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THE INTERNATIONAL GEMOLOGICAL SYMPOSIUM: FACING THE FUTURE WITH GIA

Sixty years ago, industry visionary Robert M. Shipley had an idea. He believed there should be a central educational resource and repository for gemological knowledge and science to train professional jewelers, and, in 1931, he founded the Gemological Institute of America to meet that need. The Institute has grown in size and scope over the last six decades to become a major factor in education and research for the international gem and jewelry trade, achieving a reputation for excellence and becoming a model for other industries.

Four years ago, when we began to plan the celebration of our milestone Diamond Jubilee, we had an idea. We wanted to bring together the best and the brightest from the world of gems and jewelry and to provide them with a unique forum for the exchange of information and ideas. We wanted to make this opportunity available to the widest audience possible. And we wanted it to make a lasting contribution to the body of gemological knowledge.

From June 20 to 24, that idea, too, becomes a reality as we proudly present the International Gemological Symposium—our Diamond Jubilee celebration—at the Century Plaza Hotel in Los Angeles. Its theme, FACING THE FUTURE, will set the pace and the tone for an array of speeches, panels, presentations, and social events that will include the top echelon of our industry as participants and corporate sponsors. From its inception in 1987, to this moment, Symposium has grown to a depth and richness of character that surpasses anything we, or you, might imagine. It is with equal pride that we present in this issue of *Gems & Gemology* a very special pre-Symposium section including abstracts of the more than 70 feature presentations and other highlights of what some are now calling "**The** event in the history of the industry."

Gems & Gemology, too, is marking a milestone. This issue begins its second decade of success in its now-familiar expanded format and commemorates the international reputation it has won as the premier professional journal in gemology. In tandem celebration with GIA's Diamond Jubilee, *G&G* presents this preview special to whet your appetite and begin what will be an extended series of Symposium coverage. It is designed so that you, our valued readers, can witness first hand, through these pages, the gemological history to be made in June, just as you have witnessed the Institute's growth and development around the world over the years. Our goal is to include as much coverage of Symposium as publication space allows, and we will be publishing articles in upcoming issues on all significant and groundbreaking presentations—preserving them for posterity in the literature of gemology.

Ideally, we would like each and every one of you to attend Symposium, and we invite you to register, using the enrollment form enclosed for your convenience. Then, as you receive your next several issues of *G&G,* you can re-live, through in-depth articles and notes, many of the exciting experiences you will have had. Either way, whether you can be with us in person, or merely in spirit, the Gemological Institute of America and *Gems & Gemology* want you to be a part of our continuing progress in a global industry, because we can't imagine FACING THE FUTURE without you.

William E. Boyajian
President, GIA

AGE, ORIGIN, AND EMPLACEMENT OF DIAMONDS:

Scientific Advances in the Last Decade

By Melissa B. Kirkley, John J. Gurney, and Alfred A. Levinson

Scientific advances in the past decade have completely altered our understanding of certain concepts relating to the age and origin of diamonds. As a generalization, most diamonds formed more than 990 million years ago, deep within the earth, from either of two rock types, peridotite and eclogite. They were stored below the base of cratons for varying periods of time, some as long as 3,200 million years, before being transported to the surface. Kimberlite and lamproite, the two rock types usually associated with diamonds, are only the mechanisms that brought diamonds to the surface and are in no way related to the formation of most diamonds. Other topics that are somewhat more speculative, for example, the source of carbon for the crystallization of diamonds and the mechanism of kimberlite and lamproite emplacement, are also discussed and the latest concepts presented.

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The decade of the 1980s saw major advances in our understanding of the age, origin, and emplacement of diamonds. Much of the new data and their interpretations are found in highly technical scientific journals and conference proceedings that are rarely encountered by gemologists. Therefore, we have prepared this review article to update gemologists on some of the latest facts and concepts with respect to the above topics.

The information contained in this article is applicable to virtually all natural diamonds, both gem and industrial (figure 1), except possibly for certain rare types of diamonds, such as those referred to as "fibrous" or "coated," and microdiamonds, as well as for diamonds related to meteorite impacts. In addition to our own experiences, we have drawn from many volumes in the technical literature. For those interested in pursuing these topics further, we recommend the books by Ross (1989), Nixon (1987), Mitchell (1986), Glover and Harris (1984), Kornprobst (1984), and Dawson (1980), and the review articles by Gurney (1989) and Meyer (1985).

AGE OF DIAMONDS

Until recently, one of the major unresolved problems in diamond research revolved around the age of diamonds. Age dating of diamonds assists in understanding their origin, which is a significant factor in diamond exploration. For many minerals, age can be determined directly using a number of well-established geochronological techniques, such as the uranium-lead (U-Pb) method. However, because diamond is essentially pure carbon, it does not contain any of the radiogenic elements on which such methods depend. Even the well-known carbon-14 (^{14}C) method is useless for diamonds because it is restricted to organic carbon that has been involved in the earth's recent near-surface carbon cycle.

Although diamonds themselves cannot be dated, some of their minute inclusions, such as pyroxene and garnet,

Figure 1. Today, diamonds are the most popular gemstone and a valuable industrial material. As a consequence, there has been considerable research into the geologic origins of diamonds to aid in exploration and mining. The last decade, in particular, has produced some important advances in our understanding of the complex processes required for the formation and deposition of diamonds. The ultimate result of such research is evident in these superb earrings and necklace. The three large diamonds in the necklace are (from the left) 9.81, 16.18, and 12.73 ct; they are surrounded by 254 diamonds with a total weight of 67 ct; the earrings contain 84 diamonds with a total weight of 11 ct. Jewelry by Van Cleef and Arpels; photo courtesy of Sotheby's, New York.

can, because these minerals contain measurable quantities of the elements involved in radioactive decay systems. Some inclusions (e.g., garnet) were formed at the same time, and in the same place, as their mineral host (e.g., diamond), so that the age of the inclusion is also the age of the host. Detailed studies of olivine, garnet, pyroxene, chromite, and other minerals in diamond have shown that these minerals were growing adjacent to the diamond, which then grew around and enclosed them (figure 2). This physical relationship between diamond and its cogenic inclusions is sometimes reflected by the crystal form of the silicate inclusions, which take on the morphology (called cubo-octahedron) of the diamond rather than that of their species (figure 3).

Several attempts were made prior to 1981 to date inclusions in diamonds; the study by Kramers (1979) is the most significant. Using lead (Pb) isotopic compositions of sulphide inclusions in diamonds, he determined ages on the order of 2,000 million years (My) for inclusions in diamonds from the Finsch and Kimberley pipes in South Africa; those from the Premier mine appeared to be about 1,200 My in age. However, Richardson et al. (1984) were the first to date successfully a significant number of inclusions in diamonds, specifically inclusions of garnet in Finsch and Kimberley

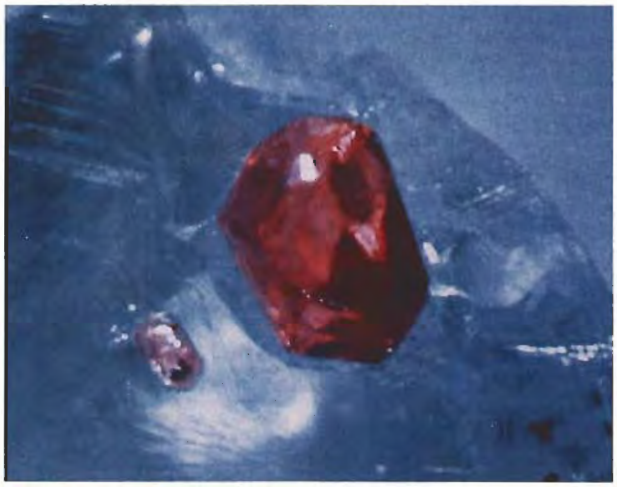


Figure 2. This garnet inclusion in a diamond (1 mm across) from the Finsch mine, South Africa, was dated by geochronological methods to be about 3,300 million years old. Because such inclusions undoubtedly formed at the same time as their hosts, they are the best means of age dating diamonds, which cannot be tested directly by standard dating methods. Photo courtesy of Dr. S. H. Richardson.

Figure 3. Trigons, which are typical of a diamond octahedron, can be seen on the face of this flattened inclusion of pyrope garnet, with a colorless enstatite (orthopyroxene) or olivine crystal at the end. These features are taken as evidence that the diamond has forced its crystal habit on the guest mineral during the simultaneous crystallization of inclusion and host. Photomicrograph by Eduard J. Gübelin; transmitted illumination, magnified 50×. From Gübelin and Koivula (1986, p. 95).

diamonds, by means of the relatively new samarium-neodymium (Sm-Nd) geochronological method combined with the rubidium-strontium (Rb-Sr) technique. Table 1 summarizes these results along with more recent data (Richardson, 1986; Richardson et al., 1990) on diamonds from several other pipes in southern Africa and Australia. (For a discussion of some earlier studies that have a bearing on the dating of inclusions in diamonds, see Meyer, 1985, and Gurney, 1989.)

The results presented in table 1 may well be the most striking information about diamonds to emerge in the past decade, not only because they put accurate ages on diamonds in millions of years (My) but also because of other implications, as discussed below:

1. Diamonds are old and may have been forming continually, certainly intermittently, throughout most of earth's history. The 2,300 My period between ~3,300 and 990 My represents about half of the earth's 4,500 My existence, and inclusions in diamond may yet be found that extend this range.

2. Diamonds are usually very much older than the kimberlite that brought them to the surface. For example, diamonds from the Kimberley pipe are as much as 3,200 My older than the age of kimberlite emplacement (i.e., when the pipe reached the surface, about 100 My ago). This example implies that: (a) diamonds can be stored deep within the earth for an extended period of time before being carried to the surface by the kimberlite; and (b) kimberlite is merely the transporting medium for bringing diamonds (as well as other materials) to the surface. This process has been picturesquely described by the analogy of an elevator or a bus (the kimberlite) picking up passengers (diamonds) in the earth's mantle along its route of ascent toward the surface. Note, though, that there is no resolvable age difference between the diamonds and kimberlite emplacement at the Premier mine. This suggests that, in this example, they may be contemporaneous. Whether the Premier mine is unusual awaits the determination of diamond ages from additional localities.

3. In samples from the Finsch mine, two ages—~3,300 and 1,580 My—have been obtained, the former for peridotitic, and the latter for eclogitic, inclusions. These two main types of inclusions in diamond are discussed in greater detail below. The presence of diamonds of different ages within one pipe can, for the present, most easily be explained by the fact

that kimberlites may obtain their diamonds from more than one geologic environment (mantle source) during their rise toward the surface.

4. The data reported in table 1 have settled a long-standing debate in which scientists advocated one of two hypotheses with respect to the origin of diamonds. The "phenocryst school" maintained that diamonds originally formed at depth from the crystallization of a kimberlite magma (molten mass) and, hence, are genetically related to the magma and are *phenocrysts* (def: a relatively large crystal set in a fine-grained groundmass to which it is genetically related [Gk. *pheno:* to show + *cryst*(al)]). The "xenocryst school," on the other hand, believed that diamonds were formed prior to the intrusion of kimberlite, are not genetically related to it, and are merely accidental inclusions known as *xenocrysts* (def: a crystal or a fragment of a crystal included in a magma and not formed by the magma itself, i.e., foreign to it [Gk. *xeno:* strange, foreign + *cryst*(al)]). In view of the newly confirmed fact that diamonds are, in general, much older than their kimberlite (or lamproite) host rocks, the xenocryst theory is now known to be correct. The data from the Premier mine (diamond and kimberlite are the same age) could be the result of an extremely short interval between the formation of diamond at an extraneous source and its capture by the Premier kimberlite.

   Although the concept that diamonds are xenocrysts in kimberlite was proposed as early as 1905, it was not until the Third International Kimberlite Conference, held in France in 1981, that "there was a realization that diamonds are xenocrysts in kimberlites" (Mitchell, 1986, p. 8). The proof, however, has come only since 1984, with the work of Richardson and his associates on the age of diamonds and their host rocks (table 1).

In summary, recent geochronological studies clearly show that most diamonds: (a) are much older than the volcanic rocks (kimberlite and lamproite) that carried them to the surface; (b) are not genetically related to these volcanic rocks; and (c) have crystallized, possibly episodically, during a large part of earth's history. Further, it must be emphasized that it is the ability to date mineral inclusions separated from diamonds, which has only existed during the last decade, that has made age dating of diamonds possible. This is further evidence that mineral inclusions have great scientific value in addition to their gemological importance.

ORIGIN OF DIAMONDS

The study of the origin (genesis) of diamond ideally involves the collection, assimilation, and interpretation of a vast amount of data from many

TABLE 1. Ages of diamonds and emplacement of associated kimberlite[a] pipes in My (millions of years), and type of inclusions.

Location (mine)	Age of diamonds (My)	Age of emplacement of kimberlite[a] pipe (My)	Type of inclusions in diamonds	Reference
Kimberley, South Africa	~3,300	~100	Peridotitic	Richardson et al. (1984)
Finsch, South Africa	~3,300	~100	Peridotitic	Richardson et al. (1984)
Finsch, South Africa	1,580	~100	Eclogitic	Richardson et al. (1990)
Premier, South Africa	1,150	1,100–1,200	Eclogitic	Richardson (1986)
Argyle, Australia[a]	1,580	1,100–1,200	Eclogitic	Richardson (1986)
Orapa, Botswana	990	~100	Eclogitic	Richardson et al. (1990)

[a] *In the case of the Argyle sample, the pipe is a lamproite.*

Figure 4. Boulder-size xenoliths of eclogite, which frequently contain diamonds, are seen here at the Roberts Victor mine, near Kimberley, South Africa. Study of xenoliths such as these, which were brought up from the earth's mantle (depth at least 150 km) by kimberlite, enable scientists to determine pressure-temperature (P-T) conditions within the mantle and, by analogy, P-T conditions for the formation of diamonds.

disciplines related to the physical, chemical, and mineralogic properties of diamonds, the rocks in which they crystallize, as well as the rocks that brought them to the surface and in which they now are found as primary deposits. Clearly, such a broad survey is beyond the scope of this article. Therefore, we will focus on those aspects of diamond genesis that are of the greatest interest to gemologists, particularly those in which major advances have been made in the past decade. Such topics include: (1) the types and properties of rocks in which diamonds form; (2) the pressure-temperature conditions under which diamonds crystallize within the earth; and (3) the source of the carbon of which diamond is composed.

Rocks in Which Diamonds Form. Now that it has been established that kimberlite and lamproite are only the transporting mechanisms for bringing diamonds to the surface, and are not genetically related to diamond, the question that must be answered is: From what type of magma or preexisting material do diamonds actually crystallize? The two most rewarding areas of investigation in which answers to this question have been found are: (1) the study of diamond-bearing xenoliths, and (2) the study of mineral inclusions within diamonds.

Diamond-bearing Xenoliths. A *xenolith* can be defined as a rock fragment that is foreign to the igneous mass in which it occurs [Gk. *xeno:* strange, foreign + *lith:* stone, rock]. Xenoliths are not formed from the magma itself; rather, they become included in the magma as it rises. Xenoliths may be as small as a single crystal, boulder size (figure 4), and even much larger (figure 5).

Xenoliths in kimberlites and lamproites represent fragments of wall rock adjacent to an intrusion that have broken off and been incorporated into the magma as it works its way along fractures or cracks to the surface. Thus, xenoliths may represent blocks of buried crustal formations brought closer to the surface, such as metamorphic rocks derived from deep-seated terrains within the earth's lower crust, or sedimentary rocks in the upper crust and, perhaps most importantly, rocks believed to be derived from the earth's upper mantle. Kimberlites and lamproites are the only means of obtaining samples of such deep rock types.

Xenoliths are usually rounded, especially if they originate at great depths, probably because of chemical dissolution at the margins of the fragments (e.g., figure 4), but they are likely to be angular if they originate from shallow wall rocks. Xenoliths that contain diamonds are extremely important because they permit us to determine the characteristics of the rock types from which diamonds crystallize. Such characteristics include chemical composition, pressure-temperature reg-

Figure 5. This rounded xenolith of sandstone, about 2 m in its longest dimension, is an example of rock broken off from the walls of the conduit along which the kimberlite magma ascended to the surface. As sandstone is characteristic of the upper part of the earth's crust (generally found within 10 km of the surface), this xenolith will not contain diamonds. Exact location unknown (probably South Africa).

Figure 6. Altered olivine and other magnesium-rich minerals (a "kelyphite" rim) surround this 8-cm-long xenocryst of garnet. The alteration resulted from reaction with kimberlite fluids. Chemical reactions, along with fragmentation by physical forces, tend to break up xenoliths, especially those of the peridotite type, releasing xenocrysts of diamond. From the Monastery mine, South Africa.

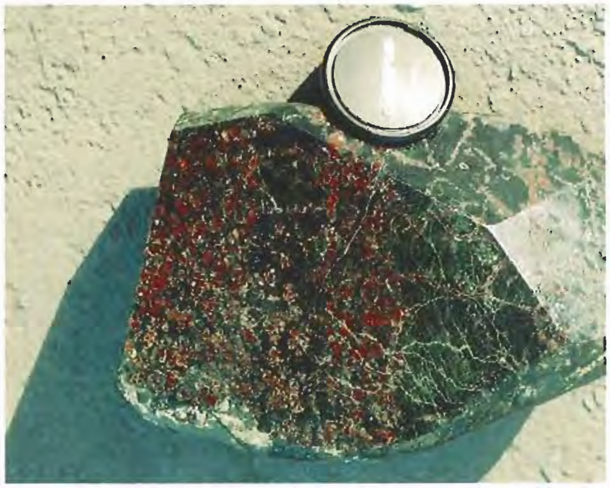


Figure 7. The polished surface of this eclogite xenolith specimen displays the pyrope-almandine garnet (red mineral) and clinopyroxene (green) that are its chief components. From the Roberts Victor mine, near Kimberley, South Africa.

ime, the nature of any volatiles (e.g., CO_2, H_2O) present, and other parameters pertinent to deciphering the genesis of diamonds. Eclogites and peridotites are the predominant xenoliths found to contain diamonds (see box A for details of the mineralogy, chemistry, and classification of these two rock types).

