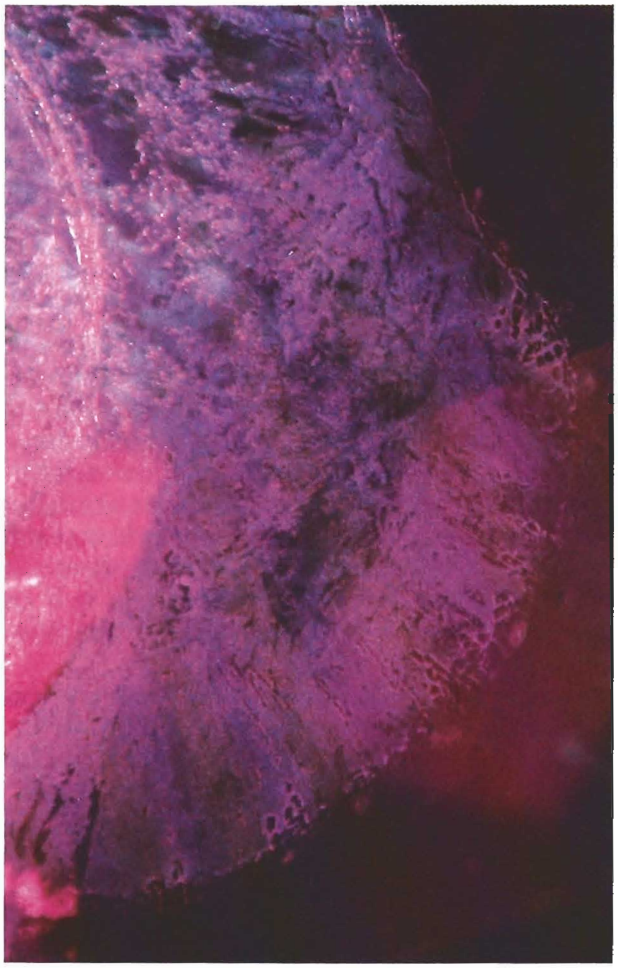


Figure 11. Borax (?) induced fingerprint in a flame-fusion synthetic sapphire. Dark-field and oblique illumination, magnified 65×.

common practice to use borax or a borax-based solution, purportedly on the outside of the crucible holding the stones (Abraham, 1982). Any skilled bench jeweler or gemologist knows that corundum becomes soluble in borax at elevated temperatures. That is to say, borax acts as a flux to the corundum; it is an agent capable of promoting quick healing in any fractures—whether placed accidentally or on purpose—that may be present. The mechanism of fracture repair at work in these cases is the same three-step process described earlier for natural stones.

IDENTIFYING GEMS WITH INDUCED FINGERPRINTS

For some time gemologists have known that unless one is very skilled in the study of inclusions, it is no longer possible to say a gemstone is natural merely because it contains fingerprint inclusions. Now, however, with the presence of induced fingerprints in Verneuil and Czochralski synthetic corundum, the question is not only whether the gem is natural or synthetic, but if it is synthetic, is it a more costly flux-grown synthetic or is it an upgraded flame-fusion or pulled synthetic with induced fingerprints?

There is no question that recognizing induced fingerprint inclusions can be a problem. When fingerprint inclusions that reach the surface are the only immediately observable internal characteristics, be suspicious. Check the gem in question for color zoning both by diffused transmitted light and by immersion in methylene iodide. The presence of curved color zoning together with fingerprint inclusions would tell you that the fingerprints have been induced into a synthetic stone. The presence of curved striae in conjunction with fingerprint inclusions in synthetic rubies and some synthetic sapphires is a sure sign that a flame-fusion gem has been doctored. Gas bubbles are another clue to the less expensive synthetics.

With the above clues, treated synthetic rubies and sapphires grown by the Verneuil flame-fusion process are easily spotted. However, gems cut from Czochralski pulled crystals rarely have any recognizable inclusions: quite often they are essentially flawless. Therefore, gems with fingerprint inclusions that are otherwise flawless should be treated with the highest suspicion. Straight or sharply angular growth and color zoning and recognizable included crystals are important clues that a gem is not a melt-grown Verneuil or Czochralski synthetic.

CONCLUSION: WITH THOUGHTS TO THE FUTURE

Of the three experiments conducted, experiment 1, regrowth in a flux environment, performed at the Chatham laboratories in San Francisco, was by far the most successful.

Although the introduction of organic chemical dendrites into pre-existing fractures proved both successful and interesting, the dendrites achieved in experiment 3 in no way resembled or could be mistaken for fingerprint inclusions. Problems could result, however, for gemologists who, in the past, have considered dendrites a sign of natural origin. The attempt to produce fingerprints through secondary fusion met with very little success. Although some inclusions were produced that slightly resembled fingerprints, they were few and far between, and were always accompanied by numerous unrepaired fractures, areas containing large gas bubbles, and zones of translucent cloudy material. Or, in a few words, they were useless as gemstones. However, flux regrowth was, as expected by the author, a complete success. All of the fractures showed fingerprint-healing patterns. Once the regrowth layer was removed, the remaining material, containing the induced fingerprints, could easily have been cut into gemstones.

Possible future applications for this and similar techniques are interesting, to say the least. If the technology that exists to repair fractures today is further refined, we might someday encounter synthetically repaired natural gem materials.

In his excellent book *Gems Made By Man,* Kurt Nassau shows before and after photographs of a Japan-law twin of quartz that was broken and subsequently successfully repaired synthetically by Giorgio Spezia . . . the year was 1908. In more recent work (Shelton and Orville, 1980), synthetic fingerprint inclusions were produced hydrothermally in natural quartz. Imagine in the future if we had the ability to hydrothermally repair a ruby, emerald, or sapphire that had been accidentally fractured during setting, repair, or cutting. Surely a fingerprint inclusion is infinitely more desirable—and infinitely more durable—than a fracture.

In spite of the future potential for good, the logical application today of induced fingerprints is to upgrade less expensive Verneuil flame-fusion and Czochralski pulled synthetic corundums so that they may be sold to the unsuspecting trade either as more costly flux-grown synthetics or even as natural gems.

Because of this, induced fingerprints, whether intentionally or accidentally produced, represent a type of treatment that must be disclosed. A treatment of this type should concern not only the gemologist and the jeweler, but also those involved in the flux growth of synthetic gems as well, because the presence of such a treated material on the market could seriously undermine the sale of their products. It is only through mutual cooperation between gemologists and crystal growers that such a problem can be dealt with.

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COBALT GLASS AS A LAPIS LAZULI IMITATION

By George Bosshart

A necklace of round beads offered as "blue quartz from India" was analyzed by gemological and additional advanced techniques. The violet-blue ornamental material, which resembled fine-quality lapis lazuli, turned out to be a nontransparent cobalt glass, unlike any glass observed before as a gem substitute. The characteristic color irregularities of lapis (white in blue) had been imitated by white crystallites of low-cristobalite included in the deep blue glass.

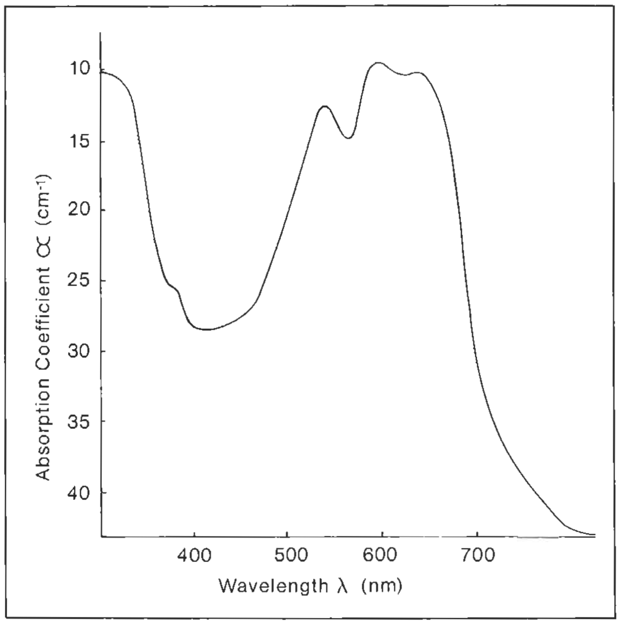

Figure 1. Absorption spectrum of a cobalt glass imitating lapis lazuli recorded through a chip of approximately 1.44 mm thickness in the range of 820 nm to 300 nm, at room temperature (Pye Unicam SP8-100 Spectrophotometer).

The gemological world is accustomed to seeing gemstones from new localities, as well as new or improved synthetic crystals. With this in mind, it is not surprising that novel gem imitations are also encountered. One recent example is "opalite," a convincing yet inexpensive plastic imitation of white opal manufactured in Japan. This article describes another gem substitute that recently appeared in the marketplace.

Hearing of an "intense blue quartz from India" was intriguing enough to arouse the author's suspicion when a necklace of spherical opaque violet-blue 8-mm beads was submitted to the SSEF laboratory for identification. Because blue quartz in nature is normally gray-blue as a result of the presence of TiO_2 (Deer et al., 1975, p. 207) or tourmaline fibers (Stalder, 1967), this particular identification could be immediately rejected. Although synthetic cobalt-colored quartz exists, thus far it has been produced only in a transparent form. The beads of the necklace we examined resembled more closely a fine lapis lazuli, with the characteristic color irregularities of lapis, yet they displayed a tinge of violet exceeding that of top-quality lapis and they contained no pyrite grains. Accordingly, a series of gemological and other tests were conducted to determine the precise nature of this unusual material.

RESULTS OF GEMOLOGICAL TESTING

The properties compiled in table 1 clearly indicate that the material is not lapis lazuli or any other natural material, but rather a man-made cobalt-colored substance, apparently a glass. While the refractive index of the tested material (1.508) does not differ markedly from that of lapis (approximately 1.50), its specific gravity of 2.453 is significantly lower than the average for lapis (approximately 2.80). The absorption spectrum (figure 1) differs from that of a blue-filter glass only by its slightly stronger iron peaks and by a shift in the ultraviolet absorption edge from approximately

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TABLE 1. Properties of a cobalt glass imitating lapis lazuli.

Property	Description
Color	Violetish blue of strong saturation
DIN 6164 color indices[a]	15½ : 6 : 4 (hue, saturation, darkness)
Degree of transparency	Opaque to semitranslucent (in thin sections, translucent to transparent)
Absorption (recorded at room temperature)	Strong bands at 642, 592, 535 nm (cobalt); faint bands at 490, 438, 378 nm (iron)
U.V. fluorescence	Long-wave: extremely weak Short-wave: absent
Refractive index, n_D	1.508 on a section (spot readings slightly lower)
Optical character	Isotropic (in thin sections: anomalous extinction)
Luster	Vitreous (slightly silky sheen on inclusions)
Apparent porosity	Nonporous
Specific gravity (4°C)	2.453 (one specimen)
Surface	Smooth, spherically molded
Surface of fractures	Conchoidal to almost flat, with fine structure
Luster of fractures	Waxy to vitreous
Streak, scratch	Both white
Mohs hardness	Approximately 5½
External characteristics	Regular circular shrinkages around drillholes, few subspherical depressions (molding marks?), and several filled angular cavities on bead surfaces
Internal characteristics	White crystallites of micrometer size forming dendritic and large radiating to stellate patterns, in most cases surrounded by transparent blue areas and emanating from a grainy center
Reaction to heat	None to thermal test tip
Reaction to ferromagnetism	None
Reaction to diluted HCl	None
Chemical elements	Si; Ca, Ti, Mn, Fe, Co, Cu, Zn, As (as detected by energy-dispersive X-ray fluorescence)

[a] *West German color chart system on the basis of C.I.E. illuminants.*

290 nm to 320 nm (also the result of trace amounts of Fe). It must be stressed that the peak positions and intensities visually observed with the spectroscope partially deviate from the recorded spectrometer data provided in figure 1. With the spectroscope, the bands were seen to be centered at about 660 nm (strong), 585 nm (medium, narrow), and 530 nm (medium strong, very wide, asymmetric). Apart from the band at 490 nm (very weak), no other faint iron bands, recorded by the spectrometer, were detected with the spectroscope.

The photographs in figures 2 and 3, taken in reflected light, show bands and aggregates of white inclusions that are essentially of two types. One is a flat dendritic or fernlike array (similar to that in figure 9, "metajade," of Hobbs, 1982). The other consists of planes in radiating to stellate patterns similar to coral septa, with the planes perpendicular to the bead surface, indicating that the glass was annealed. In contrast to the macroscopic appearance of the material, the inclusion patterns seen under magnification are completely different from the aggregates of small blue, white, and frequently metallic yellow grains commonly seen in lapis lazuli. In figure 3, shallow depressions on the spherically molded glass can be recognized, and are in part filled with a white, grainy material that evidently had never melted. However, true bubbles or swirls were not detected, although the glass was observed with the microscope to be fairly transparent around the white inclusions. The inclusions themselves ranged in size from a few micrometers for the tiny white grains that form the two types of aggregates to approximately 3 mm for the longest septa and several millimeters for the ferns.

CHEMICAL AND X-RAY DIFFRACTION DATA

According to Bannister's diagram for conventional glasses (Webster, 1975, p. 386), a calcium or even a borosilicate glass could account for the refractive index and specific gravity determined, but no reference to this particular lapis-imitation glass was found in the gemological literature (Crowningshield, 1974; Farn, 1977; Schiffmann, 1976; Webster, 1975; and footnote below*; although

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**A very old, if not the oldest, artificial lapis-like material dates back to pre-Christian times, when Egyptians sintered calcite, quartz, malachite, and azurite to create a brilliant blue substance that is now called "Egyptian blue." In ancient Egypt this material was used for scarabs, to ornament royal tombs, and, in powdered form, as a pigment and cosmetic. The chemical composition of "Egyptian blue" is close to, and its crystalline structure identical with, the mineral cuprorivaite, CaCu [Si_4O_{10}] (G. Bayer, personal communication). The production of this material was made particularly successful through the application of lead oxide or alkali fluxes. If less Ca and Cu, but more alkalis, were used, a well-melted transparent-to-opaque glass (colored by Cu alone, or by Cu, Co, and Fe) would result (Bayer and Wiedemann, 1976).*

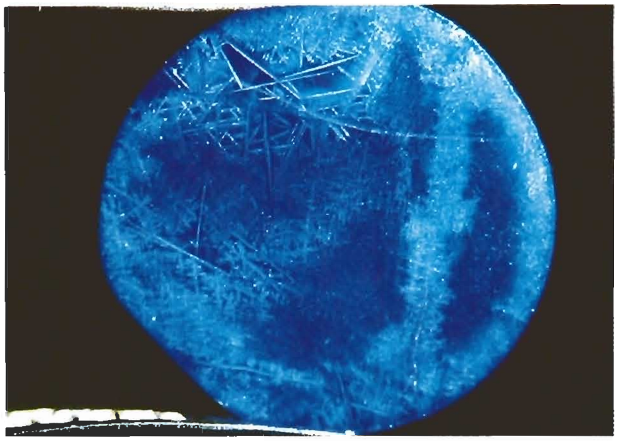

Figure 2. White bands and radiating septa of low-cristobalite in a devitrified, opaque cobalt-glass bead imitating lapis lazuli. Section through bead in reflected light; magnified 6× (Wild M8/MPS55).

Figure 3. Dendritic and radiating patterns of white low-cristobalite exsolutions and essentially transparent blue areas in a cobalt-glass bead imitating lapis lazuli. Reflected light, magnified 13× (Wild M8/MPS55).

Nassau, (1980), reported a pyrite-lapis imitation made of another blue specialty glass that contains copper crystals, similar to a "goldstone"). Chemical data, nowadays readily available through nondestructive energy-dispersive X-ray fluorescence (XRF-EDS; Stern and Hänni, 1982), were certainly of interest in this case. Figure 4 exhibits no fewer than eight metallic element signals in addition to the strong silicon peak. When the AgL series produced by the silver tube radiation was successfully masked by a filter, the intensity of the Si peak was greatly reduced and an additional peak due to potassium was resolved, providing for the identification of at least nine metal oxides ad-

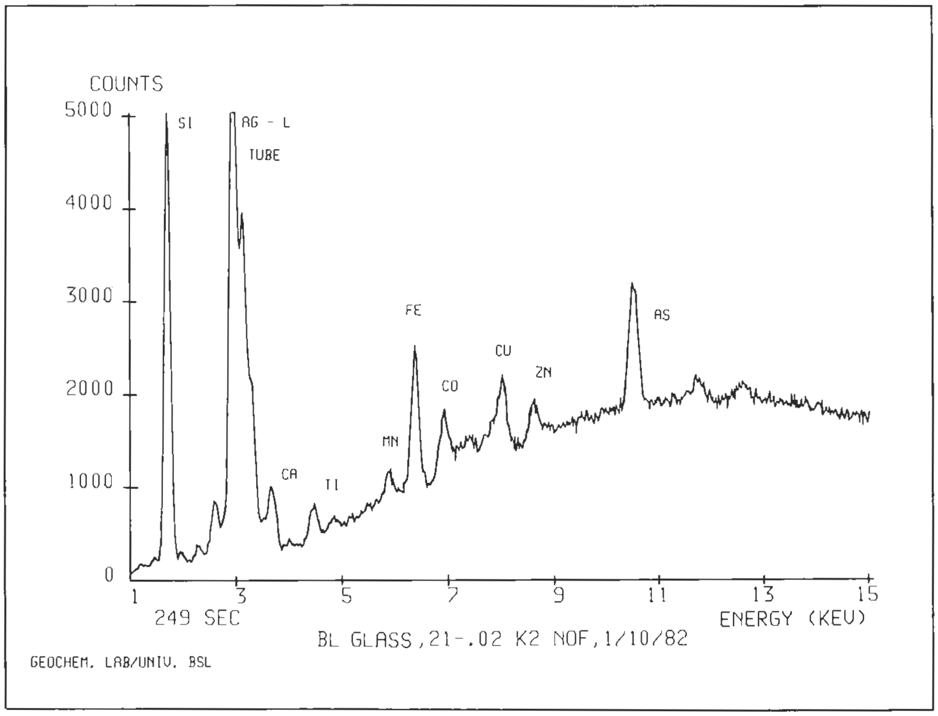

Figure 4. Unfiltered energy spectrum of a specialty cobalt glass imitating lapis lazuli; counting time 249 seconds (Tracor Northern 1710 X-ray Fluorescence Spectrometer).

mixed to the SiO_2 glass. Although boron cannot be detected by XRF-EDS analysis, the fact that the beads examined had a Mohs hardness of less than 6 (which is low for a borosilicate glass) would suggest that boron is not present in this material in significant amounts.

X-ray diffraction (XRD) provided the net identification of *alpha-cristobalite.* The X-ray film showed 12 sharp lines in appropriate identifying positions and relative intensities (JCPDS Powder Diffraction Data, 1974). The four strongest lines (with their estimated intensities indicated in parentheses) were at 4.05 Å (100), 3.14 Å (10), 2.84 Å (10), and 2.48 Å (20). Cristobalite is the only crystalline phase found in the glass. The mineralogical literature (Deer et al., 1975, etc.) describes natural alpha-cristobalite as the metastable low-temperature polymorph of SiO_2, with a tetragonal (pseudocubic) structure, a specific gravity of 2.32–2.36, and refractive indices of 1.484 (e) and 1.489 (o). Low-cristobalite is known to exsolve from certain glass types through a devitrification process. The degree of order in the low-cristobalite lattice depends on its thermal genesis.

CONCLUSION

The cobalt glass described in this article is the best glass imitation of lapis lazuli that this author has seen to date (see also Webster, 1975, p. 221). Although lapis lazuli was immediately eliminated as a possible identification, the results of the investigation were unexpected because:

- Glasses are not generally associated with opaque solids.
- The macroscopic appearance of the glass was confusing.
- No bubbles or swirls could be detected in the material studied.

The most diagnostic gemological property (considered along with the refractive index and specific gravity appropriate to a glass) is represented by cristobalite exsolution patterns seen under slight magnification. In this instance, the identification was secured beyond any doubt by the advanced techniques of spectrophotometry, XRF-EDS, and X-ray diffraction.

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Gem Trade LAB NOTES

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CORUNDUM, More on Heat Treatment

We have been told that conservative gem traders in Sri Lanka have been reluctant to start heat treating their own "geuda" corundum, fearful of the impact this would have on the market for blue and yellow sapphires mined on the island. However, the heat treatment activities of Thai operators using the "geuda" have already placed the Sri Lankans in competition with themselves for these colored sapphires. A new gas oven from Japan that can be used with either a reducing flame (for blue sapphires) or an oxidizing flame (for rubies and yellow/orange sapphires) could encourage heat treatment of corundum in Sri Lanka.

Although heat treatment is virtually undetectable in some corundum, occasionally we see a stone that shows obvious signs of treatment. The New York laboratory recently examined an unusual sapphire cabochon that was approximately 90% colorless and had a thin band of dark blue color on its base (figure 1). The fact that the stone fluoresced chalky green in bands when exposed to short-wave ultraviolet radiation, and that the base exhibited "heat" craters with no "bleeding" (figure 2), indicates that the stone was heat treated rather than diffusion treated. Figure 2 also shows the even appearance of the color when viewed face up.

A 2.55-ct natural ruby of excellent color that was recently offered at auction also showed unmistakable signs of heat treatment. Unfortunately, the treatment caused severe internal fracturing, and one whole side of the pavilion (including the culet) had chipped away (figure 3). The stone looked pleasant enough table up, but could not stand scrutiny.

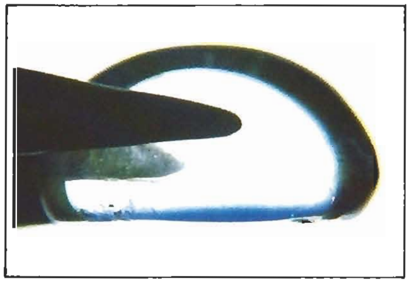


Figure 1. A thin band of blue on an otherwise colorless sapphire. Magnified 12×.

Figure 2. The craters in the base of the sapphire shown in figure 1 prove that this stone was heat treated rather than diffusion treated. Magnified 12×.

Figure 3. Note the internal fracturing and external chipping on this 2.55-ct ruby, caused by heat treatment. Magnified 16×.

"C-Ox," Another Trade Name for Cubic Zirconia

The Los Angeles laboratory received for examination two colored stones that had been offered on the European market under the trade name "C-Ox." Figure 4 shows the deep green emerald-cut stone, which weighed approximately 4.14 ct, and the intense blue oval modified brilliant, which weighed approximately 3.73 ct. Both stones had a very high, almost metallic luster; both were singly refractive, and their refractive indices were above the limit of our standard duplex refractometer. The specific gravity was determined by hydrostatic weighing to be 5.52 for the green stone and 5.34 for the blue stone. Both stones were inert to ultraviolet radiation. With the micro-

Figure 4. Green (4.14 ct) and blue (3.73 ct) cubic zirconia, marketed under the trade name "C-Ox."

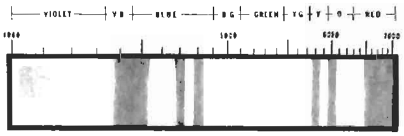


Figure 5. Absorption spectrum of the green "C-Ox" illustrated in figure 4.

scope, no inclusions were visible in the blue stone, but the green stone showed a dense cloud of minute white inclusions that we could not identify. The absorption spectra of the stones were interesting. The blue stone showed a general absorption area around 5900 Å and a cut-off area starting at 6500 Å upwards. The green stone had a different absorption pattern: one broad, main absorption area was centered at 4450 Å, with narrower bands at 4700, 4800, 5800, and 6000 Å and a cut-off area from 6500 Å up, as illustrated in figure 5. By means of X-ray diffraction, we were able to prove that both stones were synthetic cubic zirconia.

DIAMOND

A Colored-Diamond Comet

The New York laboratory recently examined the diamond brooch set with fancy yellow to yellow-brown diamonds pictured in figure 6. The small stars are mounted *en tremblant* and are interspersed with small colorless diamonds. The piece is unusual in that all of the stones, including the small colorless ones, are fluorescent, which suggests that whoever designed the piece and chose the stones had more than a passing interest in diamond fluorescence. Figure 7 shows the brooch as it appears when exposed to long-wave ultraviolet radiation.

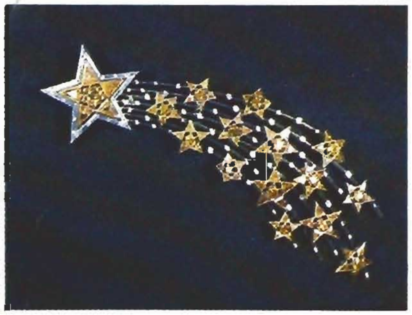


Figure 6. Comet-design diamond brooch set with colored diamonds. Approximately 3½ in. (9 cm).

Dendritic Inclusions

Although we at the New York lab have encountered dendritic inclusions in diamonds several times before (*Gems & Gemology*, Winter 1965-66, Fall 1966, Fall 1974, Fall 1979, and Spring 1980), we have never seen anything that equals the one in the approximately 4-ct stone pictured in figure 8. Viewed from the pavilion, the major inclusion looks like a branching root system. However, because of its location within the diamond and the fact that the stone is pear shaped, the odd pattern is reflected throughout the entire stone (figure 9).