During transportation of both peridotitic and eclogitic xenoliths within kimberlite or lamproite, fragmentation of the xenoliths may take place, adding smaller xenoliths or even xenocrysts to the transporting magma; this is probably the best way to explain the occurrence of diamond xenocrysts, as well as single crystals of other minerals (e.g., garnet, chromite), in kimberlite and lamproite rocks. It is also important to recognize that xenoliths in kimberlite and lamproite do not always represent with fidelity the mineralogy and pressure-temperature conditions of the mantle in which they are supposed to have formed, because extensive modification may take place as they react chemically with the fluids in the transporting magmas (figure 6). Inclusions, however, are shielded from extraneous influences by the surrounding diamond, so the conditions of formation they indicate are considered better representations of the actual mantle conditions in which diamonds formed. By comparing inclusion and xenolith compositions, scientists are confident that they can recognize altered *vs.* unaltered compositions in their study of eclogites and peridotites.

Eclogite is a coarse-grained ultramafic rock consisting essentially of a granular aggregate of red garnet (almandine-pyrope) and green pyroxene (technically jadeitic clinopyroxene or a solid solution between jadeite and diopside), with minor amounts of rutile, kyanite, corundum, and coesite (figure 7). Eclogite is indicative of a high pressure–high temperature (with emphasis on the former) environment, consistent with that in which dia-

Figure 8. Diamonds protrude from the surface of this broken eclogite xenolith obtained from the Ardo-Excelsior mine, South Africa. Such samples, corroborated by experimental studies in which the pressure-temperature conditions required for the formation of garnet and clinopyroxene are taken into account, are considered evidence that diamond may crystallize as a primary constituent of an eclogite.

BOX A: CLASSIFICATION AND NOMENCLATURE OF IGNEOUS ROCKS

The subdivisions of igneous rocks named in figure A-1 are those used by most geologists. Of special significance in this review article are the terms *mafic* and *ultramafic*, because kimberlite, peridotite, and eclogite are ultramafic rocks. The term *mafic* (from *ma*gnesium and *f*erric [iron]) is used to describe a rock composed chiefly of one or more iron-magnesium (ferro-magnesium) dark-colored minerals such as pyroxene, amphibole, and olivine. Typically a rock of this type will have 42–52 wt.% SiO_2 and 16–26 wt.% combined FeO and MgO. Basalt (extrusive or volcanic) and gabbro (intrusive or plutonic) are the most common mafic rocks. The term *ultramafic* is applied to a rock with even lower SiO_2 than a mafic rock (we use the division at 42 wt.%) and, by analogy, even higher FeO and MgO. These rocks are composed of

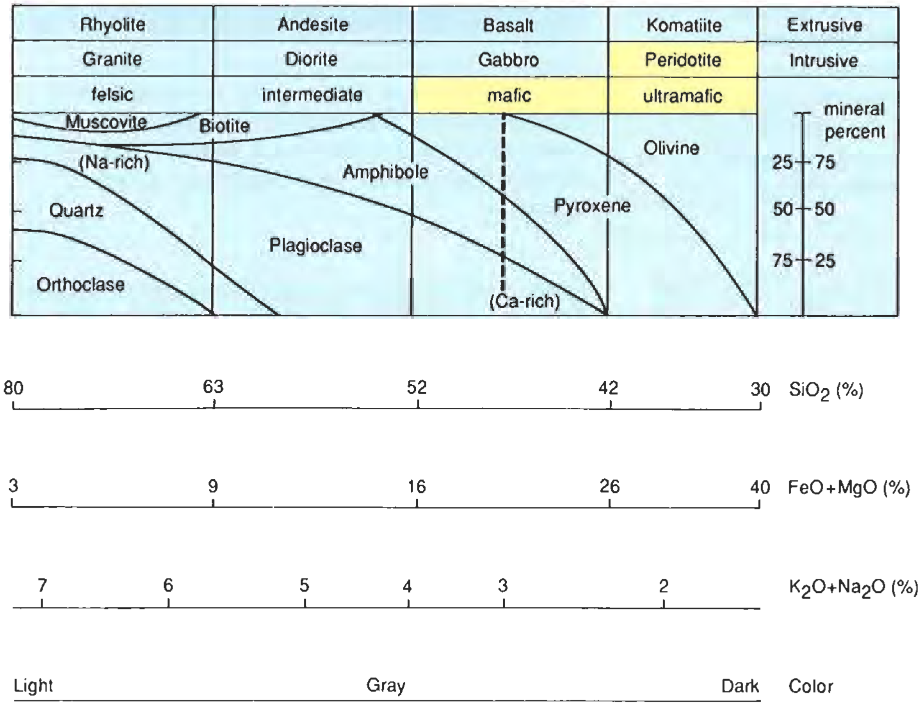


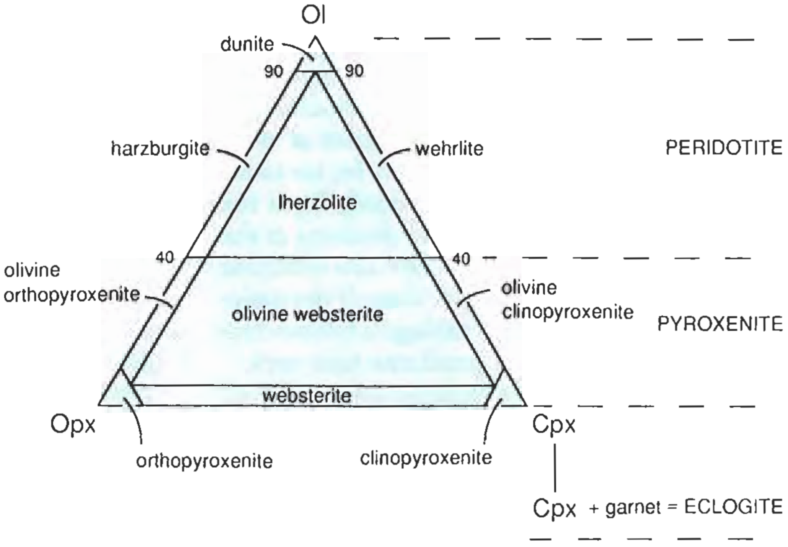
Figure A-1. This illustration shows the mineralogic compositions, selected chemical changes, and changes in color associated with the common extrusive and intrusive igneous rocks. The center of each vertical column represents the average mineralogic and chemical compositions of each rock. For example, the average basalt (see vertical broken line) would have about 48 vol.% pyroxene, 28 vol.% amphibole, 24 vol.% calcium-rich plagioclase, and a trace of olivine. A chemical analysis would yield about 47 wt.% SiO_2 and 20 wt.% FeO + MgO.

monds form (figure 8). Typically, eclogite occurs in deep crustal metamorphic regions below continents; it became eclogite by means of solid-state (metamorphic) transformation of previously existing rock, probably basalt. Eclogite found in the mantle probably forms in the same way, through subduction of crustal rocks (discussed below). As an aside, in its own right unaltered eclogite could well be considered a gem material because of the combination of two very attractive gem minerals (again, see figure 7).

Peridotite is a general term for a coarse-grained ultramafic rock consisting chiefly of olivine with or without other mafic (high in Fe and Mg) minerals, such as pyroxenes (again, see box A). Garnet and spinel frequently occur in small amounts. Peridotite is believed to be the most common and abundant rock type in the earth's mantle. Most peridotitic diamonds are formed in garnet-bearing harzburgite, with minor amounts formed in lherzolite (Gurney, 1989).

Following our practice of illustrating important concepts and features, such as eclogite xenoliths (figures 4, 7, 8), we would like to show a photograph of a diamondiferous peridotite xenolith, but such xenoliths are extremely rare and are typically extensively altered. Whereas over 100 diamond-bearing eclogites have been described in detail in the literature, there are probably fewer than 20 comparable descriptions for diamondiferous peridotite xenoliths. This is most remarkable, since harzburgite is probably the source of

Figure A-2. This classification scheme for ultramafic (intrusive) rocks, recommended by a Committee of the IUGS (International Union of Geological Sciences), is based on the proportions of olivine (Ol), orthopyroxene (Opx), and clinopyroxene (Cpx). The apexes of the triangle represent 100% each of the above-mentioned minerals. Most diamonds found in rocks broadly called peridotite are actually from rocks more accurately classified as harzburgite (see text for details). Eclogite is actually a specific case of clinopyroxene plus garnet, as is shown at the lower right corner of the diagram.



olivine and pyroxene, usually together as in peridotite, but each may constitute a rock on its own: dunite and pyroxenite, respectively.

The ultramafic rock peridotite is particularly important in gemology both because it is one of the two rocks from which diamonds crystallize (eclogite is the other) and because it is the rock from which melts of kimberlite and lamproite (the two rock types that transport diamonds to the surface) originate.

From figure A-2, however, we see that there are two broad categories of ultramafic rocks, peridotites and pyroxenites. The classification of a rock as peridotite or pyroxenite depends on the volume percentages of the mafic minerals olivine and pyroxene. That is, peridotite must contain more than 40 vol.% olivine (Ol), with the remainder orthopyroxene (Opx) and/or clinopyroxene (Cpx). Peridotite, in fact, is actually a general name that includes the more specific rock types dunite, harzburgite, lherzolite, and wehrlite, the distinction between them being the relative proportions of Ol, Opx, and Cpx. For example, dunite must contain at least 90 vol.% olivine, with Opx and Cpx combined providing the remaining volume percentage. Harzburgite, the variety of peridotite from which many diamonds crystallize, contains 40–90 vol.% olivine, 5–60 vol.% orthopyroxene, and not more than 5 vol.% clinopyroxene. As the diagram indicates, eclogite is actually clinopyroxene plus garnet.

most of the diamonds in kimberlite (discussed in detail in the next section). Clearly, diamond-containing peridotite xenoliths must have been disaggregated by some incredibly efficient process. Several mechanisms have been proposed to explain this phenomenon, based mainly on laboratory experiments involving the gases CO_2 and H_2O, which are likely to be found in the mantle. It has been suggested that these gases are released following certain mineral reactions (e.g., the breakdown of dolomite, for CO_2) within the peridotite area of stability in the mantle, resulting in the self-destruction of diamondiferous peridotite xenoliths (Gurney, 1989, p. 957).

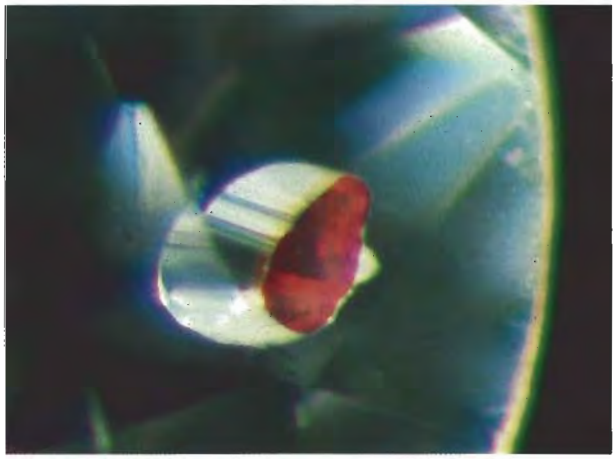
Mineral Inclusions in Diamond. The study of mineral inclusions in diamonds has been greatly aided by the advent of new analytical techniques, which have resulted in major discoveries during the past decade. As every gemologist knows, even those "large inclusions" that can be seen with the naked eye in diamonds classified as I_2 or I_3 are very small indeed. Yet, such instruments as the electron microprobe and the even more recent ion microprobe now make it possible to analyze chemically minerals and rock fragments as small as one micrometer (μm, one millionth of a meter). Other analytical techniques, such as Raman spectroscopy and X-ray diffraction, permit the identification of minerals while they are still within the diamond but cannot provide chemical data.

The subject and importance of mineral inclusions in diamonds have been reviewed comprehensively by Meyer (1987) and by Gurney (1989). As was explained above in connection with the dating of diamonds, the assumption is made that in order for most minerals (e.g., garnet) or aggregates of minerals (e.g., eclogite or peridotite) to be included within another mineral (e.g., diamond), both the inclusion and host must have been forming at the same time and place. Therefore, we can conclude that both have a common origin. Thus, if the inclusions are of the peridotitic assemblage it follows that the diamond formed within peridotite host rock.

Most of the mineral inclusions in diamond are very small (~100 μm) and usually are composed of just one mineral (monomineralic); however, bimineralic and polymineralic inclusions do occur. The multiphase mineral inclusions are particularly important not only in determining peridotitic or eclogitic origin, but also because analyses of the chemical and physical properties of two or more coexisting minerals enable us to estimate the pressure and temperature environments in which they and, by analogy, the host diamond formed.

In total, 22 contemporaneously formed (syngenetic) minerals have been found as inclusions in diamond, including diamond itself (Gurney, 1989). Six of these occur in both the peridotitic and eclogitic assemblages: olivine, orthopyroxene, clinopyroxene, garnet, chromite, and sulphides (e.g., pyrrhotite). Four other minerals – rutile, kyanite, corundum, and coesite – are minor constituents characteristic only of the eclogitic assemblage (figure 9). The remaining 11 minerals are so rare that they need not be considered here. Unfortunately, inclusions in diamonds cannot be used to determine geographic origin, as is frequently possible with colored stones (Gübelin and Koivula, 1986, p. 88).

Figure 9. This ruby is the first definitely identified as an inclusion in diamond. It proves that the diamond is of eclogitic origin. Photomicrograph by Eduard J. Gübelin; darkfield illumination, magnified 100×. From Gübelin and Koivula (1986, p. 97).



Detailed chemical studies of the most important minerals listed above have made it possible to characterize with confidence 98% of all included diamonds as peridotitic (mainly harzburgite) or eclogitic (sometimes referred to, respectively, as "P-type" and "E-type" diamonds). The minerals in one type of mineral assemblage chemically will not be the same as those in the other type; that is, they are mutually exclusive. The only exception would be the very rare case in which the diamond began to grow in one environment (e.g., eclogitic) and then was moved and later continued to crystallize in a different environment (e.g., peridotitic). However, both P- and E- type diamonds may be found within the same kimberlite pipe, indicating that the pipe sampled at least two different "diamond source areas" en route to the surface.

A logical question could be raised concerning the categorization of a diamond as P- or E-type if the inclusion consisted of a single mineral, say, garnet, that is common to both types of occurrences. This matter may be resolved by determining the chemical composition of that inclusion (see figure 10). For example, the ideal formula for a pyrope-almandite garnet would be a mixture of both garnet types; that is, both Mg and Fe can substitute in the silicate structure so that the formula for any specific garnet in this series could be written as $(Mg, Fe)_3Al_2Si_3O_{12}$. However, from figure 10 it can be seen that the relative proportions of Fe and Mg and minor Ca in garnet differ, characteristically, for both the P- and E-types of diamond associations; specifically, P-type garnets have higher Mg and lower Fe than do E-type garnets. Other inclusions in diamond (e.g., olivine, orthopyroxene) can be classified by similar analytical methods. Returning briefly again to garnet, experienced individuals can accurately distinguish between the two types on the basis of color. The pyrope type is typically purple-red whereas almandine is usually orange-red.

As discussed earlier, diamondiferous xenoliths of the E-type are relatively abundant, whereas diamondiferous P-types are very rare. Yet P-type

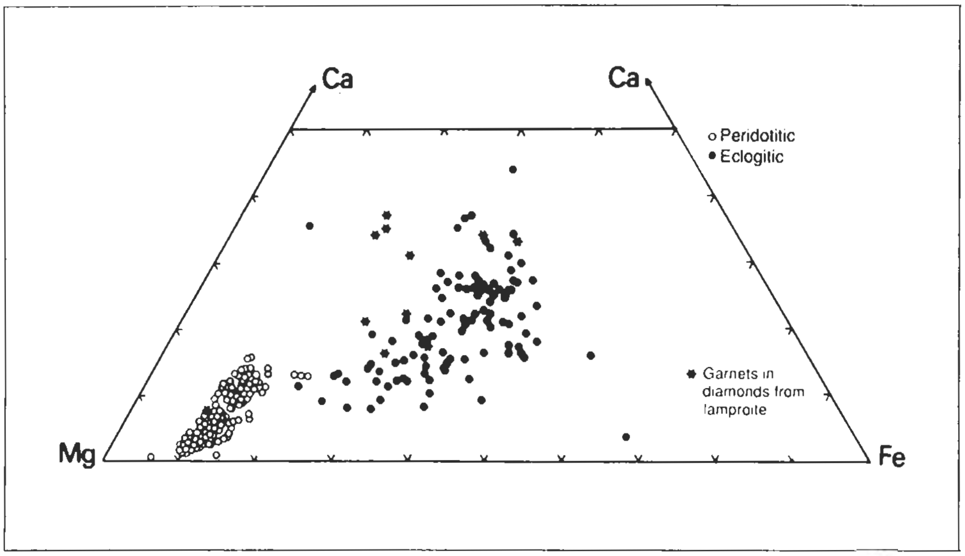


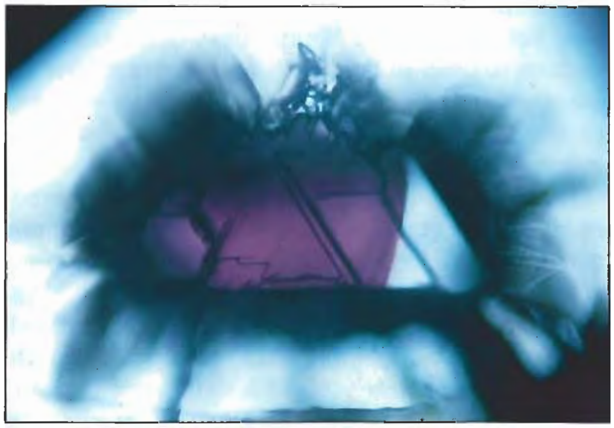
Figure 10. This plot shows the relative abundances of calcium (Ca), magnesium (Mg), and iron (Fe) in garnet inclusions from diamonds worldwide. Peridotitic garnets are much higher in Mg, and lower in both Fe and Ca, than garnets from eclogites. Although not shown, peridotitic garnets are higher in chromium than eclogitic garnets; the latter also have minor, but characteristic, sodium, that is, $>0.09\%$ Na_2O. (Adapted from Meyer, 1987.)

inclusions are much more common than the E-type. It is clear that once mineral inclusions are encapsulated within diamond, they are protected from reactions with the surrounding magma, or from disaggregation, as occurs with the diamondiferous peridotite xenoliths. Therefore, it seems logical to accept the relative abundances of P-type and E-type assemblages that occur as inclusions in diamonds as most representative of their relative proportions and, by analogy, the relative importance of each rock type as the source material from which diamonds originate. Although various scientists will propose different proportions, we believe that peridotite-type inclusions outnumber the eclogite type by a ratio of 3:1. P-type diamonds are particularly more abundant in smaller sizes.