JADE Simulant

A small (3 cm diameter), round ornament carved out of an opaque, yellowish brown, black, and grayish green material was submitted to the Santa Monica laboratory for identifi-

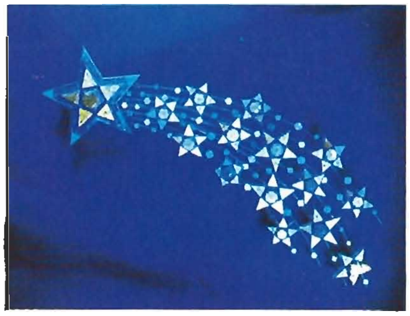


Figure 7. All of the stones in the brooch illustrated in figure 6 fluoresce when exposed to long-wave U.V. radiation.

Figure 8. Dendrites in diamond. Magnified 12×.

Figure 9. The pin containing the approximately 4-ct diamond illustrated in figure 8 with the dendrite pattern reflected throughout the stone.

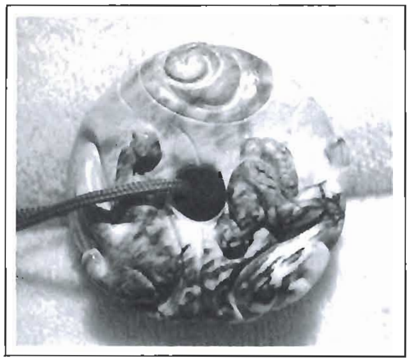


Figure 10. Ornament composed primarily of serpentine as a jade simulant.

cation (figure 10). The material was very soft and could be scratched with a pin. Although the polish was not good, we were able to obtain a vague refractive index reading of 1.57 in some areas. The specific gravity was determined by hydrostatic weighing to be approximately 2.5. There was a distinct yellow fluorescence to both long- and short-wave ultraviolet radiation. X-ray diffraction revealed patterns of forsterite and antigorite as well as additional lines that proved the material was a rock consisting of several minerals, but primarily serpentine.

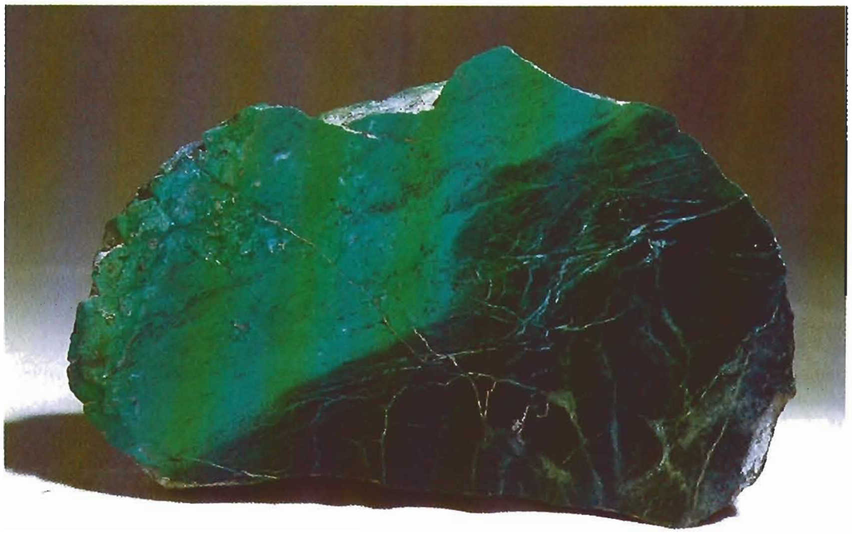
MAW-SIT-SIT?

Our New York laboratory recently examined a sawed light-green boulder that weighed approximately eight pounds (figure 11). On the reverse side of the rock a typical mawed groove has exposed a dark green area that resembles chloromelanite. The specific gravity and refractive index of the light green material indicated maw-sit-sit, while preliminary tests on the dark green material indicated chloromelanite. If additional tests are authorized and confirm these identifications, it would be the first example of this combination ever encountered in our lab.

OPAL, A New Synthetic from Inamori

A new type of synthetic white opal manufactured by Inamori has appeared on the American market. The Santa Monica laboratory had the opportunity to examine two 10 × 12 mm cabochons, each weighing approximately 2.80 ct (figure 12). One cabochon has a milky white body color with predominantly green and blue play of color, while the other stone is more translucent, with a vivid play of color in red, orange, yellow, green, and blue. The refractive index was determined to be 1.46 (spot reading) for both stones, and the specific gravity for both was 2.20. Examination with magnification did not reveal any distinctive inclusions in the more translucent stone; the

Figure 11. An eight-pound boulder that appears to consist of maw-sit-sit and chloromelanite.



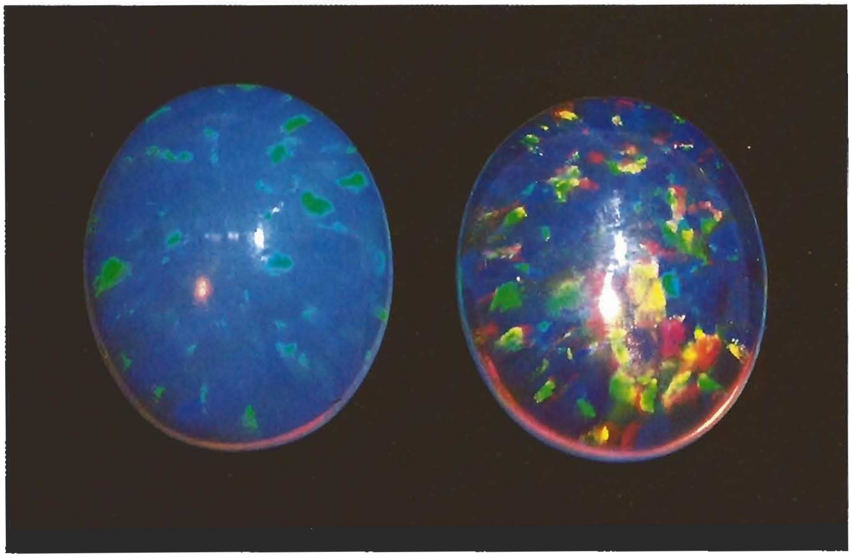


Figure 12. Two 10 × 12 mm Inamori synthetic opals.

milky white stone did show an opaque white, irregularly shaped inclusion that could not be identified.

When the stones were illuminated with overhead light, the lizard skin or chickenwire structure characteristic of synthetic opals, which was difficult to detect at first, became quite obvious. Finally, the two stones reacted differently to ultraviolet radiation. The milky white stone was completely inert, whereas the other stone showed a faint yellowish fluorescence, but only to short-wave ultraviolet radiation.

PEARLS

Cultured ¾ Blister Pearls

In the Summer 1981 issue of *Gems & Gemology* (p. 104), we introduced cultured ¾ blister pearls. To date, all of the examples of this new type of pearl that we have seen have had a mother-of-pearl bead clearly exposed at the base. Recently, the New York lab X-rayed two 18-mm cultured ¾ blister pearls in which the nuclei were not exposed. The pearls had been removed from the mollusc with shell attached. The nucleus of the smaller specimen was just visible—a white area underlying the thin shell (figure 13). The X-radiograph (figure 14) shows a considerable growth of nacre around the beads. The very thin layer of shell to which the beads were attached does not appear on the radiograph.

Eroded Pearl

A pearl importer thought our readers would be interested in seeing a badly damaged pearl that he had been asked to replace (figure 15). It was set in a ring with a typical claw mounting when he received it. After unmounting the pearl, he sent it to the Santa Monica laboratory to photograph the severe erosion at the points of contact of the prongs. We surmise that the person who wore this ring must have worn it a long time and had a very acidic skin condition, for

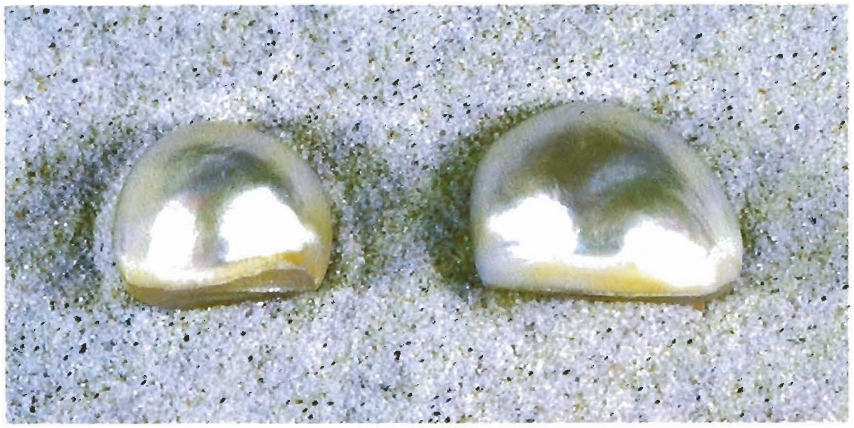


Figure 13. Cultured ¾ blister pearls without exposed nuclei. The largest is 21 × 18 mm.

Figure 14. X-radiograph of the cultured ¾ blister pearls shown in figure 13.

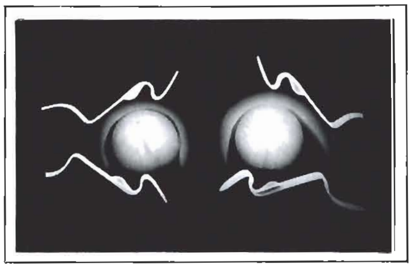


Figure 15. Eroded 8½-mm pearl.

this is one of the worst examples of erosion we have ever seen.

QUARTZ, Reddish Brown

Submitted to the Los Angeles laboratory for identification was the 4.72-ct reddish brown oval modified brilliant shown in figure 16. The refractometer showed refractive indices of $\omega = 1.540$ and $\epsilon = 1.550$. When the stone was examined with the polariscope in conjunction with a condensing lens, a bull's-eye uniaxial interference figure was observed, thereby proving the stone to be quartz.

This color has been observed in some quartz from Rio Grande do Sul, Brazil, and is also reportedly produced by heat treating some amethyst to a temperature between 400°C and 500°C.

Microscopic examination revealed only straight, parallel, and irregular growth and color zoning, which suggests that this stone is natural rather than synthetic. This color, however, could probably be produced in synthetic quartz, or by heat treating synthetic amethyst.

Figure 16. Reddish brown quartz, 4.72 ct.

Figure 17. A 1.46-ct "Geneva (synthetic) Ruby," heavily flawed.

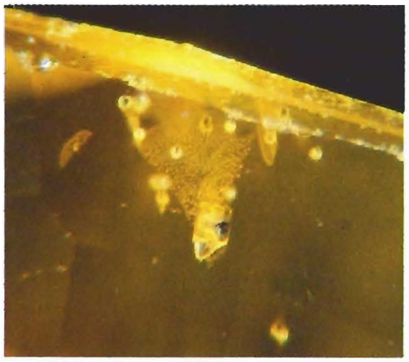
Figure 18. Note the dark inclusions in the "Geneva (synthetic) Ruby" illustrated in figure 17. Magnified 18×.

RUBY, Early Verneuil Synthetic

Figure 17, taken in New York, shows an unusually flawed 1.46-ct "Geneva Ruby." The tight curved striae that characterize this early type of Verneuil synthetic were easily seen in the stone with magnification. In addition to the striae and gas bubbles, we observed a myriad of unidentified dark crystal-appearing inclusions (figure 18).

Figure 19. A range of colors found in heat-treated yellow sapphires.

Figure 20. "Cotton-like" inclusions observed in heat-treated yellow sapphires. Magnified 63×.



YELLOW SAPPHIRES, Heat Treated

Recently, the great majority of natural yellow sapphires we have tested in New York owe their color to heat treatment. On rare occasions, we have seen an orange-brown iron-rich stone of natural color, but more frequently the naturally colored stones are pale yellow with strong orange fluorescence. Figure 19 illustrates a range of colors produced by heat treatment; the stones are all from the same batch heated in Thailand. Figure 20 shows some peculiar "cotton-like" inclusions around the crystal inclusions seen in one of the lighter-colored stones. The "cotton" may represent partial absorption of the crystal inclusions because of heat.