Pressure-Temperature Conditions in Which Diamonds Form. A knowledge of the pressure and temperature (P-T) regime in which diamonds crystallize is essential for determining the geologic origin of diamonds. *Geobarometry* is the discipline in geology that employs methods, such as the analysis of pressure-indicative minerals, to determine the pressure under which a mineral or rock formed. For example, the presence of coesite, known to be a high pressure form of SiO_2 (quartz, at low pressure), yields important information regarding pressure conditions. *Geothermometry* is the discipline concerned with the temperature of formation of similar materials.

Both of these disciplines depend heavily on experimental laboratory procedures, such as the synthesis of specific minerals under carefully controlled pressure-temperature conditions, to simulate natural situations. Again, the inclusions in diamonds are valuable in this research. In some cases, the analysis of a single inclusion for just one chemical element is sufficient. In other cases, particularly in geothermometry, several co-existing and touching mineral phases ideally should be present in the diamond (figure 11). For a variety of reasons, assumptions usually are made and the results sometimes lack the desired precision. (Technically, the temperatures and pressures determined are those that existed when the mineral systems were last in equilibrium, which may not

Figure 11. A purple chrome pyrope garnet and a colorless pyroxene have united to form a trapeze in the host diamond. This bimineralic inclusion lies parallel to an octahedron face. Co-existing and touching mineral phases such as these are ideal for geothermometry studies. Photomicrogaph by Henry O. A. Meyer; bright-field illumination, magnified 40×. From Gübelin and Koivula (1986, p. 95).



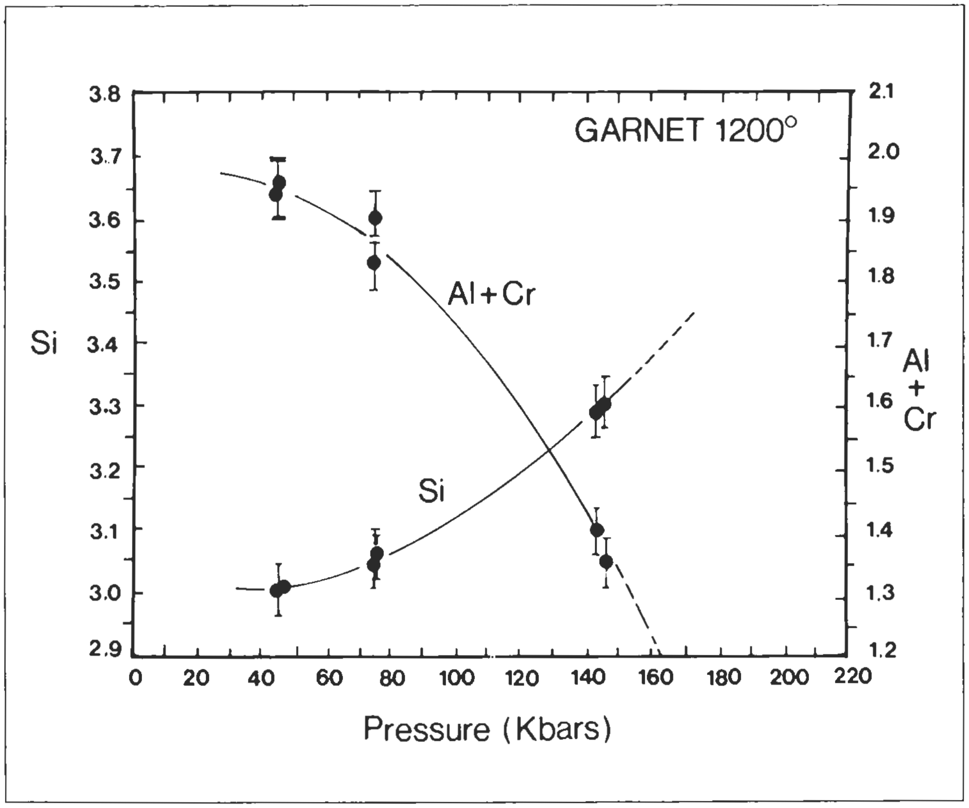


Figure 12. This diagram shows how increasing silicon (Si) and decreasing aluminum (Al) + chromium (Cr) are accommodated in the structure of garnet (which crystallizes at 1200°C) with increasing pressure (kbars). (Units are in atoms per unit cell.) Studies such as this enable the determination of pressure-temperature conditions for inclusions in diamonds at the time of formation. For example, if a garnet contains 3.0 atoms per unit cell of Si, and 1.95 atoms per unit cell of Al + Cr, it crystallized at a pressure of about 45 kbars. Data are from eclogitic garnet inclusions in diamonds from the Monastery mine, South Africa (Moore and Gurney, 1985).

agree precisely with the temperature and pressure of diamond formation.)

Examples of the types of minerals used, and elements determined, for geobarometry include: (a) aluminum substitution in orthopyroxene (enstatite) co-existing with garnet, (b) potassium substitution in clinopyroxene, and (c) sodium substitution in garnet. In all of these cases, elevated amounts of Al, K, and Na are indicative of high pressures. Examples of geothermometry include methods based on: (a) the partitioning (relative proportions) of the Ca and Mg contents of coexisting orthopyroxene (enstatite) and clinopyroxene (diopside), (b) the relative abundances of Fe and Mg in these same pyroxenes, and (c) the relationship between Fe and Mg in coexisting garnet and orthopyroxene. In figure 12, we illustrate how the pressure at the time of formation of an eclogitic garnet inclusion within a diamond can be determined.

There have been many determinations made in the past decade of the pressures and temperatures at which mineral inclusions in diamond crystallized (see, e.g., Ross, 1989). Meyer (1985) has evaluated these and concluded that in the peridotitic type of inclusions the temperature of crystallization ranged from 900° to 1300°C and pressure from 45 to 60 kbar. At 30, 50, and 60 kbar the approximate depths within the earth are 100, 150, and 200 km, respectively. Eclogitic-type inclusions fell within the same temperature range, but it was not possible to estimate their pressure of formation. Considering the rate at which temperatures increase with depth (geothermal gradient) under continental areas, as well as the corresponding increase in pressure, the estimated depth of formation of P-type diamonds is in the range 150–200 km, which is within the upper mantle. E-type diamonds appear to have higher temperatures of crystallization and to form at greater depths than do P-types. In fact, based on geobarometry, Moore and Gurney (1985) have shown that E-type diamonds in at least one South African mine (Monastery) have origins that may be deeper than 300 km, but still within the upper mantle. It must not be assumed, however, that all E-type diamonds originate from such depths.

Sources of Carbon in Diamond. The source of the carbon from which diamonds form has been a subject of interest and controversy for over a hundred years; suggestions have ranged from coal in the 1800s to carbon dioxide and methane today (see Janse, 1984, and Meyer, 1985, for the historic aspects). It is now generally agreed that there are two sources of carbon, as determined by stable carbon isotope studies, specifically the ratio of carbon-13 to carbon-12. For the sake of convenience, these ratios are reported as "delta values" and specifically, in the case of the carbon isotopes, as $\delta^{13}C$. (Technically, a delta value is the difference between the isotope ratio in a sample and that in a standard, divided by the ratio in the standard, and expressed in parts per thousand.)

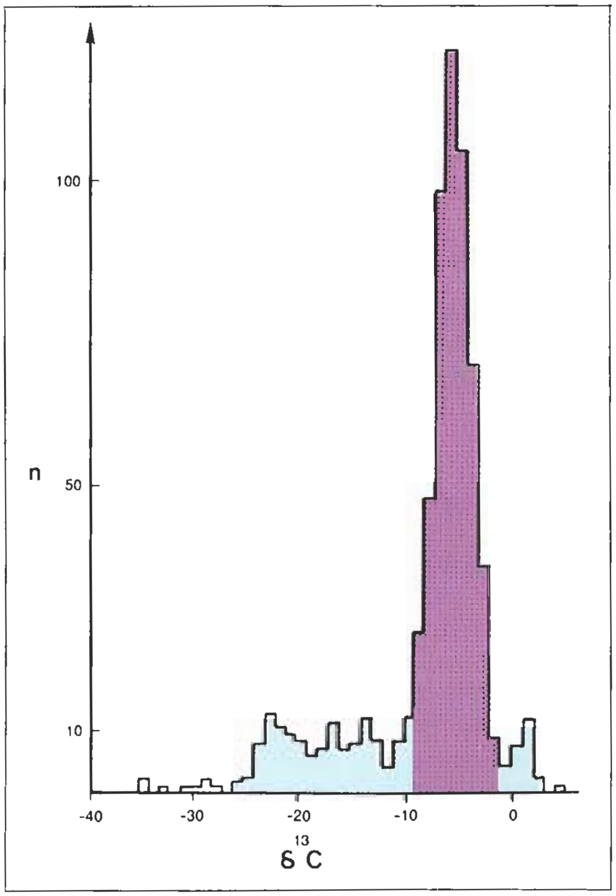
A plot of the $\delta^{13}C$ of several hundred diamonds, from many geographic locations as well as from both eclogitic and peridotitic origins, is presented in figure 13. Inspection of this figure will show a shaded area in the narrow range of -2 to -9 $\delta^{13}C$, with a peak between -5 and -6 $\delta^{13}C$. This is the area in which almost all peridotitic diamonds will plot. Although the $\delta^{13}C$ of many eclogitic diamonds will also plot in this narrow range, others will plot elsewhere on the diagram; they are not confined to the narrow range. These important data in figure 13 have been interpreted to imply that there are at least two carbon sources for diamonds: The peridotitic source, with few exceptions, is characterized by the narrow $\delta^{13}C$ range of -2 to -9, whereas the eclogitic source may have any $\delta^{13}C$ value between $+3$ and -34. In addition, detailed studies of the distributions of the populations have shown that there frequently are specific associations at specific localities. For example, at the Roberts Victor mine in South Africa, the eclogitic diamonds have two different $\delta^{13}C$ values of about -16 and about -5, which suggests two different eclogitic source areas for the carbon in these diamonds. The question arises, then: What are the major sources of carbon, that is, for the peridotitic and eclogitic diamonds?

Peridotitic diamonds are believed to have a carbon source that is derived from a homogeneous (because of the narrow range of $\delta^{13}C$ values) convecting zone within the upper mantle. This carbon may have been one of the original components of primitive earth that accumulated in the mantle perhaps 4,500 My ago, became well mixed through convection, and then remained in place until it crystallized into diamond within peridotite.

Eclogitic diamonds are a different story because of the broad range of $\delta^{13}C$ values. The $\delta^{13}C$ values for the carbon in carbonate minerals (e.g., calcite) and hydrocarbons span the range of $+3$ to -34. These values are identical to those found in eclogitic diamonds and are the basis for the theory that the carbon in such diamonds originates in material brought from the earth's near-surface environment by subduction to the depths (>150 km) necessary for the formation of diamonds.

Eclogites have a bulk chemical composition that is virtually identical to that of basalt, but the minerals comprising basalts (primarily the clinopyroxene augite and Ca-rich plagioclase feldspars; see box A) are different from those of eclogites (that is, garnet and the clinopyroxene omphacite) because of the different pressure and temperature environment in which the latter crystallize. Eclogites are formed at higher pressures

Figure 13. The distribution of carbon isotope ratios, $\delta^{13}C$, in diamonds from many geographic locations and from both eclogitic and peridotitic rock origins is illustrated here. The shaded region, with $\delta^{13}C$ values of -2 to -9, is the range for diamonds from peridotitic assemblages; eclogitic values may range anywhere from $+3$ to -34 (including the peridotitic range). The letter n *indicates the number of samples. See text for further details. From Gurney (1989).*



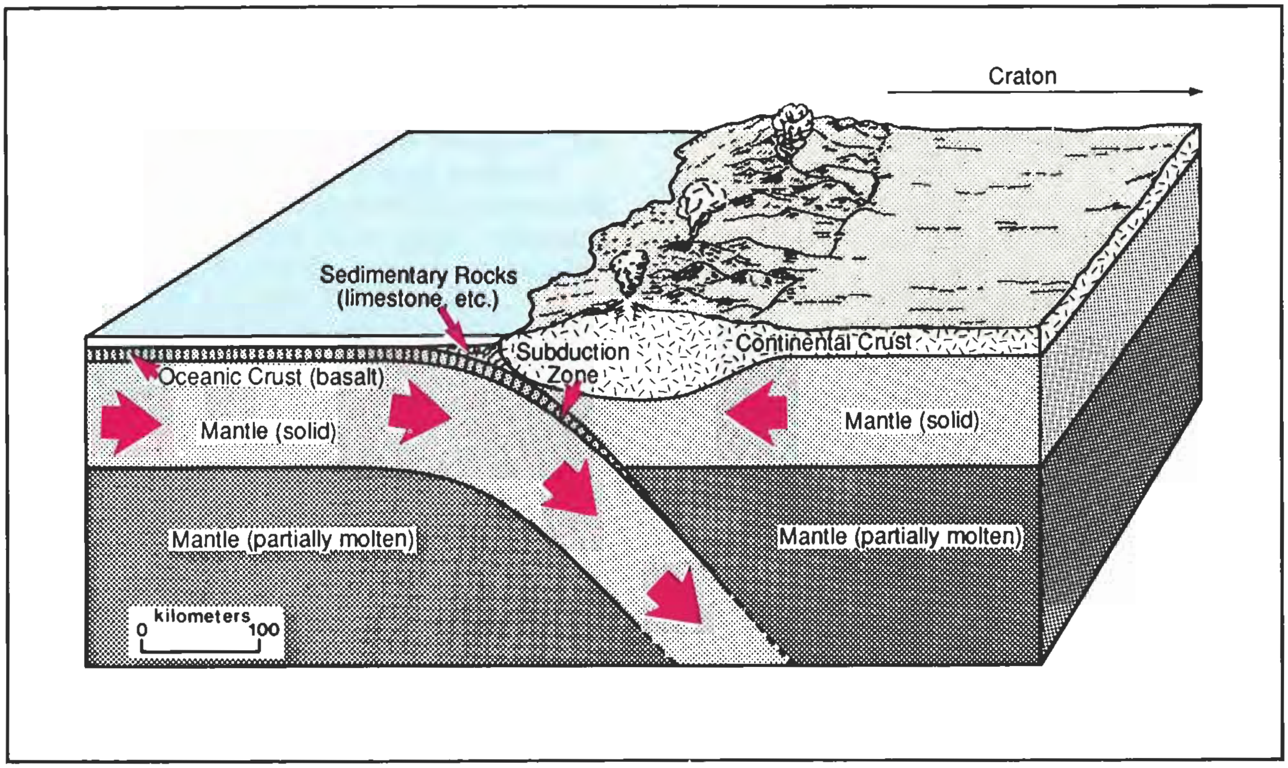


Figure 14. The theory of plate tectonics explains how the earth's solid outer portion (the lithosphere) is divided into a number of rigid thin segments (plates) which move in various ways including downward at certain boundaries, particularly where continents collide. This figure illustrates an oceanic basaltic plate being moved downward (subduction) into a region of higher pressures and temperatures below a craton (a part of the earth that has been stable for a long time; includes continental shields and platforms). Carbon present within the plate in the form of limestone (calcite) or other carbonate-bearing rocks, or as hydrocarbons (including organic remains), could be the source of this element (carbon) for diamonds formed in eclogite. (Vertical scale is exaggerated.)

relative to basalt during and following certain earth movements and mountain building (tectonic) events; basalts caught up in such tectonic processes may recrystallize into high-pressure eclogite. But, could eclogite within the earth's mantle, at depths of 150 km and greater, also represent basalt that has been converted to eclogite?

When continents collide, basalt, which is the main rock type in the oceanic basins, is pushed down beneath the continents by a process called subduction, into regions of higher pressures and temperatures (figure 14), where it eventually can be converted to eclogite. Carbon, in the form of limestone (calcite) or other carbonate rocks, or in the form of hydrocarbons (e.g., organic matter such as bacteria, algae), may have been included in the subducted slab and thus could be the source material for eventual conversion to diamond.

EMPLACEMENT OF DIAMONDS

To understand the emplacement of diamonds near the surface of the earth, we need to consider the following topics:

- ◆ What rocks did the emplacement
- ◆ Where emplacement occurred
- ◆ When emplacement occurred
- ◆ How emplacement occurred

What Rocks Did the Emplacement. We have referred repeatedly to the fact that diamonds were carried to the surface (i.e., emplaced) by kimberlite and lamproite. To understand this emplacement mechanism, it is important to understand the similarities, differences, and relationships between kimberlite and lamproite.

The most accurate definition available of the rock called kimberlite is presented in box B. For the

BOX B:
WHAT IS KIMBERLITE?

One would think that the meaning of the term *kimberlite* would be well understood and that it would have a universally accepted definition. However, although *kimberlite* was first introduced over a hundred years ago, based on descriptions of the diamond-bearing pipes of Kimberley, South Africa, there is still no unanimity on its definition (see, e.g., Glover and Harris, 1984; Clement et al., 1984; and Mitchell, 1989).

The problem stems, in part, from the fact that a satisfactory definition of *kimberlite* must take into account mineralogic composition, chemical composition, texture, and origin. This is a difficult task, indeed.

Most kimberlite professionals now accept the definition of Clement et al. (1984, pp. 223–224), but it is very complex. For a gemological audience, the definition of Dawson (1984, pp. 104–105) is instructive and, in its imaginative presentation, illustrates the complexity of defining kimberlite satisfactorily:

"In short, KIMBERLITE IS A HYBRID ROCK, comprising:

FRAGMENTS OF HIGH-T (temperature)
PERIDOTITE AND ECLOGITE

plus
MEGACRYSTS
which have reacted with
RELATIVELY LOW-T, VOLATILE-RICH MATRIX
and, during and after intrusion, with
HIGH-LEVEL GROUNDWATER
and in many diatreme-facies kimberlites
there is variable input of
WALL ROCK MATERIAL (e.g. basalt, gneiss, shale)"

[The following terms mentioned above and not previously explained are briefly defined. *Megacryst:* coarse single crystal; nongeneric term for a phenocryst or xenocryst. *Matrix:* groundmass; finer grained than megacrysts. *Diatreme:* a general term for a volcanic pipe that is emplaced in rocks by a gaseous explosion and is filled with angular broken fragments called breccia.]

Dawson uses the term *hybrid* in this explanation because kimberlite contains a mixture of (foreign) xenoliths (peridotite, eclogite, and other rock types) and xenocrysts (diamonds and others) in addition to the normal crystallization products from the kimberlite magma.

We offer the following simpler, though less precise, definition which augments that of Dawson (1984):

Kimberlite is a hybrid, volatile-rich, potassic, ultramafic igneous rock derived from deep in the earth (>150 km below the surface) which occurs near the surface as small volcanic pipes, dikes, and sills. It is composed principally of olivine (both as phenocrysts and in groundmass), with lesser amounts of phlogopite, diopside, serpentine, calcite, garnet, ilmenite, spinel, and/or other minerals; diamond is only a rare constituent.

Use of the adjectives "volatile-rich, potassic, ultramafic" to describe kimberlite indicates that there is an important and characteristic chemical signature for this rock. *Volatile-rich* (readily vaporizable, gaseous) refers to the high contents of CO_2 (8.6% average, mostly in calcite) and H_2O (7.2% average, in serpentine and phlogopite), in kimberlites. The average potassium content (K_2O = 0.6%–2.0%) is high for an ultramafic rock, whereas the average SiO_2 content (25%–35%) is extremely low for an igneous rock. In the case of kimberlite, Fe_2O_3 averages 12.7% and MgO, 23.8%. (All of the preceding values are from Mitchell, 1989, p. 35 and analysis 10, table 1, p. 36.) Although not mentioned, or even implied, in this definition, there are also unusually high concentrations, for ultramafic rocks, of certain nonessential elements found in small quantities (i.e., "trace elements"). Examples are niobium (Nb), zirconium (Zr), strontium (Sr), barium (Ba), rubidium (Rb), and cerium (Ce). These all occur in amounts significantly less than 0.1%; nevertheless, they are geochemically significant and are also important indicators of the presence of kimberlite for exploration purposes.

Exactly how kimberlites form is a subject of intense study. Although several hypotheses have been presented in the past, Eggler (1989, p. 496) reports that "partial melting of carbonated peridotite is preferred." That is, when a peridotite containing a small amount of a carbonate mineral such as dolomite (source of CO_2) as well as phlogopite (source of potassium) becomes hotter, a small portion (less than 10%) of the rock will melt initially. The fluid (magma) resulting from this partial melting will have the chemical characteristics of kimberlite mentioned above (volatile-rich, potassic, ultramafic). This process probably takes place at pressures of 50–65 kbar and temperatures of about 1200°–1500°C. Thus, kimberlite magmas, like diamonds, originate from peridotite in the upper mantle at depths of perhaps 150–200 km. It is important to remember, however, that the consensus is that diamonds will only crystallize from peridotite (in addition to eclogite) and not from kimberlite (except possibly in special cases) for reasons that are not known, and that diamonds will occur in kimberlite only as xenocrysts.

purposes of this discussion, we need only consider the highlights presented in box B and recognize the following characteristics of kimberlite.

- Kimberlite is a dark-colored (referred to as "blue ground" when fresh) hybrid rock; that is, it is a mixture of the crystallization products of the kimberlite magma itself (e.g., olivine, phlogopite) plus xenocrysts and xenoliths of peridotite and eclogite derived from the upper mantle.
- Chemically, kimberlite is an ultramafic, potassic, volatile-rich (CO_2,H_2O) rock that formed deep within the earth (at least at the depth of diamond formation) at high pressures and temperatures.
- Kimberlite is intruded from the mantle into the earth's crust; near the surface, it takes the form of a cone-shaped pipe characterized by a volcanic explosion and the formation of breccia (angular broken fragments) within the pipe (see below).

Lamproite was a relatively obscure rock type until 1979, when it was found to host primary deposits of diamonds in Australia. To date, it is only the second rock type to have gained this distinction. Although it has been the subject of many studies over the last decade, like kimberlite it is not easily defined. Currently, *lamproite* refers to a group of rocks closely related in chemical composition (a clan) rather than to a specific rock variety. Nevertheless, certain chemical, textural, and mineralogic characteristics are recognized:

- Lamproite has a characteristic gray to greenish gray mottled appearance and, like kimberlite, is a hybrid rock. The primary magmatic crystallization products, most notably olivine, occur both as phenocrysts and as groundmass constituents. Upper-mantle xenoliths and xenocrysts are the same as those found in kimberlites.
- Chemically, lamproite is an ultrapotassic (potassium values are typically 6%–8% K_2O, compared to 0.6%–2.0% K_2O for kimberlites), magnesium-rich (mafic) igneous rock. Significant trace elements include zirconium (Zr), niobium (Nb), strontium (Sr), barium (Ba), and rubidium (Rb); these same elements also are enriched in kimberlites (see box B). On the other hand, CO_2, which is enriched in kimberlite (average 8.6%), generally is low (<1%) in lamproite, but another volatile element, fluorine (F), is enriched in the latter. Lamproites are also lower in magnesium (Mg), iron (Fe), and calcium (Ca), but higher in silicon (Si) and aluminum (Al), than kimberlites.
- Lamproites, like kimberlites, occur as pipes, dikes, and sills, but lamproite pipes resemble champagne glasses, rather than cones, in shape.

A comparison of the minerals present in the two rock types is particularly informative (table 2). The fact that several major, as well as some minor, minerals are common to both rock types suggests that their respective magmas have similar chemical characteristics. Further, the xenocrystic minerals are identical, which suggests that kimberlites and lamproites were, at some time in their histories, in the same high pressure-high temperature environments characterized by eclogite and peridotite (in the Argyle olivine lamproite of Australia, there are far more eclogitic than peridotitic xenocrysts in diamonds). From table 2 we see that lamproite has a number of additional minerals that distinguish it from kimberlite (although not all are present in all lamproites). These

TABLE 2. Minerals found in kimberlite and lamproite.

Minerals	Kimberlite	Lamproite
Minerals that crystallize directly from kimberlite and lamproite magmas		
Major		
Olivine	✓	✓
Diopside	✓	✓
Phlogopite	✓	✓
Calcite	✓	
Serpentine	✓	
Monticellite	✓	
Leucite		✓
Amphibole		✓
Enstatite		✓
Sanidine		✓
Minor		
Apatite	✓	✓
Perovskite	✓	✓
Ilmenite	✓	✓
Spinel	✓	✓
Priderite		✓
Nepheline		✓
Wadeite		✓
Xenocryst minerals derived from the upper mantle		
Olivine	✓	✓
Garnet	✓	✓
Clinopyroxene	✓	✓
Orthopyroxene	✓	✓
Chromite	✓	✓

include, for example, the minerals leucite ($KAlSi_2O_6$), sanidine ($KAlSi_3O_8$), wadeite ($K_2ZrSi_3O_9$) and priderite [$(K,Ba)(Ti,Fe)_8O_{16}$], from which the potassium- and zirconium-enriched character of lamproites is derived.

In summary, based on their chemical, textural, mineralogic (including those of the xenoliths and xenocrysts), and emplacement (e.g., as pipes) characteristics, kimberlites and lamproites have much in common. Certainly, the similarities are greater than the differences. Both rock types probably formed by partial melting (see box B) of similar, yet distinctive, peridotitic material at greater depths than any other known volcanic rocks. Pressures of origin can be related to the upper mantle at depths of at least 150 km, and temperatures probably were in the range of 1100°–1500°C; kimberlites appear to have crystallized at the middle to upper part of the temperature range and lamproites at the lower end. Both rock types have transported mantle xenoliths and xenocrysts, including diamonds, to the surface, although not all kimberlites and lamproites contain diamonds. Finally, it should be noted that only recently has lamproite been recognized as a host for diamond deposits and that there is no known fundamental reason why other mantle-derived rocks with sufficiently deep origins could not also transport diamonds from the same peridotitic and eclogitic sources.

Where Emplacement Occurred. There are two aspects to the topic of where emplacement of kimberlite and lamproite occurred: geographic and geologic. Both of these topics were reviewed thoroughly by Clifford (1970), Janse (1984), and Dawson (1989). Most emphasis will be placed on kimberlites because there is far more information available on these rocks than on lamproites.

Kimberlites are widespread around the earth, and over 3,000 are known in southern Africa alone. This figure includes both dikes and pipes (sills are rare), of which the former are more abundant. There are about 100 kimberlites in North America, with perhaps 60 located in what is called the Colorado-Wyoming State Line District. Of the total number of kimberlites worldwide, fewer than 1,000 contain any diamonds, only 50–60 have ever been economic, and only about 12 major pipes are being mined today. Most of the well-known diamond-producing pipes have a surface area of between 5 and 30 hectares (about 12–75 acres); in South Africa, they typically contain about one carat of rough diamond per five tons of kimberlite ore.

Kimberlites tend to occur in clusters, with 6 to 40 (excluding dikes) in any one. Certain areas, such as South Africa, Siberia, and northwestern Tanzania, contain many clusters. The five main pipes at Kimberley, South Africa, cover a circular area with a diameter of 10 km, but the entire cluster, including dikes, occupies an area with a diameter of 40 km. Janse (1984) suggests that the distance between several major clusters in both South Africa and Siberia is generally about 400 km, although the use of such estimates has been questioned by Gurney (1989). The ratio of economic to noneconomic pipes in clusters varies considerably: Janse (1984) gives figures ranging from 5 out of 15 at Kimberley and 3 out of 29 at Orapa (Botswana), to 1 out of 30 at Alakit (Siberia); some clusters, of course, have no economic value.

Unfortunately, there are no similar statistics for lamproites. Not only is the discovery of the Argyle deposit in Western Australia relatively recent, but many of the rocks previously called lamproites, as well as related types, are presently being reevaluated and reclassified. Such studies, for example, have resulted in the reclassification of the diamond-bearing Prairie Creek (Murfreesboro), Arkansas, pipe from a kimberlite to an olivine lamproite.

However, studies of kimberlites, and to a lesser extent lamproites, have provided valuable information about the geologic distribution of the diamond-bearing rocks in the earth's crust. Figure 15 shows that the geographic distribution of primary diamond deposits, predominantly kimberlites, is not random but is confined to regions of the continental crust that are old cratons (defined below). This is an observed fact that was well formalized by Clifford in several publications, culminating in Clifford (1970). It illustrates, too, the fact that kimberlites are never found in oceanic environments or young mountain belts. A *craton* (again, see figure 14) is part of the earth's crust that has attained stability and has been little deformed for a very prolonged period of time (generally more than 1,500 My). Effectively, the term applies to extensive, stable continental areas and consists of two parts: (a) a *shield* (the exposed core of a craton, e.g., the Canadian Shield), and (b) a *platform* (the part of the craton, covered by generally flat-lying sediments and sometimes associated volcanics, e.g., basalts, that is adjacent to, and an extension of, the shield). Cratons are the nuclei of all continents, and all present-day continents, except Europe, have more than one craton (again, see figure 15),

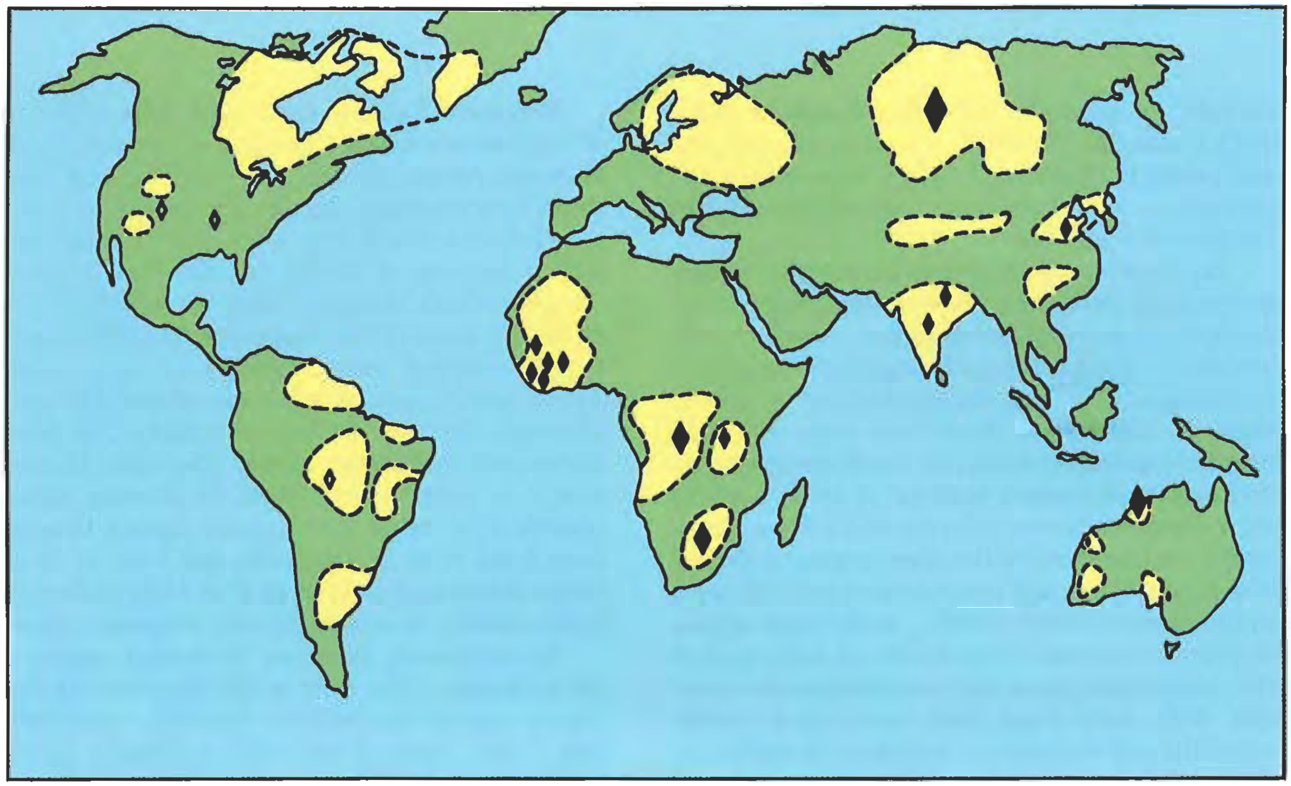


Figure 15. This world map of primary diamond deposits (i.e., those in pipes) shows cratonic areas (dashed lines) with major economic diamond deposits (large solid diamonds), minor economic deposits (small solid diamonds), and subeconomic deposits (small open diamonds). The economic deposits are in kimberlites except for the Australian deposit(s), which are in lamproite. Note that several cratons have no known diamond deposits. From Gurney (1989) and based on data in Janse (1984).

which are usually of different ages. This suggests that the continents of today may be composites of the remnants of ancient continents, each of which had its own craton. Kimberlites have been found within most cratons on all continents. Some cratons have far more diamond production and potential than others. For example, the Kaapvaal (Kalahari) craton of southern Africa has seven of the world's 11 established diamond-producing clusters.

Studies of the locations of kimberlites within cratons (this detail is not shown in figure 15) reveal that the occurrence of kimberlite pipes is most common within the younger, generally flat-lying sedimentary platform rocks that rest on the Archean (>2,500 My old) part of a craton. Very few important kimberlite pipes are known in the exposed cores (shield areas) of cratons, the principal examples being the West African and Tanzanian cratons, probably because they have been extensively eroded. This has resulted in the generalization among kimberlite specialists that the most favorable location for diamond-containing kimberlites is "on-craton" as opposed to "off-craton," that is, "on" the Archean part of the craton (including the sedimentary platform rocks above) as opposed to "off" it. The latter location includes any younger part of the craton and adjoining *mobile belts* (i.e., linear regions adjacent to cratons that were subjected to folding due to cratonic collisions and later became mountain belts, such as the present Alps). Mobile belts may eventually become "fused" to cratons. However, generalizations such as this can be dangerous. For example, the Argyle lamproite, the largest producer of diamonds in the world today, is in a mobile belt that became part of a craton 1,800 My ago. The significance of cratons from the point of view of the "storage" of diamonds between the time of their formation and their being brought to the surface will be discussed later.

When Emplacement Occurred. Diamond-bearing kimberlites and probably lamproites have intruded into the earth's crust for a very long period, as evidenced by the occurrence of diamonds in the

2,600-My-old Witwatersrand conglomerate in South Africa. The presence of diamonds in this paleoplacer (alluvial) deposit requires that a still older kimberlite (or lamproite) existed.

The oldest known kimberlites still preserved are the 1,600-My-old intrusions near Kuruman, northern Cape Province, South Africa, which are situated on the Kaapvaal Craton but contain no diamonds. Subsequently, there was a period of extensive kimberlite emplacement about 1,200 My ago, again in South Africa (e.g., Premier mine; see table 1) but also in India and Mali. Other important episodes of kimberlite intrusion are presented in table 3.

Although information on lamproites is less readily available, they are known to cover a range from the Argyle pipe, which was intruded ~1,200 My ago, to the Ellendale lamproites (about 50 bodies are known and several are potentially economic), approximately 400 km from the Argyle deposit, which were intruded in early Miocene time (~20 My ago) into platform sediments of Devonian and Permian age (~400–250 My). Some lamproites in Wyoming, Antarctica, and a few other localities may have been emplaced within the last one million years.

We may deduce from the large number of new age dates obtained in the past decade that: (a) kimberlite and/or lamproite intrusions can occur at several different times in the same vicinity; and (b) most kimberlites and lamproites were emplaced in the last 200 My, although there were major intrusions at least as early as 1,600 My ago and possibly prior to 2,600 My ago.