Figure 21 shows a group of natural sapphires that reportedly had been locked in a safe for decades. It was a pleasure to be able to report that the stones were not only natural sapphires but also natural in color, although they were quite well worn. The square, lighter-colored stone is a typically orange-fluorescing Sri Lankan stone. The oval stone next to

Figure 21. A group of naturally colored yellow sapphires. The largest is approximately 4 ct.

it is also a typical Sri Lankan stone, with a chromium line in the absorption spectrum. The small orange-pink stone was nearly flawless, but proved to be natural. The round stone again had all the characteristics of a darker than usual Sri Lankan stone, while the dark stone showed an iron absorption spectrum typical of natural yellow-brown Thai sapphires.

ZIRCON, A Rare Cat's-Eye

The Santa Monica laboratory received for identification a grayish green 3.43-ct oval cat's-eye cabochon that had been purchased as cat's-eye zircon. The stone was easily identified as zircon because it showed the diagnostic absorption spectrum with the most prominent line at 6535 Å. Microscopic examination revealed long, thin, needle-like inclusions of unknown composition running across the stone, thus causing the chatoyancy. Figure 22 shows the quite attractive cabochon. Although cat's-eye zircon does not—according to the gemological literature—occur often, our New York laboratory had previously mentioned this type of cat's-eye in the Summer 1974 issue of *Gems & Gemology.*

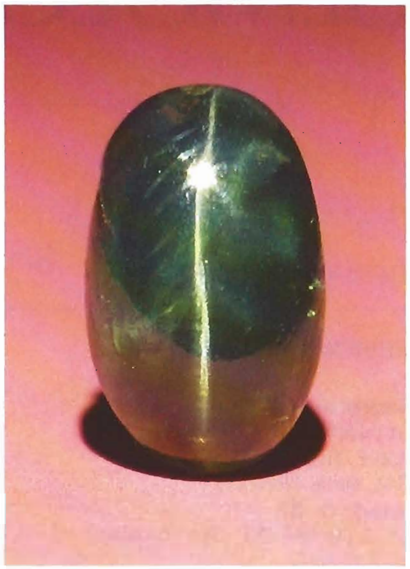


Figure 22. A 3.43-ct cat's-eye zircon.

ACKNOWLEDGMENTS
Andrew Quinlan from New York supplied figures 1, 2, 3, 6, 7, 8, 9, 11, 13, 14, 17, 18, 19, 20, and 21. Shane McClure provided figure 16. Figure 22 was supplied by Tino Hammid, and Karin Hurwit was responsible for figures 5 and 10. Mike Havstad supplied figures 4, 12, and 15.

GEMOLOGICAL ABSTRACTS

Dona M. Dirlam, Editor

COLORED STONES AND ORGANIC MATERIAL

Crystal chemistry of natural Be-Mg-Al oxides: taaffeite, taprobanite, musgravite. K. Schmetzer, *Neues Jahrbuch für Mineralogie Abhandlungen,* Vol. 146, No. 1, 1983, pp. 15–28.

Schmetzer describes the Be-Mg-Al oxides taaffeite and musgravite, and the controversy centered on the discredited term *taprobanite.* Although similar, taaffeite and musgravite have slight differences in their chemistry and crystal structure, and the present investigation was undertaken to clarify their complex interrelationship. Chemical, crystallographic, and optical data are given for 15 specimens from Sri Lanka, China, the Soviet Union, and Antarctica. Optical absorption spectra are also presented for a bluish-violet taaffeite from Sri Lanka. Taprobanite, originally thought to be a new species, is shown to be identical with taaffeite, whose correct chemical formula is $BeMg_3Al_8O_{16}$. The species name taaffeite has priority according to the rules of mineralogical nomenclature; the name taprobanite should be discontinued. Musgravite has a similar composition of $BeMg_2Al_6O_{12}$, but it has not yet been found as gem-quality crystals. *JES*

Editor's Note: Schmetzer expands on the subject of nomenclature in his article "Taaffeite or Taprobanite—a Problem of Mineralogical Nomenclature" in the Vol. 18, No. 7 issue of Journal of Gemmology, *pp. 623–634. Color pictures of nine taaffeites are included.*

Durchsichtiger Lazulith oder Scorzalith aus Brasilien (Transparent lazulite and scorzalite from Brazil). H. Bank, *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 32, No. 1, 1983, pp. 6–9.

Currently a blue transparent to translucent gemstone is being sold in Brazil under the name scorzalite. Professor Bank has suggested mineralogical and gemological methods to determine the members of the isomorphous series lazulite-scorzalite. The mineralogical methods include the use of X-ray powder diffraction patterns and the microprobe. Refractive index, birefringence, and density determinations are the gemological methods.

The Mg-rich end member lazulite and the Fe-rich end member scorzalite provide lower and higher physi-

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This section is designed to provide as complete a record as possible 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 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.

cal constants, respectively. The values given in this article for lazulite are n_x 1.608–1.610, n_z 1.640–1.644, $n_z - n_x$ 0.032–0.034; and for scorzalite, n_x 1.639, n_z 1.680, $n_z - n_x$ 0.041. The density of lazulite varies from 3.06 to 3.12; density is quite constant at 3.31 for scorzalite.

This information enables the gemologist to identify the intermediate members of the series. Analyses have also concluded that the material offered as scorzalite from Brazil is actually lazulite.

Mahinda Gunawardene

On tourmaline. T. G. Sahama, O. von Knorring, and R. Törnroos, *Lithos,* Vol. 12, 1979, pp. 109-114.

Tourmaline is a closely related group of minerals of particular gemologic interest. This brief article presents chemical analyses and physical properties of 12 tourmaline specimens of varying color—10 from Mozambique, one from Afghanistan, and one from the Malagasy Republic. The material from the Muiane district in Mozambique exhibits a range of hues from colorless achroite to black schorl. The specimen from an unknown pegmatite locality in Afghanistan is blue, while the one from the Malagasy Republic (from the Itakefa Mine near Fort Dauphin) is dark brown. These reported data are of interest because, in view of the complexity of this mineral group, sources of information on tourmaline that include complete chemical compositions and physical properties obtained from the same crystal are scarce. A short discussion of the relationship between chemical composition and unit-cell parameters is also presented. *JES*

Pearlescence. A. DiNoto, *Connoisseur,* Vol. 213, No. 858, 1983, pp. 76–87.

This is a lavish update of all the nontechnical information you have ever read or heard about pearls, with the added feature of truly informative footnotes. The author cites well-respected authorities (including G. F. Kunz and GIA), explores the myths and legends about pearls, reviews market fluctuations related to fashion trends and economic conditions, examines the varieties of pearls being found or produced today, and discusses the wide range of current prices, which reflect both quality and scarcity.

Comments from leading dealers, importers, and auction-house authorities provide ample evidence of a flourishing market and reveal astonishing new sources of supply.

While the photographs display an interesting variety of antique and contemporary pearl jewelry, there seems to have been some uncertainty about new and imaginative ways to illustrate pearls to their best advantage. Unfortunately, neither this article nor any other manages to do so with complete success since, unlike some other types of jewelry, pearls seldom appear as beautiful in photographs as they do in reality. *NL*

The thermal behavior of scapolites. G. Graziani and S. Lucchesi, *American Mineralogist,* Vol. 67, No. 11/12, 1982, pp. 1229–1241.

Graziani and Lucchesi report results from thermal-expansion experiments conducted on scapolites from different localities. They measured the release of volatile components during heating of these samples over an 800°C temperature range. They specifically chose samples that represented the marialite-meionite solid-solution series.

Of the eight specimens, a violet and a yellow came from the Umba deposits, northeast Tanzania; two were from Ankazobé and Gabenja, Madagascar; one was from Gooderham, Ontario, and another was from Greenville, Quebec, in Canada; one came from Manchester, New Hampshire; the last originated from the Mt. Somma–Mt. Vesuvius area in Italy.

While much of the data are outside the interest of most gemologists, it is important to note that water loss begins to occur at temperatures as low as 70°C. Also, the authors report a progressive lightening of the color with heating until 350–400°C, when the samples became colorless. An extensive bibliography of 40 entries is included. *DMD*

Wyoming jade. M. E. Madson, *Rocks and Minerals,* Vol. 58, No. 5, 1983, pp. 218–222.

Madson reviews the history of Wyoming nephrite before turning to a discussion of its mineralogy and petrology. One very early account of its use as a lapidary material was in 1908. Harvey Samuelson of Salinas, California, bought green nephrite from Wyoming cowboys who were wintering in California. Later, in 1936, a "jade rush" began that lasted for 10 years. This prospecting was accelerated by the widening acceptance of Wyoming nephrite as a lapidary material. By the mid-1950s, the major deposits had been claimed. Most recent production comes from these deposits.

Occasionally, however, deposits that were previously known but only lightly worked have come into prominence. Madson was involved in a major mining effort from 1971 to 1975 on the Rhoades deposit in the Granite Mountains northwest of Jeffrey City, Wyoming. He states that the mine produced 400,000 pounds of nephrite; about 6% was gem quality. This material was sent to Taiwan and Germany for manufacture.

He also reports findings from his investigation of the mineralogy of Wyoming nephrites. These nephrites are intermediate in chemical composition between tremolite and ferro-actinolite; most of the gem-quality material is tremolite. He also reviews nephrite competency (a combination of strength and hardness) and the color range exhibited in nephrites from different regions. Then, the author describes the three modes of occurrence of Wyoming nephrite: (1) float, (2) vein and fissure fillings, and (3) ellipsoidal pods.

Noting that more and more often light-colored nephrites from British Columbia are being sold in Wyoming, Madson concludes that 1935–1975 may well represent the prime period of the nephrite industry in Wyoming. *DMD*

DIAMONDS

Argyle diamond mines' operational debut. *Indiaqua,* Vol. 34, No. 1, 1983, pp. 13–23.

In a series of reprints of newspaper articles, *Indiaqua* chronicles the history of the Australian diamond deposits. It begins with a December 28, 1982, story from the *Sydney Morning Herald* announcing an agreement between two of the Argyle partners, CRA Ltd. and Ashton Mining Ltd., and the De Beers Central Selling Organization. This sales pact with De Beers is unique in that there are several provisions that allow some domestic cutting and marketing by the joint-venture partners.

The other articles are arranged in reverse chronological order, and present issues relevant to the Western Australian state government and De Beers. With so many people affected by these large finds of diamonds (up to five tons annually, most of which are of industrial or low-grade gem quality), it is interesting to read in a single format the stories of each participant. Particularly noteworthy is the article from 1976 reporting the initial diamond find.

One difficulty for the reader is that some of the articles are not dated. Thirty photographs illustrating these developments accompany the text. *FLG*

Argyle's high grade. *Mining Journal,* Vol. 301, No. 7731, October 21, 1983, pp. 291–292.

This is a short update on diamond-mining events in Australia. During the week of October 14, 1983, agreement was reached between the Western Australian Government and the partners of the Argyle Diamond Mines Joint Venture to develop the AK-1 kimberlite pipe. On November 1, 1983, construction was scheduled to begin on a treatment plant that will be capable of recovering 25 million carats of diamonds from three million tons of ore annually. It is expected that production will begin by January 1, 1986. Since most diamonds will be industrial or low-grade gem, it is expected that they will comprise 4% of the value of the worldwide production. The weight estimates for the AK 1 are predicted to be 5% gem quality, 40% cheap gem, and 55% industrial grade. In addition to summarizing information on ore grades and production figures from the 1983 annual report of Ashton Mining Ltd., this article also includes an outline map and simplified cross sections of the deposit. *DMD*

Diamond-bearing kimberlite pipes in Wyoming and Colorado. W. D. Hausel, *Rocks and Minerals,* Vol. 58, No. 5, 1983, pp. 241–244.

Hausel's account is an intriguing tale of geological investigation that led, ultimately, to the discovery of diamonds. The problem began in 1960 when geologists discovered blocks of Lower Paleozoic limestone (450–500 m.y.) in southeastern Wyoming. No rocks of similar age occur close by. Furthermore, these outcrops are in the middle of Precambrian granite dated at 1.4 b.y. The mystery continued until 1964 when similar limestone was discovered in Colorado. This time, kimberlite was found in association. The geologists concluded that when the kimberlite magma erupted 350 to 400 m.y. ago, Lower Paleozoic limestone covered the area. Since then, erosion has removed all traces except for these chunks trapped in the erupting magma.

Diamonds were not discovered until 1975. During grinding, a nodule from one of the kimberlite pipes scratched the Carborundum wheel. With further treatment, the geologists found diamonds 0.1 to 1.0 mm in the residue. Geologists from the Geological Survey of Wyoming and Colorado State University combined to explore the region. Now, nearly 100 kimberlite occurrences have been located; more than 12 of these are diamond bearing.