TABLE 3. Times of intrusion of selected kimberlite provinces (modified from Dawson, 1989).

Geologic age	Time (My ago)	Locality
Eocene	50–55	Namibia, Tanzania
Upper Cretaceous	65–80	Southern Cape (South Africa)
Middle Cretaceous	80–100	Kimberley (South Africa), Lesotho, Botswana, Brazil
Lower Cretaceous	115–135	Angola, West Africa, Siberia
Upper Jurassic	145–160	Eastern North America, Siberia
Devonian	340–360	Colorado-Wyoming, Siberia
Ordovician	440–450	Siberia
Upper Proterozoic	810	Northwest Australia
Middle Proterozoic	1,100–1,250	Premier (South Africa), India, Mali
Lower Proterozoic	1,600	Kuruman (South Africa)

How Emplacement Occurred. It is generally accepted that kimberlite and lamproite magmas result from the partial melting of similar, yet distinctive, peridotitic material 150–350 km below the earth's surface, that they intruded into cratons, and that the process of emplacement has been operative, during some periods more than others, at least since 2,600 My ago. Beyond this point matters become more speculative, particularly on the details of how emplacement occurred. Topics that must be considered are: (1) the rate of ascent of diamond-bearing kimberlites and lamproites; and (2) the configuration and formation of diatremes. Again, most emphasis will be placed on kimberlite.

Rate of Ascent. The rate of ascent of kimberlites is most frequently determined on the basis of the following observations: (a) diamonds are preserved during their ascent to the surface rather than reverting to graphite, being converted to carbon dioxide (CO_2), or dissolving in the kimberlite magma (figures 16 and 17); and (b) the diamond-bearing kimberlites also transport large xenoliths from as deep as 200 km below the surface (again, see figure 4). Both of these observations require that the ascent to the surface be reasonably rapid. During slow ascent, or ascent with many intermediate stops, diamond would likely revert to graphite (which in the pressure-temperature conditions in the earth's crust is thermodynamically more stable than diamond) and the heavy xenoliths would tend to settle back through the magma. At Beni Bouchera, Morocco, for example, we know that diamonds were transformed to graphite because they were not transported rapidly to the surface by kimberlite or lamproite (Slodkevich, 1983). The fall in temperature and pressure was sufficiently slow to permit the conversion; only with a rapid decrease in temperature and pressure will the carbon atoms "freeze" in the metastable diamond structure (figure 18).

Although we know that the ascent is rapid, estimates of the exact velocity depend on various assumptions. For our purposes, the ascent rates proposed by Eggler (1989) of 10–30 km per *hour* are realistic. In other words, diamonds are brought to

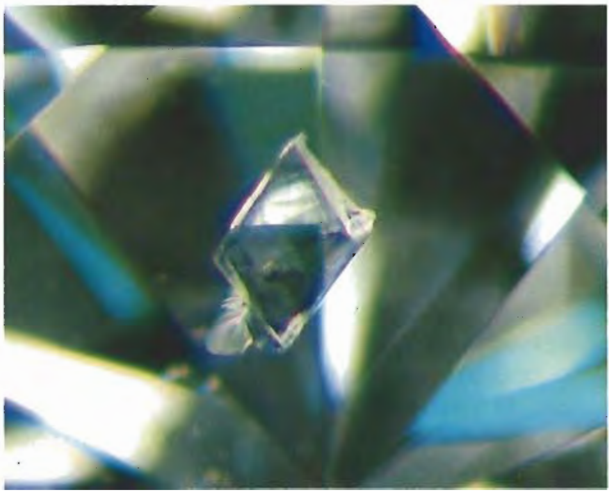


Figure 16. Extremely well-shaped diamonds with sharp octahedral edges, as seen just below the table facet of this host mineral, are unusual. Special conditions were required for their preservation; for example, they may have been protected within another mineral (diamond, in this case) or in an eclogite xenolith. Otherwise, it is likely that they would have been resorbed (dissolved) in a kimberlite or lamproite magma. Photomicrograph by Eduard J. Gübelin; darkfield illumination, magnified 20×. From Gübelin and Koivula (1986, p. 97).

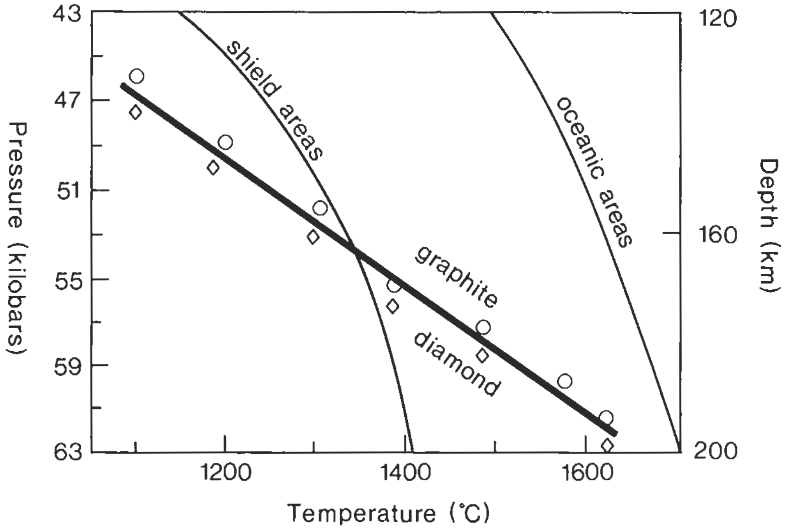
the surface from their storage areas at depths of at least 110 km (at the base of cratons) in 4–15 *hours*! Further, as the surface is approached, within the last 2–3 km, the velocity increases dramatically to perhaps several hundred kilometers per hour, for reasons that are explained later.

An obvious requirement for kimberlites to reach the surface is the availability of fractures that extend from below the base of the craton, through solid rock, for a distance in the vicinity of 150 km; these deep fractures are only possible in geologically stable areas. Exactly how these deep fractures are generated, and are even repeated from time to time in identical localities to account for kimberlite intrusions of widely different ages within the same pipe, is a matter that is not well understood. For our purposes it is only necessary to recognize the existence of a problem concerning the origin of the deep fractures and to observe that several hypotheses have been proposed, for example, crack propagation by magmatic fracturing (Eggler, 1989) and crustal thinning linked with major plate movements (Dawson, 1989). Mitchell (1986) has reviewed older theories.

Configuration and Formation of Diatremes. The term *diatreme* is synonymous in this article with the terms *breccia pipe* and simply *pipe:* It is a general term for a volcanic pipe that is emplaced in rocks by a gaseous explosion and is filled with angular broken fragments called breccia [Gk. *dia*: through + *trem(a)*: perforation = to pierce, drive through]. As a general term, *diatreme* can be used for pipes of many types in numerous geologic situations (e.g., diatremes of basalt erupting along fractures); however, the combination of features described below is possibly unique to kimberlite diatremes (and related rocks, e.g., lamproites) primarily because of the great depths from which they originate as well as the amounts and types of

Figure 17. The irregular rounded shapes frequently found on diamonds result when the transporting kimberlite (or lamproite) magmas react with, and dissolve, the diamond, starting with the octahedral edges. Isolation of diamonds from transporting magmas (see figure 16), or very rapid ascent to the surface, can minimize this effect. Photo © GIA and Tino Hammid.

Figure 18. The diamond-graphite equilibrium line is plotted here against the geothermal gradients for the continental shield (craton) and oceanic areas. (A geothermal gradient is the rate of increase of temperature with increasing depth in the earth and averages about 25°C per kilometer in the earth's crust.) Under the oceans, temperature rises much more rapidly with depth than it does under the shield areas. The geothermal gradient line for the shield areas intersects the diamond-graphite equilibrium line at 53 kbars (and about 1325°C), which corresponds to a depth of about 160 km. Under oceanic areas, it intersects at depths greater than 200 km, which is unsuitable for the production of diamonds. Modified from the GIA Diamonds course.



gases they contain. The characteristic features of kimberlite diatremes are: (a) their general shape, and (b) their three distinct depth zones (root, diatreme, crater) which, in combination, are the configuration of the pipe (figure 19).

The classic, early 20th-century studies of kimberlite pipes in the Kimberley area, South Africa, demonstrated that they occur as carrot-shaped, vertical intrusions that pinch out at depth. These observations have stood the test of time. With increasing depth of the mines over the years, new observations were made and older ones refined. These include: (a) the fragmental (brecciated) nature of kimberlite, particularly in the diatreme zone; (b) the fact that kimberlite is a "cold" rock, inasmuch as there are very few indications of thermal effects (e.g., contact metamorphism) on either the wall rocks or xenoliths of the diatreme zone as would be expected for a rising molten magma; and (c) the observation that the pipes become narrower with depth, eventually thinning into feeder dikes that are rarely thicker than one meter. In other parts of Africa, important surface features of kimberlite diatremes, e.g., maar and tuff rings (see below), were also recognized.

Hawthorne (1975) combined all the above features and facts relating to kimberlite pipes and developed an idealized model, which is illustrated in modified form in figure 19. This figure, which is a basis for modern concepts of emplacement, shows the three different zones within an idealized kimberlite.

The *root zone* is the deepest part of the pipe. It is characterized by an irregular outline and by numerous distinct intrusive phases of kimberlite and igneous features, and it extends about 0.5 km vertically about 2–3 km below the surface. It is composed of crystallized kimberlite magma with the megascopic appearance of a typical intrusive igneous rock, along with xenoliths and xenocrysts and frequently with some small breccia fragments. With depth, the root zone grades into individual feeder dikes, also of kimberlite (but without certain characteristics such as breccia), which extend downward indefinitely, but probably not continuously, as the fractures along which the magmas moved probably opened and then closed after magma passed through. Root zones and feeder dikes may contain diamonds among the xenocrysts, but they have been mined only on a small scale because of their limited volume. Economic mining is generally limited by the width of the dikes, which are usually only about 60 cm wide (although they may, rarely, be 10 m wide, known as a "blow").

The *diatreme zone* (not to be confused with diatreme = pipe) is much greater in vertical extent than the root zone and is the most important source of diamonds because of its volume. It ranges from 1 to 2 km in height and extends to within 300

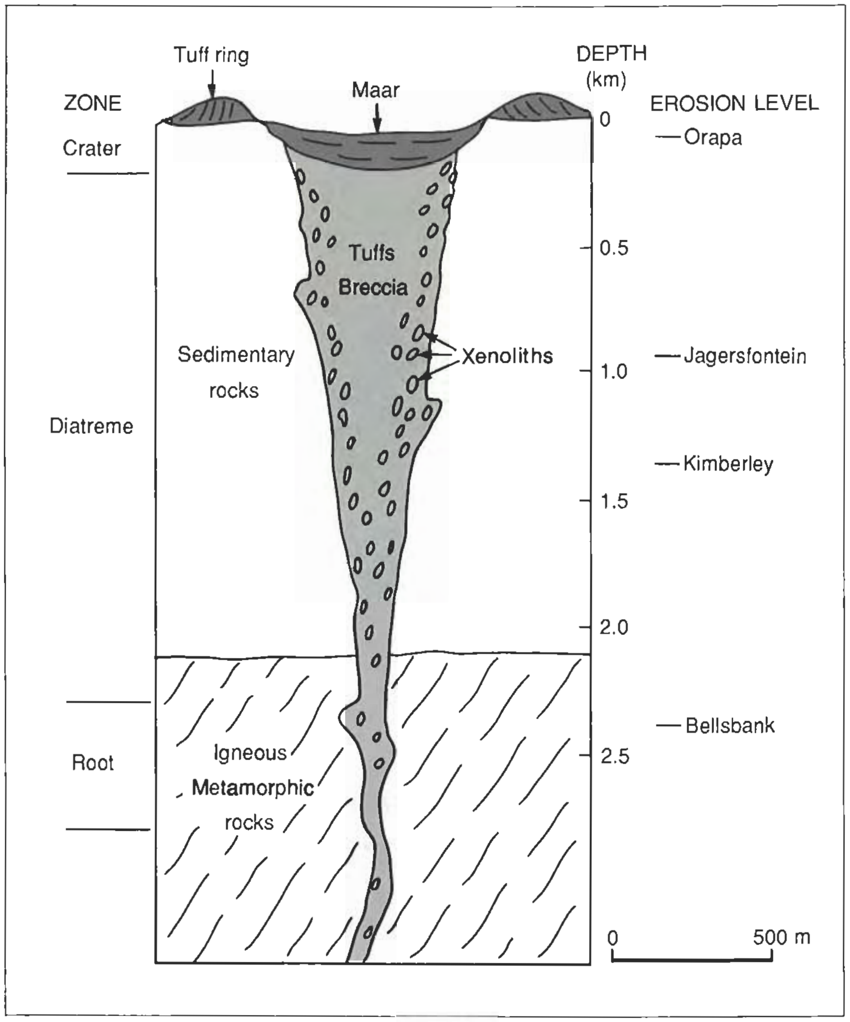


Figure 19. This idealized model of a kimberlite pipe includes the root, diatreme, and crater zones. Also shown are the present erosion levels at the Orapa pipe in Botswana and the Jagersfontein, Kimberley, and Bellsbank pipes in South Africa. Adapted from Hawthorne (1975).

m of the surface, in the idealized situation in which it has not been eroded (again, see figure 19). The diatreme zone contains xenoliths and xenocrysts from the mantle, as well as rock fragments derived from the crustal rocks through which the kimberlite passed, including wall rock (e.g., basalt, gneiss, shale) in the vicinity of the pipe. The main characteristics of this zone, however, are the kimberlite breccias and other fragmental rocks (e.g., tuffs) associated with explosive magmas.

These features develop because within the kimberlite magma there are large amounts of dissolved gases, specifically carbon dioxide and water (see box B), under great pressure. At about 2–3 km below the surface, explosions occur in the ascending kimberlite magma as the gases expand enormously at the lower near-surface pressures. Because of these explosions, the rate of ascent of the kimberlite accelerates rapidly, to perhaps several hundred kilometers per hour. As the kimberlite breaks through the overhead crustal rocks, the pipe takes on its conical shape and becomes wider. At the same time, those areas of kimberlite that had already crystallized as rock undergo fragmentation (brecciation). Because of the expansion of the gases, the kimberlite magma cools down rapidly so that there are few thermal reactions with the wall rocks or crustal xenoliths. With the temperature sufficiently low in relation to the lower pressure, the diamonds resist conversion to graphite and survive intact (figure 18).

The *crater zone* occupies the upper 300 m or so of a typical kimberlite diatreme which, at its formative stage, is a volcano. Whereas most volcanoes erupt molten lava, as typified by Mauna Loa in Hawaii, such probably is not the case with a kimberlite volcano. This is because, by the time the kimberlite has passed through the diatreme zone, it is no longer molten and does not flow out. Rather, it erupts as broken solid fragments of rock called *pyroclastics* [Gk. *pyro*: fire + *clastos*: broken into pieces], *tuffs* (a general term for all consolidated pyroclastic rocks), or *lapilli* (loose pyroclastic material in the size range of 2–64 mm), among other terms. Another factor to be considered is that the rising kimberlite magma and/or pyroclastic material, while not molten, is still hot and will eventually encounter cooler groundwater at depths that vary with locality. As the groundwater turns to steam, the eruption becomes even more volatile and, in some special situations, very violent explosions occur. Returning briefly to Dawson's (1984) explanation of the term *kimberlite* (box B), we can now understand the reason for his including the concept of "high-level groundwater."

Kimberlite volcanoes have never been observed to explode in historic times. In Tanzania, Mali, and Botswana, however, there are rare examples of the surface expression of this phenomenon that have not yet been eroded away. These include *maars* (low-relief volcanic craters formed by shallow explosive eruptions, which may be filled with water if they intersect the water table, and which are surrounded by crater rings) and *tuff rings* (wide, low-rimmed accumulations of pyroclastic debris of tuff or lapilli, slightly larger in size than an associated maar). It is likely that the explosion lifts debris no more than several hundred meters into the air and that the tuff ring is typically about 50 m high and is quickly eroded.

Inspection of depths below the surface in figure 19 will show that the typical distance from the top of the crater zone to the base of the diatreme zone is about 2,300 m. Depending on the geomorphologic, topographic, and other characteristics of the emplacement site, and assuming an erosion rate of 1 m every 30,000 years (which is the average for the earth), it could be predicted that the vast majority (except the root zone) of a typical kimberlite diatreme would be completely eroded away in 69 My. During this period, it would be continually releasing diamonds into secondary deposits, such as alluvials or beach sands. In figure 19, we see that four southern African mines—Orapa, Jagersfontein, Kimberley, and Bellsbank—all of Cretaceous age (~100 My; see table 1), are eroded to distinctly different levels. From this it follows that the Bellsbank mine has limited remaining economic potential because the entire diamond-containing diatreme and crater zones have been eroded away, whereas the Orapa mine can look forward to potential economic production to a depth of about 2,000 m which, at the present rate of production, will take several hundred years.

It is premature to make more than passing comments on the emplacement aspects of diamondiferous lamproites, because only the Argyle mine is in production and only since late 1985. There are several scientific reports describing this mine, as well as the Ellendale lamproite pipes about 400 km distant, in the volumes edited by Ross (1989). Suffice it to say that there are many similarities between these pipes and those of kimberlite. As mentioned earlier, one interesting difference is in shape. Unlike kimberlites, which are carrot-like, the root and lower diatreme zones of lamproites are thin and stem-like, but toward the top the pipes flare out in a curved manner that gives a "champagne glass" shape in cross-section.

Diamond Sampling in the Mantle. Discussion of the sampling of diamonds in the mantle and their transportation to the surface requires the integration of many of the topics considered earlier. This is accomplished by reference to figure 20, a simplified version of a diagram first published by Haggerty (1986). This figure is based on an idealized cross-section of the earth through a craton and its subcontinental regions (the lithosphere), which are characterized by very long-term tectonic stability, such as no mountain building or plate movements. (Kimberlite magmas, which originate at depths below the base of cratons, do penetrate the cratons through narrow fractures, but this minor volcanic activity does not negate the concept of a tectonically stable craton.) In all such areas, because of the tectonic stability, there are low geothermal gradients (rates of increase in temperature with depth) by comparison with the oceanic parts of the world.

Figure 20 also reflects, as noted earlier, the fact that eclogitic diamonds appear to form at greater depths than do peridotitic diamonds. As indicated by arrows, the eclogites formed from oceanic basalts that traveled down from the ocean basins by means of plate tectonic movements. The diagram also shows the relative position of the mobile belts on either side of the craton.

Of great significance is the shaded zone at depths of 110–150 km and temperatures of 900°–1200°C. This zone, like the rest of the craton and its subcontinent, has not been actively involved in plate movements or other major tectonic activities for at least 1,500 My. Of possibly even greater significance, however, is the fact that diamonds are stable within this area. Thus, diamonds that formed in the deeper parts of this keel-

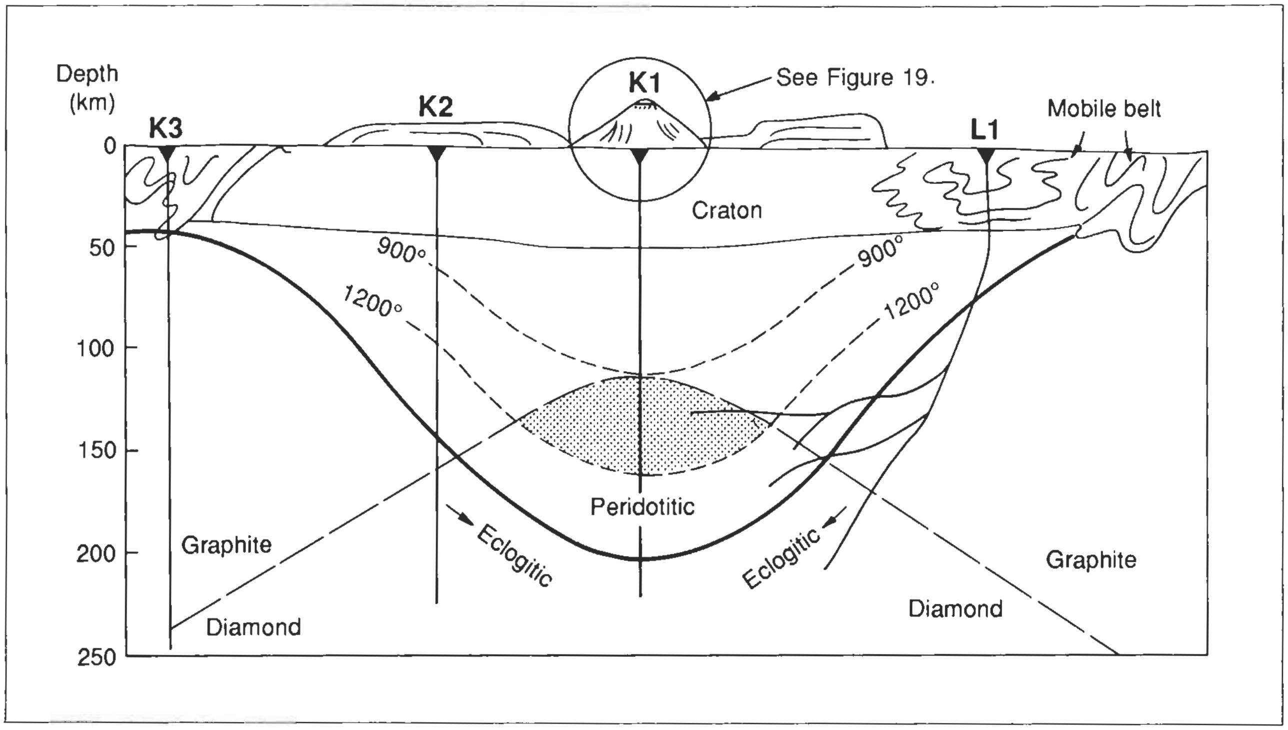


Figure 20. This model for the genesis of diamond is simplified from Haggerty (1986). The stable craton and subcratonic areas today are as much as 200 km thick (heavy solid line) and are bounded by mobile belts. The isotherms (lines connecting points of equal temperature) in the craton are concave downwards. The diamond stability field (area in which diamond is stable) is convex upward. The K1 kimberlite pipe is likely to have P-type diamonds because it sampled diamonds in the diamond "storage area" (shaded zone) at the keel of the craton, where this type of diamond is presumed to be present. Pipe K2 may have E-type diamonds. Kimberlite pipe K3 will be barren of diamonds. L1 is the possible location for Argyle-type lamproite pipes. See text for additional details.

shaped area, as well as those that formed elsewhere and somehow were moved into the same area, have been preserved and stored for as long as 3,200 My (see table 1 and accompanying discussion). One reason for the suggestion that diamonds in the storage zone may be of multiple origins is that in diamondiferous kimberlites (and lamproites) both P-type and E-type diamonds, in any proportions, may be found.

A kimberlite pipe such as K1 (figure 20), ideally situated over the keel of the craton, would be likely to contain diamonds, primarily of the P-type, provided other factors, such as a rapid ascent rate, are favorable. Pipe K2 would likely sample an eclogitic enclave hosting E-type diamonds, whereas kimberlite diatreme K3, which is "off craton," would probably be barren. The lamproite diatreme L1, as exemplified by the Argyle and Ellendale pipes in Australia, is also "off craton" in that it is intruded into the mobile belt; yet it is diamondiferous with both P-type and E-type diamonds. To account for this, Haggerty (1986) suggests a "complex plumbing system" (a system of interconnecting fractures) that is able to sample appropriate preservation and storage areas.

CONCLUSIONS

Age-dating techniques applied to the mineral inclusions (e.g., garnet) within diamond show that the inclusions are very old, ranging from 990 to 3,300 My, but this range may be extended as more age determinations are made. Inasmuch as the inclusions formed at the same time as their diamond hosts, it follows that diamonds are equally as old. On the other hand, kimberlites and lamproites, the two rock types in which primary diamonds are found, are generally much younger (the most important diamond pipes range in age from about 100 to 1,200 My) and are not the rocks in which diamonds crystallize. Hence, kimberlite and lamproite are merely the transporting media that bring diamonds to the surface by mechanisms that are not completely understood. Diamonds are formed at depths of 150–200 km below the surface; in the interval between their formation and their transport to the surface, they are stored under cratons at least 110 km below the surface, where the high pressure and relatively cool temperatures preserved them.

Study of both diamond-bearing xenoliths and mineral inclusions within diamonds shows that diamonds form within two different rock types, peridotite and eclogite. Carbon isotope studies on diamonds show that the carbon from which peridotitic diamonds crystallize originates from a homogeneous source within the earth's mantle, whereas the carbon for eclogitic diamonds probably originates from sources on the earth's crust that have been subducted below cratons by plate movements.

Knowledge of the age, origin, and emplacement of diamonds is extremely valuable in the search for primary deposits. For example, exploration geologists now know that those areas with the greatest potential are ancient cratons that contain ultramafic rocks that originated at great depths. For the gemologist, such knowledge results in a better appreciation of the complex geologic processes that are required to bring the world's most important gem to the surface.

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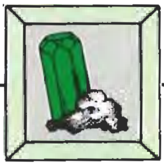

EMERALDS OF THE PANJSHIR VALLEY, AFGHANISTAN

By Gary Bowersox, Lawrence W. Snee, Eugene E. Foord, and Robert R. Seal II

With the withdrawal of Soviet troops from Afghanistan, villagers in the Panjshir Valley are turning their attention to the emerald riches of the nearby Hindu Kush Mountains. Large, dark green crystals have been found in the hundreds of tunnels and shafts dug there. Teams of miners use explosives and drills to remove the limestone that hosts the emerald-bearing quartz and ankerite veins. The gemological properties of Panjshir emeralds are consistent with those of emeralds from other localities; chemically, they are most similar to emeralds from the Muzo mine in Colombia. "Nodules," previously reported only in tourmaline and morganite, have been found in Panjshir emeralds as well. Approximately $10 million in emeralds were produced in 1990; future prospects are excellent.

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Although "emeralds" have been reported from this region for literally thousands of years, the Panjshir Valley of Afghanistan has produced commercial amounts of emerald only for the last two decades (figure 1). Because of the Soviet occupation of Afghanistan during much of this time, as well as regional political instability, access by Westerners has been limited. In July and August of 1990, however, the senior author visited the Panjshir Valley, collected specimens, and studied the emerald-mining operation.

He found that, although the conflicts in Afghanistan are far from settled, the *Mujahideen* ("freedom fighters") have shifted their energies from the Soviet troops they once battled to the harsh mountains that promise great riches (figure 2). As challenging as the Soviets were, the Hindu Kush Mountains are even more formidable. Commander Ahmed Shah Masood, known as the "Lion of Panjshir" (Follet, 1986), now governs more than 5,000 villagers mining emeralds in the Panjshir Valley (Commander Abdul Mahmood, pers. comm., 1990; O'Donnell, 1990). As first reported in Bowersox (1985), large (more than 190 ct) crystals have been found in the Panjshir Valley, in colors comparable to the finest emeralds of the Muzo mine in Colombia.

This article describes the Panjshir emeralds, their mining, geology, gemology, production, and marketing. The impact of emeralds from Afghanistan on the future gem market could be considerable (Ward, 1990), as the authors feel that the production potential of this area is excellent.

HISTORY

Most authorities believe that the only true emeralds known during ancient Greek and Roman times were from Egypt (Sinkankas, 1981). However, in his first-century A.D. *Natural History,* Pliny mentions *"smaragdus"* from Bactria (Gall, 1959), an area that includes present-day Iran

Figure 1. Only for the last two decades have fine emeralds been mined commercially in the many deposits that dot the Panjshir Valley of Afghanistan. These cut Afghan emeralds range from 1.04 to 12.49 ct. Photo © Harold & Erica Van Pelt.

and Afghanistan (Malte-Brun, 1828). *Smaragdus* is a Latin term that was used in ancient times to refer to emerald and many other green stones. It is questionable, though, whether any of the *smaragdus* from Bactria was emerald.

After Pliny, there is a void in the literature on gems of Afghanistan until approximately 1300 A.D., when the report of Marco Polo's travels of 1265 A.D. first appeared. Marco Polo mentioned silver mines, ruby, and azure (lapis lazuli) from Badakhshan.

Little is known about mining in the Panjshir (also spelled *Panjsher*) area from the time of Marco Polo until the 1900s. During the last 100 years, geologists from Great Britain, France, Germany, Italy, Japan, Canada, and the United States have produced many reports (see, e.g., Hayden, 1916; Argand, 1924; Bordet and Boutière, 1968; and Chmyriov and Mirzad, 1972) on the geology of Afghanistan, but virtually nothing had been written on the emerald deposits prior to 1976. In the early 1970s, emerald was discovered at what is now called the Buzmal mine, east of Dest-e-Rewat village in the Panjshir Valley (Bariand and Poullen, 1978). At about the same time, Soviet geologists began a systematic survey of Afghanistan's gem sources. Although this resulted in a number of publications (Rossovskiy et al., 1976; Abdullah et al., 1977; Rossovskiy, 1981; Chmyriov et al., 1982), the most detailed reports were not released. Following the death in 1973 of President Daoud, political changes hindered geologic work throughout Afghanistan. Nonetheless, in 1977 the names and locations of emerald mines in Panjshir were listed in a report by the United Nations Development Program (Neilson and Gannon, 1977). Agnew

Figure 2. The Hindu Kush Mountains are imposing obstacles to travel into and out of the Panjshir Valley. They are known, however, to carry great mineral wealth, including emeralds. Photo by Gary Bowersox.

(1982) also included a discussion of the Afghan emerald deposits. Information from these reports formed the basis for the senior author's 1985 *Gems & Gemology* article on the Panjshir deposits (Bowersox, 1985).

LOCATION AND ACCESS

The emerald mines are located at elevations between approximately 7,000 and 14,300 ft. (2,135 and 4,270 m) in mountainous terrain on the eastern side of the Panjshir River (figure 3). A dirt road follows the southwest-flowing Panjshir River for 90 mi. (145 km) and provides limited access to the mines. The road begins in the valley's northernmost village of Parian and extends southwestward through the villages of Dest-e-Rewat, Mikeni, and Khenj; Khenj is 70 mi. (113 km) from Kabul. The northernmost emerald deposit is located near the village of Aryu (also spelled *Arew*). The eastern extent of the emerald deposits is defined by the crest of the mountains east of the Panjshir Valley. Currently, the total area of known emerald deposits is approximately 150 sq. mi. (400 km^2) – double the area known in 1985. To the best of the authors' knowledge, Afghanistan has no producing emerald deposits outside the Panjshir Valley.

Because travel from the USSR, China, and Iran to Afghanistan is restricted, the only reasonable option for foreigners to enter the emerald-mining region of Afghanistan is through northern Pakistan. Border crossing, even with the permission of Pakistani authorities (which is not easy to obtain) and the Afghan commanders, is still extremely difficult and dangerous because of the rugged country, tribal rivalries, and the presence of land mines. Then, after crossing the border, one must travel by foot, mule, and horse (figure 4) for 150 mi. (240 km) through fields of land mines and over several mountain passes (some as high as 14,900 ft.) to reach the Panjshir Valley. The senior author needed six days to travel from the Pakistani

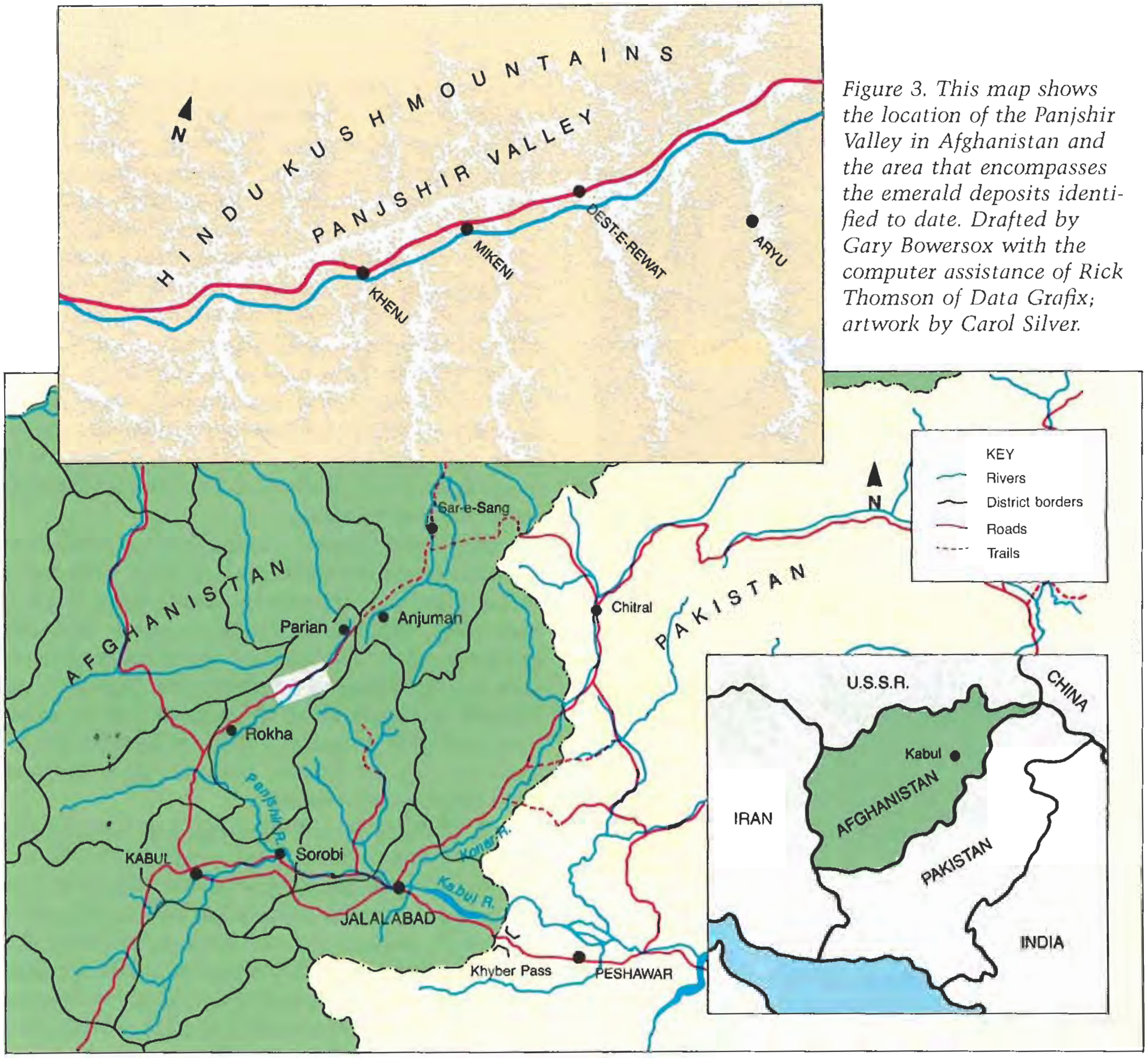


Figure 3. This map shows the location of the Panjshir Valley in Afghanistan and the area that encompasses the emerald deposits identified to date. Drafted by Gary Bowersox with the computer assistance of Rick Thomson of Data Grafix; artwork by Carol Silver.

border near Chitral to Panjshir in the summer of 1990.

The villages of Khenj (figure 5) and Mikeni are comparable to boom towns in the western United States during the gold-rush days of the mid-19th century. Although there are many shops with items such as tools for mining, wood for house construction, and food supplies, including familiar soft drinks such as Sprite and Pepsi, there is no electricity; candles or oil lamps provide light. The only communication with the outside world is via military radio, which is controlled by the local commander, Abdul Mahmood, and is used only for emergency and military purposes.

Because the mines are located at high elevations and the villages are several thousand feet below them, the miners live in tents at the mine sites from Saturday afternoon until Thursday afternoon of each week. During their two days off, they return to their villages to be with their families and to obtain supplies for the following week. Food is meager and mostly consists of rice, *nan* (a wheat bread), beans, and tea.