Two mining firms, Cominco America, Inc., and Superior Minerals Company, are investigating the commercial diamond potential of the Colorado-Wyoming region. The Geological Survey of Wyoming continues to test kimberlites for diamonds. Although Hausel includes two photographs of diamonds and one cross-section of a Wyoming diatreme, the map of the kimberlite localities and the bibliography are the most useful supplements to the text. *DMD*

Diamonds, diggers and dreams. D. E. Schaefer, *Optima,* Vol. 31, No. 2, 1983, pp. 74–90.

"Diamonds, Diggers and Dreams" is a historical yet colorful account of the hopes and dreams that sent gamblers to the South African diamond fields. This look back at the early days of diamond mining restricts itself to a very brief moment in history in the late 1800s, making one feel part of the excitement, hard work, lost hopes, and fulfilled dreams of the men and women who gambled with their lives to find those elusive crystals—diamonds. "Of course I thought that once on the field every load a stone would yield; But, I owned, after many a weary day, that gravel is gravel and clay is clay. It really was very unpleasant. But it can't be helped, you know."

As one can already feel from this brief lament, "Diamonds, Diggers and Dreams" is much more enjoyable reading than a standard history text on the early days of diamond mining. We view these times through wonderful photographs, poetry, and other writings from the men and women who were there. This helps remind us how sought-after and precious these adamantine crystals of colorless carbon really are. "I have a wife, a claim I mean, a baby and a cradle too, which I constantly work from daylight till dark in search of a diamond or two." Yes, those were exciting times, the early days of diamond mining. And this reading makes you wish you could have been there. "Hurrah! for the diamond fields! With its stores of wealth untold. Hurrah! for the rich and sparkling gems to win us piles of gold." *GAR*

Diamonds in the People's Republic of China, part I and part II. B. Hawkins, *Diamant,* Vol. 26, No. 267, 1983, pp. 29–30; No. 268, 1983, pp. 25–32.

In part I, Hawkins summarizes the longer version presented in part II, which begins with a description of China's diamond deposits. The only confirmed mine is called Changte, after the nearby town in the northern part of Hunan province. A geographic outline map of the People's Republic of China allows one to locate Changte as well as the other deposits reviewed. These latter locations have been derived from reports of discoveries of individual diamonds since the government is reticent to talk about the diamond localities.

In a short section on diamond production, Hawkins reports an output for 1980 of 1.8 to 2.8 million carats, with about 20% of the diamonds ranked as gem quality. In the next two sections, Hawkins focuses on the diamond trade and the cutting industry. He speculates that the exported cut stones go to the United Kingdom and West Germany. In a brief note on synthetic diamonds, he reports that the first synthetic grit was produced in China in 1963, and by 1980 six synthetic production units were in operation, allowing a significant reduction in China's importation of industrial diamonds.

Hawkins concludes with a prediction of a gradual increase in both natural and synthetic diamond production, although one not large enough to make China a significant diamond leader. In an interesting appendix entitled "Diamonds: China's Connections with De Beers," instances of contact between the two since 1975 are cited. *DMD*

Digging for diamonds. P. Read, *Canadian Jeweller,* Vol. 104, No. 5, 1983, pp. 28–32.

Read reports on his November 1982 trip to the Finsch diamond mine, located 160 km northwest of Kimberley, South Africa. He begins by summarizing the discovery of the mine by Allister Fincham and Ernest Schwabel. In the 1950s, while prospecting for sources of asbestos, they discovered garnets. Realizing that this occurrence also suggested diamonds, they started to search for kimberlite. By November 1961, they began to remove overburden from a likely area. A 0.75-ct diamond was found in the first washing of gravel. By May 1963, output of diamonds was up to 1,634.45 ct. That same month, the two partners sold the rights of the Fincham mine to De Beers Mining Company (Finsch is an amalgam of *Fin*cham and *Sch*wabel).

Today, the Finsch mine, now covering an area of 44.2 acres, is the second largest diamond mine in South Africa. Read also describes in detail the current efforts to convert the mine from an open-cast to an underground operation. This project is expected to be completed by 1988, with production estimated at four million tons, and more than three million carats of diamond, per year. This article is followed by Read's one-page description of the De Beers Diamond Research Laboratory, which celebrated its 36th-year anniversary in 1983. *DMD*

Famous diamonds of the world (XV): the "Hastings" diamond. I. Balfour, *Indiaqua,* Vol. 34, No. 1, 1983, pp. 129–133.

As with many other large diamonds, the Hastings diamond has a history of intrigue and mystery. Ian Balfour, in another article from his series, "Famous Diamonds of the World," has spun an interesting tale.

This 101-ct rough diamond received its name from the first British Governor General of India, Warren Hastings. Mr. Hastings was in attendance on the presentation of this diamond to King George III by the important Indian prince, Nazam Ali Cawn. A story was then circulated that Mr. Hastings had sought to curry the king's favor by helping him acquire this diamond. Once begun, the scandal progressed under its own momentum. Two years later Mr. Hastings was formally impeached, and the trial that followed lasted over seven years. Ultimately, Hastings was acquitted of all charges.

Although there is no proof, Mr. Balfour speculates that the diamond became part of the British Crown jewels and was cut into a 32.20-ct round brilliant and mounted into the coronation crown of George IV. Subsequently purchased at auction by the marquis of Westminster, the Hastings diamond was then mounted in the Westminster Tiara along with two other famous diamonds, the Arcots. In 1959 Mr. Harry Winston purchased the tiara and later sold the stone to a private collector. *FLG*

GEM INSTRUMENTS AND TECHNIQUES

A spindle state study of the optical properties of topaz. M. F. Carman, Jr., *Bulletin de Minéralogie,* Vol. 104, 1981, pp. 742–749.

The author has made very accurate measurements of the optical properties of a topaz crystal of unknown origin using a recently perfected microscopic technique. This technique involves mounting a tiny crystal fragment on a needle, or spindle, attached to a movable stage. The fragment is then rotated into various positions for optical measurements under the microscope. Refractive indices using 589-nm light are N_x = 1.6109 (3), N_y =

1.6137 (3), and N_z = 1.6209 (3). Data on other optical properties are also presented. The analyzed fluorine content (19.3–19.7%) determined by electron microprobe agrees closely with the content calculated from these measurements. *JES*

GEM LOCALITIES

Gem azurite from the Eclipse Mine, Muldiva—Chillagoe area, Queensland. A. D. Robertson, *Australian Gemmologist,* Vol. 15, No. 2, 1983, pp. 46–49.

From 1892 to 1927 silver was mined at Muldiva in Queensland, Australia; gem-quality azurite crystals were recovered from the Eclipse Mine in this area as well. Economic mineralization at Muldiva was associated with contact skarn deposits developed in limestone. Extensive weathering of the garnetiferous skarn and subsequent oxidation of copper sulfides in the weathering zone produced large azurite crystal clusters; the largest group weighed 0.9 kg, while the largest single crystal weighed 8.75 gm.

The author has classified the azurite crystals into three fundamental categories, based on the type of termination and the development of crystal faces. Physical properties of the azurite are described and include the following: step-like cleavage breaks partially obscured by conchoidal fractures; strong pleochroism in blue; specific gravity of 3.789 ± 0.003; absorption above approximately 480 nm and below approximately 430 nm. Refractive indices were not determined. Some of the specimens showed replacement by malachite while retaining the azurite crystal forms (pseudomorphism). The various stages of replacement are noted in detail.

In addition, the article includes a listing of 21 minerals found in the Muldiva ores.

Robert C. Kammerling

Neues vom Smaragd-Vorkommen von Sta. Terezinha de Goiás, Goiás, Brasilien (New information from an emerald source in Sta. Terezinha in Goiás, Brazil). H. A. Hänni and C. J. Kerez, *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 32, No. 1, 1983, pp. 50–58.

The authors examined emerald crystals and rock samples from the new emerald mine in Santa Terezinha, Brazil. The hexagonal prismatic crystals are found in talc and in biotite schists. Color varied from light green to dark green with a bluish overtone resembling emeralds found in Zambia. The R.I. ranged from 1.585–1.587 to 1.592–1.595; birefringence was 0.006 to 0.008; S. G. ranged from 2.752 to 2.764. The absorption spectrum was the same as the spectrum encountered in emeralds from Madagascar. The inclusions were examined by electron microprobe and identified as dolomite and picotite, a chromian spinel. A quantitative chemical analysis on four crystals showed volume percentages that are characteristic of most natural emeralds. In the 12 color photographs are examples of the inclusions, an assortment of rough stones, and two views of the mine.

KNH

JEWELRY ARTS

Archaic jades, ancient & modern. M. Gulbenkian, *Arts of Asia,* Vol. 13, No. 3, 1983, pp. 97–105.

Mr. Gulbenkian provides a pictorial essay of jade in various eras. He divides his discussion of samples into stages. The first six are the Neolithic, Shang, Western Chou, Spring and Autumn, Warring States, and Han. Next, Gulbenkian covers the Archaistic, Northern Wei, Southern Tan, Sung, the 13th through 17th centuries, Ming, and Manchu periods.

Gulbenkian describes one or more pieces of jade in each period. In most of these short descriptions, some attempt is made to give the historical significance of each piece. The author's purpose of writing the article was to "give a clear idea of current fashions as well as the linear development of the craft." Unfortunately, neither theme is adequately developed.

Some of the pieces illustrated are: a pi of the Shang period, a huang of white jade of the Western Chou period, a chape (tip of a scabbard) of the Warring States period, a sword of the Han period, a belt buckle with a feline image from the Sung dynasty, and a curling monster carving from the Ming dynasty. The author also provides his own sketches of jade carvings from many of these periods. *JMW*

Bracelets for bullets. V. Becker, *House & Garden,* Vol. 155, No. 6, 1983, pp. 48–52.

Berlin iron jewelry became fashionable during the Napoleonic Wars of the late 18th and early 19th centuries; the first factory for the production of this type of ornament opened in 1804 in Berlin. Less than a decade later appeals were being made to the wealthy to surrender their jewels for the Prussian national cause, with iron jewelry being issued as a form of receipt. While its popularity grew out of the difficult time of war, Berlin iron jewelry did not disappear when peace was restored and, passing through various stylistic changes, survived until the 1860s.

The skill of its fabrication lay in the casting, and its visual effect depended on the startling contrast of delicate, lacy black jewelry with white skin, since at that time women did not seek the sun, and a soft, white complexion was much admired.

In this article, the author writes more engagingly and informatively than in the section of her own book (*Antique and 20th Century Jewellery,* London: N.A.G. Press, Ltd., 1980) which deals with this period of jewelry history. However, the article does not mention Ann Clifford's *Cut Steel and Berlin Iron Jewellery* (Bath: Adams & Dart, 1971), the definitive work on Berlin iron jewelry, and therefore does a slight disservice to readers who might wish to pursue the subject beyond the limitations of a short article. *NL*

Chinese jade books in the Chester Beatty collection. J. Chapman, *Arts of Asia,* Vol. 13, No. 3, 1983, pp. 110–119.

Chapman, the Far East curator of the Charles Beatty Library and Gallery of Oriental Art located in Dublin, Ireland, presents another facet of this remarkable collection as he focuses on the 15 jade books. These are not books about jade; rather, they are books written *on* jade. The practice dates back at least 2,000 years. An ancient Chinese ritual book, *Li Ki,* states that while bamboo was the writing material used by commoners, jade was strictly reserved for the emperor. From the Ch'in dynasty (221–206 B.C.) on, two sets of jade tablets were used in a ceremony called *feng-shan* which thanked the ruling spirits and petitioned them to continue to preserve peace and prosperity. One set of tablets was buried at the site of the altar while the other was taken to the ancestral shrine of the emperor.

Horizontal holes were drilled in the top and bottom of each tablet. Then a cord was threaded through so that the books could be folded in concertina fashion. For storage, special boxes were constructed to hold each book, which sometimes numbered as many as 53 tablets. Two of the books have Manchu script as well as Chinese.

Of the 15 books in the Chester Beatty collection, seven are imperial notes and poems, five are Buddhist texts, and three are official records. Chapman summarizes the known history of the different books, as well as details about how Beatty acquired them. Photographs of eight of the 15 are included, five in color. *DMD*

Dazzled by nature. G. Trotta, *Connoisseur,* Vol. 213, No. 859, 1983, pp. 86–89.

Brazilian Haroldo Burle Marx is the dazzled one. He in turn dazzles the reader with his designs in gold and silver alloy set with emeralds, aquamarines, tourmalines, topazes, opals, and other colored stones of Brazil, which are worn by the rich and powerful around the world.

Marx, who has designed jewelry for Pope John Paul I as well as for Happy Rockefeller, calls his workshop in Rio de Janeiro "a team bound together more by love than by business." The social and aesthetic philosophy that informs his work is the subject of this interview which, despite Trotta's oddly patronizing tone, is informative and thought-provoking. Dane Penland's five photographs and three of Marx's own drawings complement the text and make one hunger for more. *FS*

Precious platinum. J. M. Filstrup, *Town & Country,* Vol. 137, No. 5037, 1983, pp. 112–187.

Ms. Filstrup describes the wide range of uses for platinum, as well as its history and its alluring qualities in famous jewelry pieces.

Platinum is an invaluable metal in many fields of technology, from space exploration to chemotherapy treatments. Because of its rarity, the majority of the U.S. supply is used for industrial purposes.

In jewelry, platinum is becoming a more popular setting material, due in part to the renewed interest in Art Deco. Certain stones seem to be more aesthetically pleasing than others when set in platinum; some examples given by the author are aquamarines, amethysts, tourmalines, and diamonds.

The author also discusses the investment possibilities of platinum—from ingots and stocks to the futures market. The revived interest leads many to believe that platinum is becoming a lucrative investment.

Accompanying this article are 22 photographs; 20 of these are in color and depict the variety of jewelry settings fashioned in platinum. *Jane Flannelly*

A pride of boxes. N. Richardson, *House & Garden,* Vol. 155, No. 5, 1983, pp. 111–117; 182–185.

The gold snuff box was an 18th-century phenomenon—an object of use, luxury, and superb craftsmanship. It was the counterpart for its time of the Renaissance pendant jewel and the 19th-century Fabergé eggs. It came into being in the 1700s and remained in favor for well over a hundred years. Because it was essentially an element of costume, its style changed as often as fashion.

In this article, the lore and lure of the gold box is reviewed with accuracy and style by Nancy Richardson, an editor at *House & Garden,* and is illustrated with splendid photographs by Lee Boltin. The author quotes the most authoritative sources (Kenneth Snowman, Clare Le Corbeiller, Martin Norton, and Sir Francis Watson) and discusses examples from the most opulent and representative collections (Wrightsman, Rothschild, Thyssen-Bornemisza, and Firestone) in one of the best articles on this subject to appear in recent years.

Like most popular magazines, *House & Garden* was unable to resist the temptation to reproduce details of many of the boxes much larger than their actual size, thus at one stroke giving the item a misleading appearance and making the illustration less useful to the serious student. Of course, it can be argued convincingly that *House & Garden* is not aimed at serious students, and that its greatly enlarged details give a clearer idea of the precision and technical excellence of the craftsmanship. In any case, one of the most compelling charms of the 18th-century gold box is its scale and proportion. *NL*

René Lalique: Art Nouveau jeweler and goldsmith. K. M. McClinton, *Art & Antiques,* Vol. 6, No. 2, 1983, pp. 90–95.

Jewelry was one of the most important expressions of the Art Nouveau movement, and René Lalique (1860–1945) was the acknowledged master of the period. Prior to his time, 19th-century jewelry, dominated by historicism, was judged by the purity and size of the stones. Lalique changed the emphasis to creative workmanship and directed attention to color, texture, and effect rather than intrinsic value alone.

Lalique borrowed his dominant themes from the free-flowing forms of nature, and he mixed his materials in dramatic and unexpected combinations—pearls with ivory, opals with carnelian, *plique-à-jour* enamel with bone and horn. He escaped the "tyranny of the diamond" by using moonstone, peridot, amethyst, and chrysoprase in his jewelry. The drooping lily, the violets of Lesbos, the wisteria vine, and the poppy all appear in his creations. Birds fascinated him—especially swans and peacocks. Strange and eerie creatures were used as well—the bat, the snake, and the dragonfly. Also in Lalique's jewelry, the faces and forms of women of "fatal beauty" emerge from disordered tresses—Medusa, Leda, Psyche, and Salomé. The zenith of Lalique's success in jewelry design came with the Exposition Universelle in Paris in 1900; soon afterward he began the transition from jeweler to glassmaker.

Katherine Morrison McClinton, a distinguished authority on the decorative and applied arts of the 19th century, and author of *Introduction to Lalique Glass*, has written a compelling and well-balanced article on Lalique's life and work. Her approach is not entirely typological: she places her subject in his proper cultural background and is particularly informative on the chronological development of his career. The illustrations are shown in correct and comprehensible scale, and a box by Margaret Caldwell at the end of the piece discusses the current Lalique market and the care of these fragile jewels. *NL*

Topkapi. A. T. Bruno, *Connoisseur*, Vol. 213, No. 857, 1983, pp. 67–73.

To commemorate the 60th anniversary of the founding of the Republic of Turkey, a special exhibition, "Anatolian Civilizations," is being held at Topkapi Palace Museum. In her article, Bruno gives a very interesting account of this major museum. She quotes once classic description of Topkapi: "More splendid than Versailles, more bloody than the Kremlin, and more mysterious than the Imperial Palace of Peking." Sultan Mehmed II, conqueror of Constantinople, began construction of the building in 1462. Enlarged by his successors, it served as the palace for the Ottoman rulers until 1853, when it was replaced by a European-style palace. Topkapi was converted into a museum in 1923 after Kemal Atatürk founded the Republic of Turkey.

Bruno describes in detail the various rooms and courtyards of Topkapi, pointing out notable pieces of art in the collection. To many Westerners, Topkapi is best known from a movie of the same title released in 1964 that featured the theft of a famous emerald-studded dagger. This dagger is among the 11 photographs, as is the Spoonmaker diamond, an 86-ct stone with a controversial history. These pieces are displayed in the rooms of the Imperial Treasury, along with other gems and jewelry. *DMD*

RETAILING

The backlash has begun. M. E. Thomas, *Goldsmith*, Vol. 163, No. 4, 1983, pp. 95–104.

Thomas focuses on the increased role of federal agencies in the problem of appraisals. Using two new tax laws, the Internal Revenue Service's involvement is becoming ever more prominent. The direct cause of this is a combination of different events involving tax shelters and the trading of personal and real property for colored stones with an inflated appraised value.

Under certain government provisions, anything overvalued will incur an additional tax liability based on the amount the item is overvalued. The IRS bulletin states: "The best evidence of fair market value depends on actual transactions and not on some artificial estimate." Fair market value defined by the IRS is the price the *jeweler* would pay.

The Federal Trade Commission's plans for dealing with these problems do not appear to be well defined: "If it could be demonstrated to the commissioners that the appraisal situation is scandalous or fraudulent, and they can be convinced of this, then they might take action against one or a number of companies," the FTC staffer says.

The different societies and organizations for appraisers are emphasizing the need for education in establishing values, handling conflicts of interest, and determining fees for services. However, gem traders, jewelers, and appraisers believe that laws and regulations are not the answer. Only individual efforts will improve the state of appraising. A handy guide to appraisal organizations follows this article. *Marcia Hucker*

A game that has no rules. E. Farrell, *Goldsmith*, Vol. 136, No. 4, 1983, pp. 82–94.

Farrell begins this issue devoted to jewelry appraisals with an article bearing witness to the many horror stories surrounding the world of appraising. The article describes the efforts of a gemologist named "Joe" and his search for the accurate retail value of a 1.50-ct marquise-cut diamond. Assisting Joe in his research, staff from the *Goldsmith* took the diamond to a laboratory, a jewelry store, and a department store for an appraisal. The results: the appraised prices of the diamond varied from $3500 to $6000.

The article stresses the need for the jeweler to establish communication with the customer and to follow specific guidelines when performing appraisals. Jewelers must be well informed about the type of merchandise they appraise. As Jewelers Vigilance Committee's executive vice-president Joel Windman said, "If you don't know, don't appraise." *Marcia Hucker*

SYNTHETICS AND SIMULANTS

The Regency synthetic emerald. G. Brown and J. Snow, *Australian Gemmologist*, Vol. 15, No. 2, 1983, pp. 57–60.

This brief article begins with an overview of hydrothermal synthetic emeralds, which were first produced in 1960 in the form of the Lechleitner synthetic emerald-coated beryls. This development was followed in the late 1960s by Linde's production of a wholly synthetic emerald. In summarizing the Linde process, the authors note that by using natural beryl seed plates cut at an angle to the c-axis, maximum growth could be obtained with a minimum formation of inclusions. To produce stones that were thick enough for faceting, the manufacturers often had to submit the crystals to a number of growth cycles in the autoclave. In the late 1970s, Linde sold its emerald-synthesizing equipment to Vacuum Ventures, Inc. which, under license from Linde, began producing the Regency synthetic emerald.

Brown and Snow describe the results of their macroscopic and microscopic investigations of the Regency synthetic emerald. Observed features include a seed plate, phenakite crystals, "dagger-like" inclusions, and occasional flattened "healed crack"-type inclusions. Examination of the latter two types of inclusions at 50× revealed them to be two-phased. Eight black-and-white photographs augment these descriptions.

The authors provide a list of standard gemological properties they determined for the Regency synthetic emerald and conclude that, while the emeralds' synthetic origin can be determined by a combination of data, including refractive index (1.568–1.573), specific gravity (2.68), and characteristic inclusions, it is not possible to distinguish them from their Linde predecessors. *Robert C. Kammerling*

TREATED STONES

Irradiation controversy on rubellite. D. T. Maddern, *Wahroongai News*, Vol. 17, No. 1, 1983, pp. 17–18.

Maddern's short article is in response to the controversy of whether many of the bright red rubellite tourmalines that have appeared on the market in 1983 have been irradiated. Maddern discussed the issue with Frank L. Davis, currently head of a mining company in Brazil, who reported that a pocket of red tourmalines had been discovered in the Ouro Fino mining area of Minas Gerais, Brazil, in November 1982.

Davis argues that although a larger than usual number of small stones appeared on the market at less than usual prices, this does not prove the stones were irradiated. Rather, it reflects cutting and marketing decisions made in Brazil. (It should be noted that this also does not prove they were not irradiated.) Currently, no diagnostic test exists to detect irradiation in rubellite. *DMD*

Naturally-coloured and treated yellow and orange-brown sapphires. K. Schmetzer, G. Bosshart, and H. A. Hänni, *Journal of Gemmology*, Vol. 18, No. 7, 1983, pp. 607–622.

The authors describe a new type of annealed yellow-orange sapphire that has an intense color similar to that of irradiated yellow sapphire, but is apparently stable upon heating, at least up to 1000°C. The coloration of both natural and synthetic yellow, orange, and orange-brown sapphires is due to their color centers and/or various trace elements. However, differences between natural and synthetic stones are often apparent in their optical absorption spectra, because the trace elements that give rise to these colors are not the same for both stones. Chemical data on several natural and synthetic yellow sapphires illustrate this compositional difference.

The characteristic features of natural yellow sapphires from major localities are compared with those of the new type of sapphire. Inclusions in this new material exhibit characteristics found in other types of natural corundums that have been heat treated. The spectra of these annealed yellow sapphires lack the distinct absorption bands present in natural yellow stones. The causes of color in this annealed material are presently unknown. The authors suggest that annealed and irradiated yellow sapphires can be separated from untreated natural stones on the basis of spectroscopic and microscopic observations, and can be further distinguished from one another by their color stability when heated above several hundred degrees centigrade. *JES*

Editor's Note: The same article appeared in German in the Zeitschrift der Deutschen Gemmologischen Gesellschaft, *Vol. 31, No. 4, 1982, pp. 265–279.*

GEM NEWS

John I. Koivula, *Editor*

DIAMONDS

Australia. Ashton Joint Venture (restructured into the Argyle Diamond Mines Joint Venture and the Ashton Exploration Joint Venture) recently sold the first consignment of its rough diamond production through the Central Selling Organization. The Australian firm reportedly received approximately 1.9 million dollars for the 200,000 ct, or about US$9.50 per carat.

The CSO starts a quarterly journal. The Central Selling Organization has just published the first issue of its new quarterly magazine *In-Sight.* This new publication, written exclusively for international sight-holders, will be a permanent feature of the CSO's official communication program. It is designed to foster closer contact between the CSO (seller) and its sight-holders (buyers). *In-Sight* was established to clarify or correct "a great deal of misinformation" that has caused considerable concern among CSO sight-holders. The main purpose of the journal will be to shed inside light on outside comment released in the general press on both the diamond industry and De Beers.

Improvement expected in the world diamond market. *Gem and Jewellery Business Intelligence* reports that since August of 1982, world diamond prices have remained somewhat stable. Falling interest rates in the United States and the expectation of a continuing worldwide economic recovery among diamond-consuming nations have instilled renewed confidence in the diamond industry, and the future outlook is optimistic.

Japan removes import duty on diamonds. Japan has dropped its import duty on cut gem diamonds. This action could result in the expansion of Japan's diamond industry and will certainly affect the number of diamonds purchased annually by the Japanese.