THE MINES AND MINING TECHNIQUES

The Buzmal mine is the oldest and, because the miners continue to use unsafe methods, the most dangerous mine in Panjshir Valley. This "mine" is actually a collection of literally dozens of pits and tunnels that speckle a mountain 10,000-ft. (ap-

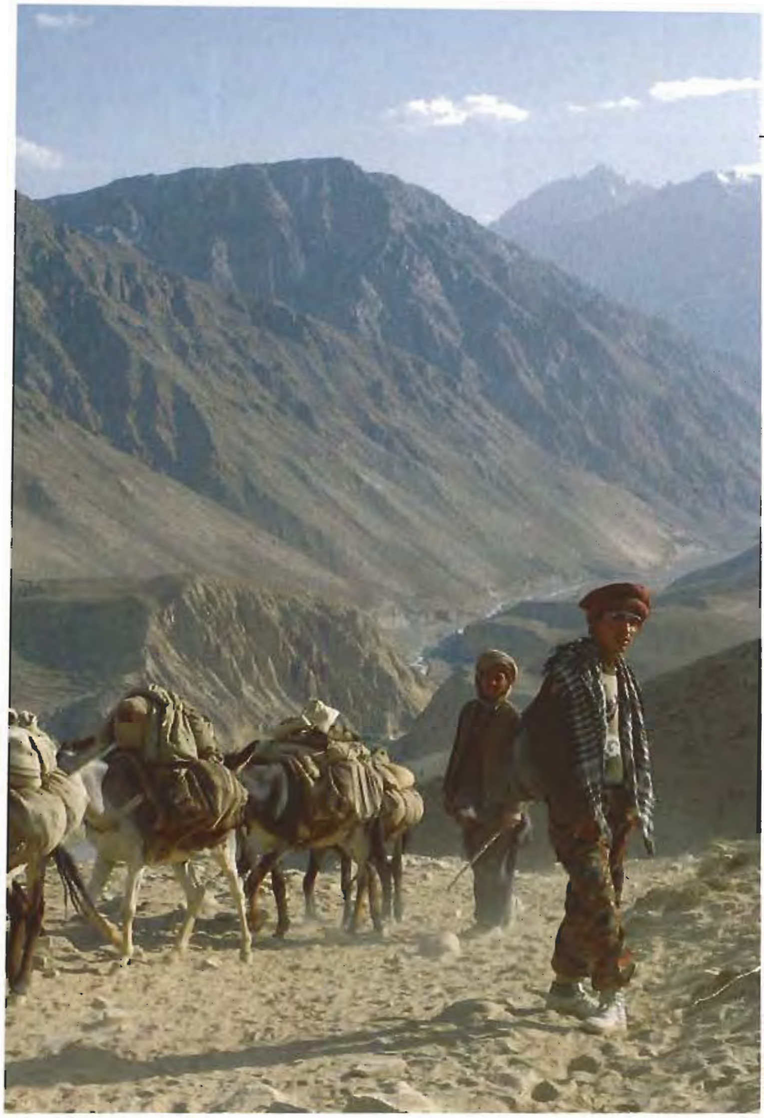


Figure 4. Mule trains are used to carry supplies into the Panjshir Valley from Pakistan. Not only is the path rough and steep in many places as one goes over the mountains, but fields of land mines also pose a constant threat. Photo by Gary Bowersox.

proximately 3,000 m) high. Each group of miners randomly picks a location for tunneling in the technique of "gophering," a term that refers to any small, irregular, unsystematic mine working. Each group tunnels into the limestone with drills and dynamite as far as 30 to 50 yards. The direction may be changed abruptly toward the tunnel of another group that has found emerald. Throughout the Panjshir Valley, the miners do not monitor the amount of explosive used (figure 6) or the timing of the explosions. They tend to use too much explosive, which often destroys the emerald crystals. The senior author experienced considerable uneasiness when, in a matter of minutes, six dynamite blasts from the shaft above shook a tunnel through which he was traveling.

Shafts and tunnels blasted into the limestone are usually approximately 4 ft. (1.2 m) wide and 4 to 5 ft. high, but they may be larger (figure 7). They are oval in shape and lack timber support. With the exception of the Khenj mine, there are no generators or compressors to light the hundreds of tunnels or supply air to the miners. For the most part, passageways are poorly lit by lanterns or oil-burning cans. Miners do not wear hard hats, so head injuries are common.

In addition to the blasting, gas- and diesel-powered hand drills are used, often well inside the tunnels, to work the hard limestone (figure 8). The smoke and carbon monoxide gas have made many miners ill, and caused death for a few. Even the local miners realize that these methods are dangerous; they leave the shafts frequently to breathe fresh air. Because the rocks are riddled with fractures, the potential for cave-ins is also great.

Picks or crowbars may be used on some of the loosened wallrock (figure 9) that does not come completely free with blasting or the drill. All of the broken rock is then carried out of the tunnel by wheelbarrow or simply with a large container. Once in daylight, it is quickly examined, as the miners search for signs of emerald. If no "green" is found, the "waste" rock is simply dumped over the side of the mountain (again, see figure 6). Rocks that do contain emerald are stored by the various members of the team at their campsite until they return to the village.

Figure 5. The village of Khenj bustles with activity these days. Emerald mining is now a primary industry in the region, and shops have sprung up to meet the many needs of mining and the miners. Photo by Gary Bowersox.

During colder months (October through May), snow forces the men either to work mines at lower elevations (where the emeralds found are generally of poorer quality) or sort through the waste rock that was dumped from higher-elevation mines during the normal working season. Plans are being developed for improved processing of the waste material.

There are several mining areas in addition to Buzmal, Khenj, and Mikeni: Sahpetaw, Pghanda, Butak, Abal, Sakhulo, Qalat, Zarakhel, Yakhnaw, Derik, Shoboki, Takatsang, Darun Rewat, Aryu, and Puzughur. They are all similar in both the workings and the character of the terrain; many are at the highest elevations. Work at some, however, is further complicated by the thousands of land mines still left in the area. For example, the mountain top near the Mikeni mine is unworked because it is a known land-mine field.

MINING PARTNERSHIPS

A typical mining team in Panjshir consists of eight miners who do not receive salaries but do share equally the profits from the sale of emeralds they find. Because each team requires blasting and mining equipment, they also normally allot three shares to those who provide mining equipment and three to those who provide blasting materials. Therefore, it is common for the income of a mining team to be divided 14 ways. Mining partners do not have to all be from the same village, but only miners from the local village have a voice at the *buly* of that village. *Buly*, in the Dari language (the most common in Afghanistan), refers to a meeting where the value of the recently mined emeralds is established, the stones are auctioned, and taxes are paid.

Disputes continually arise over mining rights and shaft ownership; they are normally settled by village elders. In difficult cases, the elders may transfer the dispute to Commander Mahmood and appointed judges located in Bazarat, the headquarters of the Jamiat-e-Islami party of Panjshir Province. Because there is no formal registration or bureau of conveyances for record keeping—and there have been diverse land ownership policies over the last 20 years—resolution of the claims is often very complicated.

REGIONAL GEOLOGY

Just as demographically Afghanistan is a collection of tribes and diverse peoples, geologically it is a collection of crustal plates. These plates amalga-

Figure 6. Blasting is common in all of the Panjshir Valley emerald mines. At the Khenj mine shown here, a smoke cloud can be seen toward the top of the diggings, the result of blasting in the mine shaft. Note also the large amount of waste material dumped from the mine. Photo by Gary Bowersox.

Figure 7. This shaft opening in limestone at the Khenj mine is one of the larger ones in the Panjshir Valley. Photo by Gary Bowersox.

Figure 8. Diesel-powered drills are also used to remove the hard wallrock. Because the miners wear virtually no protective gear, injuries from falling or flying rock—as well as illness from the carbon monoxide fumes—are common. Photo by Gary Bowersox.

mated between about 75 and 40 million years ago as fragments of Gondwana (an ancient supercontinent that began to rift apart about 200 million years ago) collided with, and sutured to, ancestral Asia, creating the Himalaya Mountains (Klootwijk et al., 1985; Scotese, 1990). These bits and pieces form a geologic mosaic that is now Afghanistan (De Bon et al., 1987). In fact, a study of the geologic history of Afghanistan provides an excellent example of the theory of plate tectonics (see, e.g., Wilson, 1976).

Panjshir Valley is a major fault zone between two of these crustal plates: the ancestral Asian plate to the northwest and the microcontinental fragment known as Cimmeria to the southeast. Panjshir Valley marks the location of the closure of a major ocean basin known as the Paleotethys.

GEOLOGY OF THE PANJSHIR EMERALD DEPOSITS

The emerald deposits lie southeast of the Panjshir fault zone (again, see figure 3). The geology of this part of the Cimmerian microcontinental fragment is not well known, but the rocks are thought to be an extension of those exposed in the southwestern Pamir Range (DeBon et al., 1987). The rocks of eastern Panjshir include abundant intrusions that were emplaced into a metamorphic basement comprising migmatite, gneiss, schist, marble, and amphibolite of presumed Precambrian age. These older crystalline rocks are overlain by a metasedimentary sequence of schist, quartzite, and marble of probable Paleozoic to Mesozoic age (Kafarskiy et al, 1976). Emeralds have been found only on the eastern side of the valley, even though the western side has been searched extensively. Until the geology of the Panjshir area can be mapped, the detailed nature of this fault zone, and the reason for the absence of emeralds to the west of the valley, will remain unknown.

During his trip to Panjshir, the senior author collected samples of host rock from the three emerald-mining areas of Khenj, Buzmal, and Mikeni. In general, these samples are from a layered metasedimentary sequence of probable Paleozoic age that was metamorphosed to the upper greenschist facies (figure 10). These metamorphic rocks were reportedly intruded by sills and dikes of gabbro, diorite, and quartz porphyry (Kafarskiy et al., 1976). The metasedimentary rocks are hydrothermally altered and are cut by quartz and ankerite (iron carbonate) veins that carry the emeralds (figure 11); pyrite is present in places. Emeralds are also found in silicified shear zones that contain phlogopite, albite, tourmaline, and pyrite

Figure 9. Picks and crowbars are also used in the mine to remove loosened wallrock. Photo by Gary Bowersox.

Figure 10. Emerald mineralization commonly occurs in the quartz and ankerite veins that traverse the sills and dikes intruded into the host limestone. Photo by Gary Bowersox.

Figure 11. The Panjshir emerald crystals are commonly found in quartz (here, from the Buzmal mine). It is not unusual to find literally hundreds of small crystals in a single block. Photo by Gary Bowersox.

as well. Some of the highest-quality material is found in veinlet networks that cut metasomatically altered gabbro and metadolomite.

ORIGIN OF THE PANJSHIR EMERALDS

Emerald, which is generally the result of the substitution of a small amount of chromium for aluminum in the beryl crystal structure (Deer et al., 1986), is the product of unusual geologic conditions. Two of the essential elements contained in emerald, chromium (which produces the color) and beryllium, are geochemically incompatible. Beryllium occurs most commonly in late-stage felsic igneous rocks, such as pegmatites. Chromium is found only in significant abundance in "primitive" rocks such as ultramafic igneous rocks that are characteristic of the ocean floor and mantle; in these rocks, however, beryllium is absent. Thus, special circumstances are necessary to bring chromium and beryllium together to form emerald.

More study of the rocks in the Panjshir Valley is needed before we can confidently draw a conclusion on the origin of the emeralds. However, we speculate that it is highly likely that the Panjshir fault zone is a suture between two crustal plates along which pieces of ultramafic rock, derived from the ocean floor that once existed between the two plates, were trapped. These slivers of ultramafic rock are common along similar structures elsewhere in the world (e.g., the Pakistan emerald deposits), and would be ideal sources of chromium. In addition, the numerous intrusive rocks, including quartz porphyries, of northwest Nuristan would be good sources for the beryllium-bearing hydrothermal fluid, which may have acquired chromium as it passed through chromium-rich rock before it altered the host rock of the emerald-bearing veins. Alternatively, Panjshir emeralds may have been formed during regional metamorphism caused by continental collision in a process similar to that described by Grundmann and Morteani (1989) for "classic schist-host deposits." A detailed discussion of the origin of emeralds, including those of Afghanistan, is presented in Schwarz (1987) and Kazmi and Snee (1989).

PHYSICAL AND CHEMICAL PROPERTIES OF PANJSHIR EMERALDS

Appearance. The emerald crystals from Panjshir vary in quality from mine to mine. As was reported to the senior author in 1985, the miners feel that the best material still comes from the Mikeni and Darkhenj (Valley of Khenj) mines, in the southern end of the mining region.

In general, the crystals are transparent to translucent or opaque. They are commonly color zoned, with very pale interiors and darker green exteriors.

Most of the crystals found to date range from 4 to 5 ct. Crystals over 50 ct continue to be found on a somewhat regular basis (figure 12). Crystals over 100 ct, such as the 190-ct emerald pictured in Bowersox (1985), are considered to be rare.

Morphology. The emeralds occur as euhedral, prismatic crystals with the following crystal forms:

Figure 12. Large emerald crystals are not uncommon in the Panjshir mines. The crystals shown here range up to 132 ct. Photo by Gary Bowersox.

{0001} basal pinacoid and {10$\bar{1}$0} first-order prism (common); {11$\bar{2}$0} second-order prism (rare). First- and second-order dipyramids were not observed on the crystals examined.

Gemological Properties. Examination of nine crystals ranging up to 10 ct revealed conchoidal fracture, vitreous luster, specific gravity of 2.68–2.74 (determined on whole crystals using a Westphal balance), and indistinct (0001) cleavage.

The samples tested proved to be uniaxial negative, in some cases slightly biaxial (2E approaches 6°) because of internal strain. The refractive indices (determined on crushed crystal fragments) of one light green crystal (S.G. = 2.73) were $n_e = 1.582$ and $n_o = 1.588$; the R.I.'s of one medium green crystal (S.G. = 2.70) were $n_e = 1.574$ and $n_o = 1.580$. These values, measured in index oils in sodium light, were representative of the nine crystals tested. All stones were distinctly dichroic: n_o = pale yellowish green, n_e = pale bluish green.

The crystals did not react to either long- or short-wave U.V. radiation. They appeared light red to reddish orange under the Chelsea color filter.

Inclusions. Polished sections of Panjshir emeralds were examined under a petrographic microscope and found to contain numerous primary, three- and other multiphase inclusions that are characterized by three distinct morphologies and crystallographic orientations. The three morphologies are chemically similar and define growth zones within the emeralds. The first group, tubular inclusions oriented parallel to the c-axis, range up to 1000 μm × 100 μm. The second group, tabular inclusions that formed perpendicular to the c-axis, typically are less than 250 μm in maximum dimension. The final group consists of subhedral, equant inclusions that occur at the intersection of zones defined by the first and second groups. These latter inclusions are typically less than 150 μm in diameter. The multiphase inclusions contain up to eight daughter minerals, an H_2O-dominated brine, and, in some, CO_2—liquid and gas (figure 13). The most abundant solid displays a cubic habit, suggestive of halite (NaCl). A second isotropic phase of lower refractive index, probably sylvite (KCl), is the next most abundant daughter mineral and forms equant, subhedral grains. Most of these multiphase inclusions also contain up to two additional isotropic daughters and one or two highly birefringent, subhedral to euhedral rhombic phases (carbonates). Noted, too, in some inclusions are minute grains of other unidentified anisotropic solids. The total solids may comprise over 50% of the volume of the multiphase inclusion. Also common are oblique fractures that contain pseudosecondary multiphase inclusions similar to those described above. In addition, several samples contain numerous two-phase (H_2O—liquid and gas) inclusions of secondary or pseudosecondary origins that are oriented along oblique fractures.

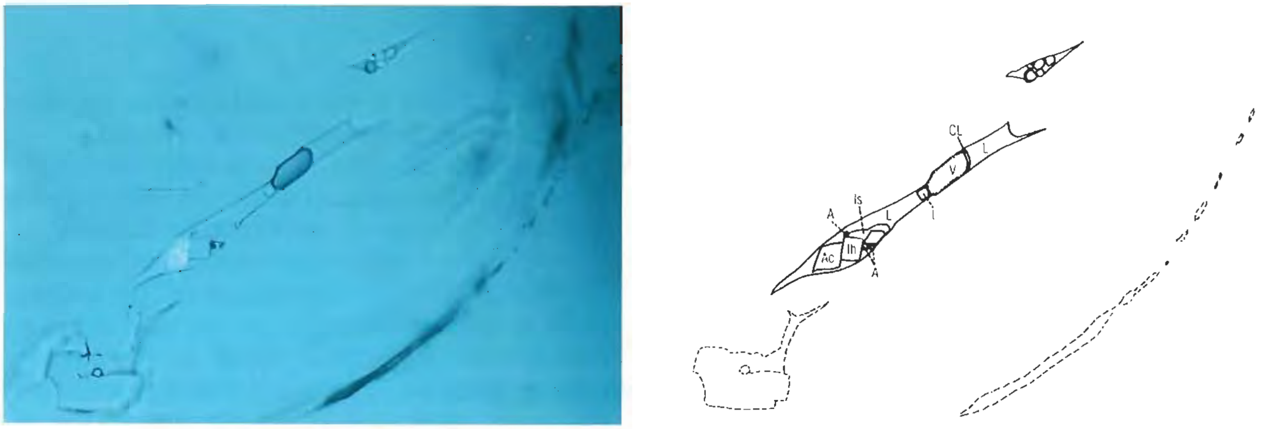


Figure 13. Multiphase fluid inclusions are common in Afghan emeralds. The larger inclusion here contains four isotropic and four anisotropic daughter minerals, brine (L), CO_2–liquid (CL) and vapor (V). The inclined cubic habit of the largest isotropic phase is suggestive of halite (Ih). The lower refractive index isotropic mineral may be sylvite (Is). The identity of the other isotropic daughters (I) is unknown. The large rhombic daughter is probably a carbonate (Ac). The identity of the three smaller anisotropic minerals (A) is unknown. The CO_2 liquid forms a barely visible crescent between the vapor bubble and brine. The smaller inclusion contains two isotropic and two anisotropic daughter minerals in addition to brine and vapor. The length of the large inclusion is 200 μm. Photomicrograph by Robert R. Seal II; magnified 200×.