Le Grand Coeur d'Afrique. During a visit to West Africa in 1982, London jeweler Laurence Graff obtained a 278-ct rough diamond. After more than a year of careful study, three stones were produced from the triangular rough. The smallest was a 14.25-ct marquise. A 25.22-ct heart-shaped gem named Le Petit Coeur d'Afrique was the second largest gem produced. The largest of the three diamonds weighs 70.03 ct and is claimed by Mr. Graff to be the world's largest heart-shaped diamond. Now called Le Grand Coeur d'Afrique, this stone will eventually carry the name of its purchaser.

COLORED STONES

India puts a ban on rough gem exports. A ban placed on the export of rough gemstones from India is apparently designed to stimulate the cutting industry in that country. In its annual report, however, the Gem and Jewelry Export Promotion Council states that it fears that such a ban might adversely affect gemstone mining activity in India.

Opal. Information released in the trade states that opal production in Australia fell by an estimated 60% in 1983 from 1982 levels. Fewer miners are currently seeking opal and more mines are now inactive. These factors, together with a lack of substantial new opal finds, have driven prices up on all grades of opal.

Yogo sapphire. Intergem Inc. of Aurora, Colorado, presently owns the sapphire deposit in Yogo Gulch, Montana. In 1983, the mine produced approximately 200,000 ct of sapphire in limited surface mining. (The percentage of this material that was of cuttable gem quality was not reported.) Once it has completed careful exploration, the company plans to put the mine into full operation.

Zoisite from Sri Lanka. Mr. Olle Fjordgren of the Göteborg (Sweden) Gemological Laboratory reports that in March of 1983, while working as director and chief gemologist of the United Gem Laboratory in Columbo, Sri Lanka, he examined a small rough stone found in Rakwana, south of Ratnapura. The gem was tentatively identified as zoisite, which would be the first time this gem has been found in Sri Lanka. The following properties were noted by Mr. Fjordgren:

Weight: 2.16 ct
Refractive index: 1.704–1.710
Optical sign: Positive, biaxial
Birefringence: 0.06
SW/LW light: Inert
Spectrum: None
Pleochroism: Blue-green, light blue
Specific gravity: Over 3.32
Inclusions: Actinolite (?) needles

Readers interested in further information on this find should contact Mr. Fjordgren at Göteborgs Gemmologiska Laboratorium, Foreningsgatan 4, S-411, 27 Göteborg, Sweden.

SYNTHETICS AND SIMULANTS

More information on C-Ox. X-ray diffraction studies done in GIA's Applied Gemology department on this supposedly "new" Russian diamond substitute (reported in the Fall 1983 Gem News section) show that this material has a structure identical to that of cubic zirconia. See the Lab Notes section of this issue for further information on "C-Ox."

Synthetic diamond. Using a high-energy particle accelerator, scientists at the atomic energy research establishment at Marwell, Oxfordshire, England, have succeeded in putting a layer of diamond on a preexisting diamond crystal. The accelerator fires carbon atoms into the existing structure of the diamond. Subsequent annealing at 800°C allows the newly added carbon atoms to be incorporated into the diamond's lattice structure. The added layer can be detected as a slight ridge when a finger is moved over the surface. The research team says that theoretically there is no reason why this technique could not be used to build a large gem-quality diamond using a small crystal as a nucleus.

MISCELLANEOUS

New French postage stamp for collectors. The French Postal Service has just issued a stamp honoring "The Art of Jewelry." The new stamp was unveiled at the 76th Bijorhca, the French jewelry show held annually in Paris. The stamp is part of a series of stamps issued annually by the French Post Office in collaboration with the Société d'Encouragement aux Métiers d'Art to honor a chosen profession. Collectors wishing to obtain stamps for their collection may contact the French Chamber of Commerce at (212) 869-1720.

ANNOUNCEMENTS

Accredited Gemologists Association to meet in Tucson. The Accredited Gemologists Association is planning a gemological conference to be held in Tucson, Arizona, concurrent with the 30th Annual Tucson Gem and Mineral Show. Topics to be covered at the conference will include the latest in synthetics, gemstone treatments, and identification techniques. The conference will be held at the Holiday Inn on South Palo Verde Blvd. and will run from Sunday, February 5, through Saturday, February 11. For further information on the conference, please contact Myriam or Tom Tashey at the AGA editorial office, 608 South Hill St., Suite 1013, Los Angeles, CA 90014, telephone (213) 623-8092.

American Gem Society to celebrate its Golden Jubilee. The American Gem Society has selected Atlanta, Georgia, as the site for its first International Conclave and its Golden Jubilee (50th year) celebration. The four-day event, which will run from March 31 to April 3, 1984, will be held at the Hyatt Regency Hotel in Atlanta. The theme for the 1984 International Conclave is "Developing and Promoting the Educated and Ethical Jeweler." Jewelers and gemologists from all over the world have been invited to attend. Further information concerning the 1984 Conclave can be obtained by contacting the American Gem Society, 3460 Wilshire Blvd., Suite 914, Los Angeles, CA 90010, telephone (213) 387-7375.

American Gem Trade Association to hold gemstone congress. The American Gem Trade Association will host an International Gemstone Congress in Acapulco, Mexico, from January 28 to February 1, 1984. The agenda is expected to include a discussion of synthetic gemstones and their identification, problems with treated gemstones, appraising, inter-organizational cooperation, and the formation of a new international gemstone organization. For further information, please contact the American Gem Trade Association at P.O. Box 32086, Phoenix, AZ 85064, telephone (602) 279-7171.

Tucson 1984: the 30th Annual Gem and Mineral Show. The entire city of Tucson is virtually swallowed up by this annual gem and mineral event. The 30th Tucson show will be held February 9–12, 1984, in the Tucson Convention Center, although a multitude of gem- and mineral-related activities will be going on in area hotels and motels before, after, and concurrent with the main "Tucson Show." The theme mineral this year is tourmaline, but virtually every variety of gemstone and mineral available today can be found at Tucson. A detailed report of the highlights of the Tucson show will appear in the next issue of *Gems & Gemology.*

Several pieces of finished jewelry, loose stones, and pocket watches were stolen from Kenneth Cousens' (president of Kenneth Cousens, Inc., Santa Rosa, CA) car while it was parked in downtown Los Angeles on November 3, 1983. The most noteworthy piece stolen is the large sapphire and diamond necklace that was featured on the cover of the Fall 1982 issue of *Gems & Gemology.* The center stone is a 17.22-ct antique cushion-cut sapphire. One end of the clean, medium-color stone is noticeably wider than the other.

Among the loose stones that are missing is an unusual 1.40-ct oval blue spinel from Sri Lanka. There is a rounded, dodecahedron crystal inclusion in one end of the cobalt-blue stone. Also included among the stolen goods were quantities of cut rubies, sapphires, emeralds, spinels, tourmalines, black opal, sphalerite, and lapis lazuli.

Anyone who encounters suspicious material that might represent any of these items is asked to contact Mr. Cousens at P.O. Box 3481, Santa Rosa, CA 95402, telephone (707) 538-3614.

Many fine pearls, loose gemstones, and pieces of jewelry were stolen from George Brooks, of Santa Barbara, in December. Two hundred very fine natural gray to black, round and baroque, South Sea pearls (8½–11½ mm) were taken, as well as a large, fine collection of polished white opal and rough (very rare) and polished boulder opal. Included in the loose faceted gems were a 46-ct peridot and a superb 10-ct emerald. Dozens of pieces of jewelry set with fine colored stones were also taken; the hand-manufactured 18-karat gold settings were stamped with "Brooks."

Anyone who believes they may have seen any of these items is asked to contact Detective Chuck Kennedy of the Santa Barbara Police Department at (805) 967-5561, ext. 307. A substantial reward is being offered for information leading to the recovery of the jewels.

EXHIBITS

American Museum of Natural History—Central Park West and 79th Street, New York, NY 10024. Telephone (212) 837-1300. This museum has one of the finest displays of gemstones and gem minerals in the United States, if not the world. Recently on display at the museum were three unusual gems owned by Alan Caplan of New York that have all appeared in various issues of *Gems & Gemology:* a 667-ct Muzo emerald crystal (Gem News, Spring 1983), the 217.8-ct Mogul emerald (cover, Summer 1981), and a 15.97-ct cushion-cut ruby from the Mogok Stone Tract, Burma (this issue).

We Welcome Your Contributions. *Gems & Gemology* welcomes news of exhibits, events, and other items of a gemological nature regarding diamonds, colored stones, ornamental materials, organic materials, gem minerals for collectors, precious metals, and synthetics. If you have a news item, please contact John I. Koivula, Gemological Institute of America, 1660 Stewart St., Santa Monica, CA 90404, telephone (213) 829-2991, ext. 237.

THIRD ANNUAL
GEMS & GEMOLOGY MOST VALUABLE ARTICLE AWARD

This issue marks the end of the 1983 volume year of *Gems & Gemology.* Once again, we are asking you—our readers—to select the three articles that you found most interesting and potentially useful. By participating in this ballot, you not only help us acknowledge the time and effort that these authors have contributed to expanding the gemological literature, but you also give us a better idea of your needs and interests.

Your ballot is located on the insert card inside this issue. Please choose three articles from 1983 and mark them in order of numerical preference: (1) first, (2) second, (3) third. Be sure to mark *only three articles for the entire year.* Additional comments concerning the journal are welcome in the space provided. After voting, simply detach the postcard ballot and drop it in the mail (postage pre-paid if mailed in the U.S.). Ballots must be received by March 15, 1984 to be included in the final tally.

The winning articles will be announced in the Spring 1984 issue of *Gems & Gemology,* with cash awards of $500, $300, and $100, respectively, given to the authors of the three most valuable articles.

Your participation is important to the vitality of the journal. So please take just a few minutes now to let us know how you feel, and help honor the authors whose work has educated and enlightened gemological readers around the world.

Richard Liddicoat

BOOK REVIEWS

Michael Ross, Editor

JEWELLERY OF THE ANCIENT WORLD

*By Jack Ogden, 185 pp., illus., publ. by Rizzoli International Publications, New York, 1983 (first published by Trefoil Books Ltd., London, 1982). US$50.00**

Jack Ogden, distinguished London dealer and founder of The Society of Jewellery Historians, has written the first account of the work of jewelers and goldsmiths of the pre-classical and classical world based on the study of materials available to them and the techniques they used in their considerable achievements. His writing combines the sensitivity of the connoisseur with the skill of the archaeologist, and his book will be useful to professionals and non-professionals alike.

Derek Content, one of America's leading authorities on ancient gems and jewelry, told this reviewer that the approach taken by Ogden in this book is long overdue. "It should have been written 15 years ago," Content said, complimenting Ogden's efforts, "and I wish I had written it myself."

The chapter on gemstones is noteworthy for the review of materials used in jewelry by the ancient craftsmen and a discussion of their sources. The author points out the enormous potential that exists for further work on source correlation for gemstones used in antiquity. The use of emeralds, jade, lapis lazuli, organic gem materials, glass, enamel, and faience is, of course, expected. It is surprising, however, to find that such material as cordierite, dioptase, and steatite were used. But, as Ogden says, "There can hardly be any naturally occurring substance that has not at one time or another been employed to decorate the human body." He also states that the use of diamond jewelry during this period was "limited to Roman times after the 1st century and mainly to the 3rd century."

The author gives attention to the widespread trade in gem materials in antiquity, going back some 5,000 years in Egypt and India, and speculates that trade in Whitby jet and Baltic amber probably led to Mediterranean sea trade with Northern Europe.

In the chapter dealing with fakes and forgeries, Ogden clearly and logically pulls together all the information that has helped identify spurious pieces for the last decade, and greatly furthers understanding of the genuine article. He says that, so far, gemological tests have not been used to their full potential in forgery detection, but that they have proved their worth in several cases.

In other parts of the book, there are a few isolated facts that could be questioned, e.g., "Roman agate intaglios are rare," when many late Republic agate gems are known and their popularity attested to by the well-known glass imitations of the same period. Ogden also mentions "rarely recorded Western Asiatic use" of onyx, when many examples of eye "agates" in Ur and other very early sites are documented.

The extensive footnotes and bibliography are valuable but appear in extremely small print and are hard on the eyes. The numbering system for the illustrations is awkward, and the proofreading is not all that it could be.

These are minor complaints, however, and do not detract from the *luxe* of the graphics, the splendor of the photographs, or the quality of the scholarship. Ogden's combination of technological and art-historical information in jewelry studies has not been seen previously. He has broken new ground and established the path for others to follow.

NEIL LETSON
Anniston, Alabama

CURRENT TOPICS IN MATERIAL SCIENCE, Vol. 10: "Gem Materials, Natural and Artificial"

By I. Sunagawa, 144 pp., illus., publ. by North Holland Publishing Co., New York, NY, 1982. US$106.50

In both the preface and advertising for this volume, the editor claims that "The continuous struggles in the gemmological laboratories to find methods for distinguishing between natural and synthetic gems is discussed in detail by the author [Sunagawa] and presents one of the main scientific attractions of this excellent review." However, the author only briefly mentions a few selected aspects of this subject, and even those are not at a level useful for the gemologist.

This review article contains a number of interesting microtopographs of the surfaces of natural and synthetic gemstones, the field of specialization of the author. However, Sunagawa has attempted to expand this to cover the wide field of the title within a very limited space. As a result, the treatment is uneven, indeed superficial in many places, and the reader will leave with many misconceptions. For example, Sunagawa claims that a synthetic ivory has been produced (incorrect); that the composition of cubic zirconia is $ZrO_2 \cdot Y_2O_3$ (it is approximately $9ZrO_2 \cdot Y_2O_3$); that the color of amethyst is due to iron oxides and hydroxides (it is a color center involving substitutional Fe); that the color of chalcedony is commercially changed by a hydrothermal treatment (!), and so on. There is also mention and a picture of "plastic opal" (should be "plastic opal imitation"). The heat treatment of amethyst to turn it yellow is not mentioned under quartz but is discussed as a misnomer under the heading of topaz, without ever giving the proper name of the product. And so on.

There is a brief introduction to crystal growth mechanisms but at a level of little use to the person who does not already know the meaning of "Jackson's alpha." Nor do the six unlabeled drawings of diamond

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**This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404.*

growth apparatus in figure 20 mean anything to the reader not already an expert in crystal growth (and not much even then). The four color plates do not do justice either to the color (emerald, amethyst, ruby) or to the appearance (diamond imitations) of the materials pictured. There are 137 references with only occasional coverage of the literature through 1980. Finally, diamond is the only gem material discussed in the text that appears as a primary entry in the index, and even then the wrong page listing is given.

Sunagawa does include highly technical treatments of diataxy, SbSI, nonstoichiometry, and halide vapor complexes; workers in these fields will find this information useful. However, the gemologist will find little of interest in this rather expensive volume.

KURT NASSAU
Bernardsville, NJ

SHORT COURSE IN GRANITIC PEGMATITES IN SCIENCE AND INDUSTRY

Edited by P. Černý, 555 pp., illus., publ. by the Mineralogical Association of Canada, Winnipeg, Canada, 1982. US$150

This volume represents the published proceedings of a symposium on granitic pegmatites held in Winnipeg in May 1982, under the auspices of the Mineralogical Association of Canada. This meeting brought together many of the foremost authorities on pegmatites from both academic and industrial backgrounds. As such, this volume is perhaps the most comprehensive, updated text dealing with granitic pegmatites and their relationship to more fundamental geologic processes in the Earth's crust.

The chapters in the text fall into four sections. The introductory chapter reviews the occurrence and classification of granitic pegmatites. The second section includes nine chapters dealing with various aspects of pegmatite mineralogy. The petrology, geochemistry, and geologic evolution of granitic pegmatites are discussed in the next five chapters. The final section consists of four chapters concerning the exploitation of granitic pegmatites for valuable mineral commodities. Each chapter includes a complete bibliography of important articles.

Since pegmatites have been, and seem destined to continue to be, the subject of only brief discussion in most geology textbooks, this volume appears to be the best reference on granitic pegmatites for interested readers regardless of their background.

JAMES E. SHIGLEY
Research Scientist, GIA

OTHER BOOKS RECEIVED IN 1983

An A-Z of Gems and Jewelry, *Bill Robins. Arco Publishing, 1982; 96 pp.; 54 line drawings; US$10.95*.* Of the 153 entries from agate to zircon, 71 are related to jewelry, 69 to gems, and 13 to metals. The short, nontechnical descriptions are illustrated by numerous line drawings. These are followed by the appendix, which is a list of 19 gemstones, their varieties, hardness, color, and main sources.

Beginner's Guide to Minerals, *Michael O'Donoghue. Newnes Technical Books, 1982; 140 pp.; one color photograph, 21 black-and-white photographs, and 34 line drawings; US$9.95*.* Reflecting his background in gemological information, O'Donoghue begins with the early study of minerals from Aristotle and Theophrastus to Pliny the Elder. In his next chapter he discusses the aspects of building a mineral collection; then he reviews how minerals form, their composition and structure, crystals and light, and, finally, ways to test minerals. The final chapter, devoted to mineral descriptions, is arranged by chemical family. In addition to important constants and other aids to identification, the author includes information on how to clean specimens and comments on significant localities.

Depositional Systems, *Richard A. Davis, Jr. Prentice-Hall, Inc., 1983; 669 pp.; many black-and-white photographs, line drawings, maps, and charts; US$33.95.* In his preface, Davis describes this book as a college-level textbook on sedimentary geology. Unlike earlier texts that were largely descriptive, focusing on sediments and sedimentary rocks, this one takes the genetic approach. It examines, in detail, the specific environments of deposition and then relates these to the sedimentary features produced. An extensive reference section, 52 pages in length, is included.

Diagrams for Faceting, Volume II, *Glenn & Martha Vargas. Glenn & Martha Vargas, 1983; 151 pp.; many line drawings; US$17.50*.* The most recent effort by Martha and Glenn Vargas is designed to accompany their two earlier books, *Faceting for Amateurs* and *Diagrams for Faceting, Volume I.* Since most of these diagrams were contributed by faceters worldwide, the authors begin with a short biographical note on each contributor. Then they explain how to convert the number settings presented in the diagrams into readings usable on any faceting equipment. This is followed by 132 diagrams, arranged in 12 sections according to shape. Each cut has step-by-step procedures for cutting and polishing, as well as special notes on the degree of difficulty and suitable faceting materials. This is a book to challenge experienced cutters.

Gem and Jewellery Year Book 1983, *ed. V. Kala. Gem & Jewellery Information Centre of India (A-95, Journal House, Janta Colony, Jaipur 302004, India); 678 pp; some black-and-white photographs, line drawings, and maps; US$30.00*(airmail), or US$20.00 (seamail).* The ninth edition of the compendium includes information about the Indian gem and jewelry trade, gemological instruments and lapidary equipment and supplies, Indian customs regulations, the international gem trade, foreign representatives in India and Indian representatives abroad, gem and jewelry organizations, and taxation. It also includes a directory of Indian supplies.

Two changes in the 1983 format are worth noting. By increasing the dimensions of this year's edition (as well as consolidating some chapters), the editor has reduced the number of pages from 854 in 1982 to 678 in 1983. Because each section has its own page numbers, it was always difficult to locate specific chapters. Now, colored sheets separate the 3 sections.

Gemmological Instruments, *Peter G. Read. Butterworths, 2nd ed., 1983, 328 pp; many black-and-white photographs, as well as many line drawings; US$39.95*.* Read has increased the text in this second edition by 101 pages and included two new sections, one on photomicrography and one on experimental equipment. Other chapter modifications include more information on synthetics and simulants, a comparative value guide on equipment prices, and a separate chapter on thermal conductivity. Once again, manufacturers and suppliers are listed in the appendix.

Lapidary Carving, *Frank W. Long. Van Nostrand Reinhold, 1982; 132 pp; 102 black-and-white photographs, 52 line drawings; US$24.95*.* Long begins by defining different types of carving as well as briefly reviewing the history of carving from a 40,000-year-old figure to today's commercial work. In his second chapter he discusses materials, grouping them by hardness. In the third chapter, he focuses on carving tools and equipment. This is particularly interesting because he includes equipment not traditionally used by lapidaries. Line drawings and photographs amply illustrate his fourth section on methods and techniques. He concludes this useful book with a short chapter on design fundamentals and an appendix with pertinent references such as speed tables and supplies of equipment and materials.

Minerals and Rocks of Jamaica, *Anthony R. D. Porter, Trevor A. Jackson, and Edward Robinson. Jamaica Publishing House, 1982; 174 pp.; 12 color photographs, 10 black-and-white photographs, three maps, and five line drawings; US$12.95.* The authors, three Jamaican geologists, combined the basics of a rock and mineral handbook with the specifics of localities in Jamaica. They divided the book into two parts: minerals and rocks. In part 1, chapters on minerals and the physical properties of minerals are followed by a description of Jamaican minerals and Jamaican mineral identification. In part 2, chapters on rocks and on a description of Jamaican rocks are followed by rock identification and the geologic history of Jamaica. Locality information is keyed to topographic and geologic maps which are described in the appendix. There is also a reference list with 93 entries.

Rocks, Minerals and Gemstones of Southern Africa, *E. K. Macintosh. C. Struik (Pty) Ltd., 1983; 120 pp.; 109 color photographs; US$15.00*.* This collecting guide to mineral resources in southern Africa begins with short chapters on collecting and on the physical properties of minerals. The majority of the book is composed of brief descriptions of materials divided into chapters: major and minor rock-forming minerals; igneous, sedimentary, and metamorphic rocks; and minerals of economic importance. This last chapter has been added since the first edition appeared in 1976. Locality information is a useful aspect of the descriptions. The color photographs are quite good, giving a visual example of most of the rocks, gems, and minerals presented.

Suggestions for Authors

GEMS & GEMOLOGY is an international publication of original contributions (not previously published in English) concerning the study of gemstones and research in gemology and related fields. Topics covered include (but are not limited to) colored stones, diamonds, gem instruments, gem localities, gem substitutes (synthetics), gemstones for the collector, jewelry arts, and retail management. Manuscripts may be submitted as:

Original Contributions—full-length articles describing previously unpublished studies and laboratory or field research. Such articles should be no longer than 6,000 words (24 double-spaced, typewritten pages) plus tables and illustrations.

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

Notes & New Techniques—brief preliminary communications of recent discoveries or developments in gemology and related fields (e.g., new instruments and instrumentation techniques, gem minerals for the collector, and lapidary techniques or new uses for old techniques). Articles for this section should be about 1,000–3,000 words (4–12 double-spaced, typewritten pages).

MANUSCRIPT PREPARATION

All material, including tables, legends, and references, should be typed double spaced on 8½ × 11" (21 × 28 cm) sheets. The various components of the manuscript should be prepared and arranged as follows:

Title page. Page 1 should provide: (a) the article title; (b) the full name of each author with his or her affiliation (the institution, city, and state or country where he/she works); and (c) acknowledgments.

Abstract. The abstract (approximately 150 words for a feature article, 75 words for a note) should state the purpose of the article, what was done, and the main conclusions.

Text. Papers should follow a clear outline with appropriate heads. For example, for a research paper, the headings might be: Introduction, Previous Studies, Methods, Results, Discussion, Conclusion. Other heads and subheads should be used as the subject warrants. For general style, see *A Manual of Style* (The University of Chicago Press, Chicago).

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

Include the following information, in the order given here, for each reference: (a) all author names (surnames followed by initials); (b) the year of publication, in parentheses; (c) for a *journal*, the full title of the article or, for a *book*, the full title of the book cited; and (d) for a *journal*, the full title of the journal plus volume number and inclusive page numbers of the article cited or, for a *book*, the publisher of the book and the city of publication. Sample references are as follows:

Daragh P.J., Sanders J.V. (1976) Opals. *Scientific American*, Vol. 234, pp. 84–95.

Liddicoat R.T. Jr., Copeland L.L. (1967) *The Jewelers' Manual*, 2nd ed. Gemological Institute of America, Santa Monica, CA.

Tables. Tables can be very useful in presenting a large amount of detail in a relatively small space, and should be considered whenever the bulk of information to be conveyed in a section threatens to overwhelm the text.

Figures. Please have line figures (graphs, charts, etc.) professionally drawn and photographed. High-contrast, glossy, black-and-white prints are preferred.

Submit black-and-white photographs and photomicrographs in the final desired size if possible.

Color photographs—35 mm slides or 4 × 5 transparencies—are encouraged.

All figure legends should be typed double spaced on a separate page. Where a magnification is appropriate and is not inserted on the photo, please include it in the legend.

MANUSCRIPT SUBMISSION

Please send three copies of each manuscript (and three sets of figures and labels) as well as material for all sections to the Editorial Office: *Gems & Gemology*, 1660 Stewart Street, Santa Monica, CA 90404.

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SUBJECT INDEX

This index gives the first author (in parentheses) and *first page* of the article, Editorial Forum, or Gem Trade Lab Notes (GTLN) section in which the indexed subject occurs. The reader is referred to the author index for the full title and the coauthors, where appropriate, of the articles cited.

AUTHOR INDEX

This index lists, in alphabetical order, the names of authors of all articles that appeared in the four issues of Volume 19 of *Gems & Gemology.* Full citation is provided under the first author only, with reference made from joint authors.

Indexes prepared by Dona Dirlam