John Koivula, of GIA Santa Monica, also examined several rough crystals with a gemological microscope. In these crystals, he observed a number of solid inclusions, particularly limonite, beryl, what appeared to be pyrite, rhombohedra of a carbonate (figure 14), and feldspar (J. Koivula, pers. comm., 1991).

In general, the fluid inclusions and associated daughter minerals of Panjshir emeralds distinguish these stones from Pakistani and Colombian emeralds (Snee et al., 1989). The fluid inclusions of Pakistani emeralds are much simpler than those of emeralds from Panjshir, containing only brine and CO_2 vapor (Seal, 1989). In addition, the fluid inclusions in Panjshir emeralds have a greater variety of daughter minerals than fluid inclusions in Colombian emeralds, which typically contain only halite, in addition to brine and CO_2 liquid and vapor (Roedder, 1963).

Chemical Analysis. The chemical composition of emeralds from Panjshir (table 1) falls within the known range for natural emeralds (Snee et al., 1989). However, Afghan emeralds seem to be most similar chemically to Colombian (Muzo) emeralds. In contrast, they can be distinguished chemically from Pakistan emeralds by the higher aluminum and lower magnesium content of the Panjshir stones (Hammarstrom, 1989; Snee et al., 1989).

Surface Etching and 'Nodules' in Panjshir Emeralds. The surface texture of rough Panjshir emeralds ranges from smooth and lustrous to rough and dull (figure 15). The latter results from a natural chemical etching process. In addition, some Panjshir emeralds contain "nodules" (round, marble-shaped bodies) within the larger crystals (figure 16).

Etched surfaces are commonly found on pegmatite gem minerals (e.g., morganite, tourmaline, kunzite, topaz, etc.). Nodules are characteristic of

Figure 14. Rhombohedra of what appeared to be a limonite-stained carbonate were found near the surface of one of the Panjshir emeralds examined. Photomicrograph by John I. Koivula; magnified 5×.

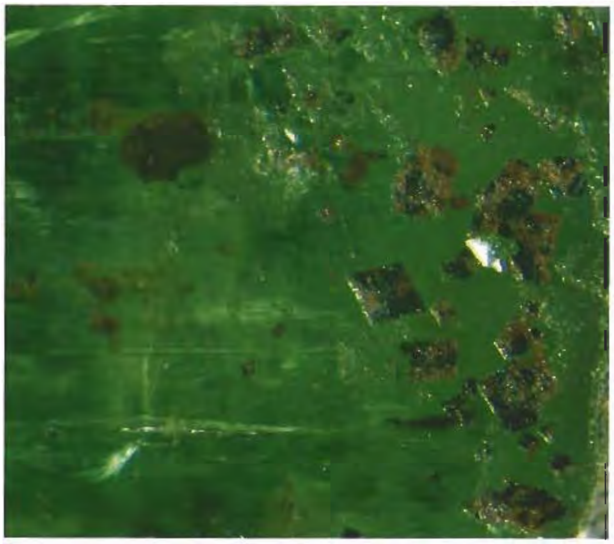


TABLE 1. Four chemical analyses of Afghan emeralds.[a]

	Analysis			
Oxide	1	2	3	4
TiO_2	na[b]	na	na	0.21
SiO_2	66.0	67.1	65.1	65.5
Al_2O_3	18.2	18.2	17.1	16.4
FeO_T (Total iron as FeO)	0.27	0.27	0.46	0.61
MgO	0.22	0.31	0.75	0.70
CaO	na	na	na	0.07
Na_2O	0.21	0.30	0.70	0.99
V_2O_3	0.08	0.07	0.03	0.10
Cr_2O_3	0.19	0.23	0.10	0.54
BeO[c]	13.8	14.0	13.5	12.04
Total	98.9	100.5	97.7	97.16
Weight loss[d]	na	2.2 %	na	na

[a] *Analyses 1, 2, and 3 are microprobe data from Hammarstrom (1989). Analysis 4 is an average of instrumental neutron activation analysis and induction–coupled argon plasma–atomic emission spectrometry data from Snee et al. (1989).*
[b] *na = not analyzed for.*
[c] *Theoretical amount of BeO computed for analyses 1, 2, and 3 assuming 3.00 Be cations per formula unit; since Al and Si can substitute in the Be site in the beryl structure, this assumption may not be valid. BeO for analysis 4 was directly determined.*
[d] *Weight loss was determined by heating one half of the emerald crystal from room temperature to 1400°C in a thermogravimetric analyzer and measuring the weight difference; the other half of the crystal was used for the microprobe analysis.*

some gem-quality crystals of tourmaline (elbaite) found in "pockets" in granitic pegmatites (e.g., Sinkankas, 1955) and have been described in zoned aquamarine-morganite crystals (Kampf and Francis, 1989). Like the nodules in these pegmatitic gem materials, the rounded bodies in Panjshir emeralds are typically cleaner than nonnodular emeralds from this locality. In the case of pegmatites, the origins of both the solution (fluid) that caused the etching and the nodules have been extensively studied (e.g., Foord et al., 1986, and references cited therein). The etching of pegmatite minerals may occur because of chemical instability during late-stage pocket evolution. Feldspar, tourmaline, beryl, and other minerals become unstable because of changing fluid conditions, resulting in partial or complete dissolution. The phenomenon of "pocket-rupture" is believed to produce the nodules in pegmatite gem crystals. Compositional differences between growth zones generate differential internal stresses within the gem crystal. The exterior "skin" on the crystal grew after pocket-rupture and is the binding agent that holds the "fractured" crystal together.

Although the conditions of formation for the Panjshir emeralds are undoubtedly substantially different from those of pegmatite pockets, we believe that a somewhat analogous situation caused the etched crystal surfaces and the nodules. Fluid inclusion, chemical, and isotopic evidence on emeralds from other localities (e.g., Muzo, Chivor, Pakistan, Zimbabwe) indicate that emeralds may have formed during two or more distinct periods of crystal growth (Kazmi and Snee, 1989). The fluid from which the initial growth of emerald took place at Panjshir contained less chromium and was of moderate salinity. With continued crystallization, the chromium content of the fluid

Figure 15. Panjshir emerald crystals, like this 43.47-ct crystal from the Khenj mine, are often etched. Photo by Robert Weldon.

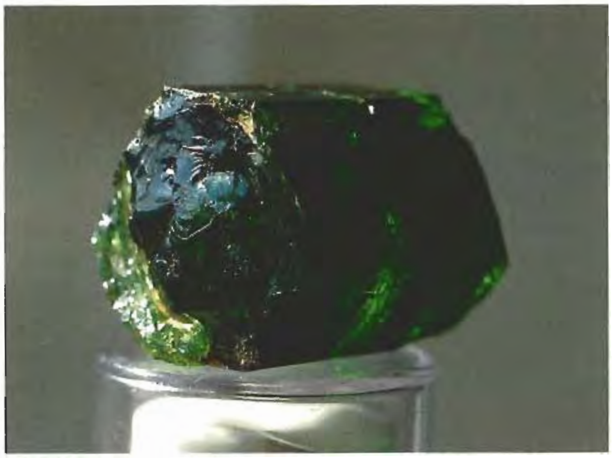


Figure 16. This 36-ct rough emerald from Panjshir contained a large nodule from which several stones, including a particularly fine one at 8.79 ct, were cut. The nodular material is usually much cleaner than the average crystal. Photo by Gary Bowersox.

Figure 17. Panjshir emeralds, like this 1.52 ct stone, are now being set in fine jewelry. Ring courtesy of Jim Saylor Jewelers; photo by Robert Weldon.

increased, as is evidenced by the darker green rims or exterior parts of the emerald crystals. Although not yet observed in Panjshir emeralds, reversals of this zoning pattern (i.e., Cr-richer cores and Cr-poorer rims) are known in emeralds from other localities. A later and distinctly separate fluid from which other minerals (e.g., quartz and/or calcite but not emerald) grew, had a lower salinity and was formed at different temperatures. It is likely that the etching of the emeralds occurred either during the hiatus between the two periods of emerald growth or when the second fluid was introduced.

The origin of the emerald nodules is more difficult to explain. However, we do know that the distinct and sharp compositional zonation with respect to chromium, magnesium, sodium, and iron contents in emerald generates differential stresses within the crystals just as pocket-rupture does in the case of pegmatite minerals. We are not aware of nodules in emeralds from other localities, but they should exist.

MARKETING AND ENHANCEMENT

In general, Panjshir emeralds are mined and marketed in what is basically a free-enterprise system. No government control is exerted except that all emeralds must be brought to one of the three villages nearest the discovery site: Khenj, Mikeni, or Dest-e-Rewat. Each village has a scheduled meeting, or *buly,* of emerald miners and businessmen on Monday and Thursday of each week. During this meeting, chaired by the local commander, the production is evaluated and a tax of 15% of the value is collected. This tax is paid to the Jamiat-e-Islami party to be used for reconstruction of the war-devastated area. After the tax is paid, the emeralds can be retained by the miners or sold via auction to any interested parties in the village. The emeralds are then normally transported to Pakistan for further distribution into the world market, or they may be sold through a newly organized Panjshir emerald syndicate. Afghan emeralds are now being set in jewelry worldwide (figure 17).

A common practice in Pakistan (as elsewhere) is to heat emeralds in one of several oils with a refractive index similar to emerald to reduce the visibility of inclusions. Emeralds that have been treated recently will usually leave oil spots on the parcel paper. Oiling can also be detected with magnification and, in some cases, by a chalky yellowish green fluorescence to long-wave ultraviolet radiation evident in the fractures (see, e.g., Kammerling et al., 1990). Recently, GIA's John Koivula, discovered a dyed crystal in a parcel of Panjshir emeralds purchased by the senior author in Pakistan; this is the first discovery of an Afghan stone treated with dye. Cut stones – usually fashioned in Pakistan or Bangkok – are also available in Pakistan. One must be careful, however, because

Figure 18. This is one of several lots of good-size crystals mined in the Panjshir Valley in 1990. Photo by Gary Bowersox.

several synthetic emeralds have been detected mixed with natural emeralds in sale lots of cut stones.

CUTTING

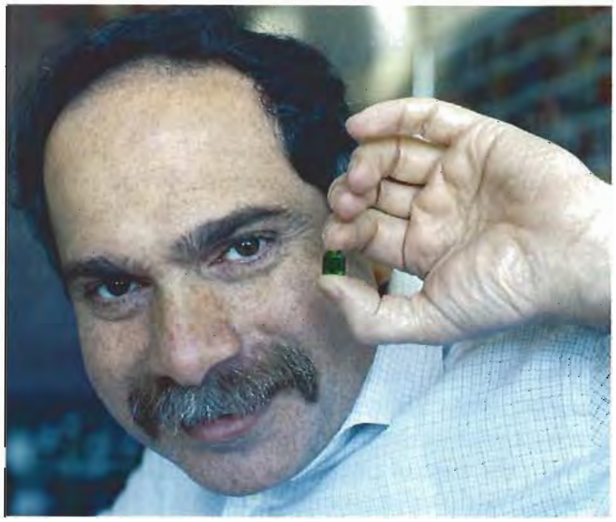
The Panjshir crystals, many of which are large, commonly show complex primary growth and fracture patterns that include outer layers or skins, color variations, complex zoning patterns, and/or etched surfaces. Normally the best color is located near the outer surface of the crystal—a characteristic common to many emeralds. Some parts of the crystals are too dark (overcolored); this is particularly common in emerald crystals from the Khenj mine. In contrast, emerald crystals from the northernmost mining areas (Buzmal, Darun, Darik, and Aryu) tend to be lighter. When faceting lighter-colored emeralds, the cutter must carefully control pavilion angles to limit the amount of light that escapes; this method darkens the color of the cut emerald. In addition, a proper orientation of the table must be maintained to prevent an overemphasis of blue or yellow tones. Panjshir emeralds polish comparably to emeralds from Colombia.

PRODUCTION

No formal records of emerald production for Panjshir exist; however, from tax reports, Commander Masood estimates that approximately US$8 million of rough emerald was produced in 1990 (Tony Davis, pers. comm., 1990). Prior to this report, the senior author had independently derived a figure for 1990 production of $10 to $12 million from discussions with miners and dealers at the 1990 symposium on Afghan gems and minerals held at Chitral, Pakistan, and from sale lots of emeralds seen in Afghanistan and Pakistan (see, e.g., figures 12 and 18). This compares with an estimated production of only $2 million for 1989. With additional miners, improved training and equipment, and development of known mines, production should increase even more dramatically in the future.

Although, as with all gem materials, prices for the Panjshir emeralds vary depending on the quality of the individual stone, an 8.79-ct stone cut from the nodular 36-ct crystal shown in figure 16 was sold by the late Eli Livian in 1987 for US$165,000 ($19,000 per carat; figure 19). The largest fine stone cut to date is approximately 15 ct.

Figure 19. The late Eli Livian is shown here holding an 8.79-ct Panjshir emerald that he sold in 1987 for $165,000. Photo by Gary Bowersox.



SUMMARY

Emerald mining in the Panjshir Valley of Afghanistan is thriving. The best emeralds from Panjshir compete with emeralds from any other source today. Like deposits from some other areas, the Afghan emeralds apparently formed in a continental suture zone. The gemological properties of Panjshir emeralds are consistent with those from other localities. Chemically, Panjshir emeralds are similar to those from Muzo, Colombia. However, this same chemistry, together with their distinctive inclusions, distinguishes them from emeralds from the relatively close Pakistani deposits. The nodules that have been found in some Panjshir emeralds are uncommon in emeralds in general.

Panjshir emeralds are now available worldwide. Some crystals are extremely large, and production of rough in 1990 was valued at approximately $10 million. As postwar conditions improve, production should increase. Future prospects appear to be excellent.

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GEM TRADE LAB NOTES

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Inscribed ALEXANDRITE

Although inscribed diamonds are not rare (in fact, the GIA Gem Trade Laboratory offers a computer-driven inscription service for diamonds), inscriptions on colored stones are uncommon. However, the East Coast laboratory recently encountered an inscription on a lower girdle facet of a 19.95-ct alexandrite.

The characters appear to have been inscribed by hand; the largest character measures about 1 mm high, which a careful observer can see without magnification. As illustrated in figure 1, the first two characters are the Arabic numerals *9* and *7*, while the remaining three characters are not recognizable. It is probable that a sharp, fine-pointed instrument was used for the two legible numbers, and a cruder instrument for the other, comparatively rougher, characters.

The client who had submitted the stone for identification suggested that these inscriptions were done decades ago in Russia. However, a staff member who is fluent in Russian and the Cyrillic alphabet did not recognize the remaining three characters.

The last time we saw an inscribed alexandrite was in 1982. See *Gems & Gemology*, Summer 1982, p. 102, for a description and illustration. *DH*

Figure 1. The inscription on this 19.95-ct alexandrite, seen here magnified at 15×, was actually visible with the unaided eye.

CHALCEDONY, "Turquoise" Color

The operator of a mine in Mexico recently shared his unusual "turquoise" blue–colored chalcedony with the East Coast laboratory (figure 2). The color is lighter than chrysocolla, with less of the green component common to chrysoprase and most chrysocolla.

Standard gemological tests proved that the material was chalcedony: R.I. (spot method) of 1.54; S.G. (heavy liquids) of approximately 2.60; and Mohs hardness (taken on an inconspicuous area, with the client's permission) of 6 $^{1}/_{2}$ to 7, which is slightly harder than most chalcedony that is naturally colored by chrysocolla. The absence of dye was proved by the lack of a spectrum visible with the Beck handheld spectroscope (an aniline dye would have produced dye bands) and a negative reaction to the color filter (which produces a faint red appearance in dyed blue or green chalcedony).

Analysis of the specimen with a Tracor X-ray fluorescence spectrometer revealed that the material was colored by copper and, possibly, titanium and iron as well.

According to the owner of the mine, supplies are abundant and the material will be marketed commercially by the end of the year. *DH*

Figure 2. This chalcedony from Mexico is an unusual turquoise blue. The largest cabochon weighs 24.72 ct and measures 23.71 × 15.03 × 10.06 mm.

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

Gems & Gemology, *Vol. 27, No. 1, pp. 40–45*

Highly Conductive Blue DIAMOND

The GIA Gem Instruments Duotester measures the rate at which heat passes through a stone as a means to distinguish diamond from its simulants; it features an alarm that buzzes when the probe tip touches metal, a reaction to the high electrical conductivity of the metal (a different property from heat conduction). The East Coast lab was surprised when a routine test of a 1.07-ct fancy gray-blue diamond (figure 3) made the Duotester alarm sound. Repeated trials set off the alarm when the stone was held either with tweezers or fingers. When the stone was set in clay, the alarm did not go off, but the tester needle moved all the way to the right, indicating the high thermal conductivity of the diamond.

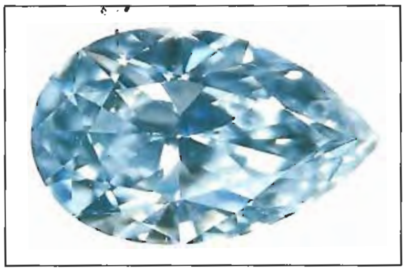


Figure 3. Routine testing of this 1.07-ct fancy gray-blue diamond revealed that it had unusually high electrical conductivity.

Type II diamonds, which have very low levels of nitrogen, typically show higher thermal conductivity than type I diamonds (see the Fall 1972 issue of *Gems & Gemology*, p. 72). These low-nitrogen stones are subdivided into two categories: high-purity, electrically insulating type IIa and boron-bearing semi-conducting type IIb. This stone showed much higher electrical conductivity than the typical IIb diamond, in that it transmitted 90% of the voltage applied to it (as compared to 80%, and as low as 15%, for other blue diamonds). Infrared spectroscopy confirmed that the stone is type IIb. In addition, it was inert to long-wave ultraviolet radiation, but fluoresced and phosphoresced a weak red to short-wave U.V., a characteristic of many blue type IIb diamonds.

Ilene Reinitz

"EMERALD" with Unusual Color Zoning

Concerned that a 3.90-ct transparent green cabochon might be assembled, a client submitted it to the East Coast lab for examination. Viewing the stone with magnification and immersion (figure 4), we noted a plane of color separation that could lead one to believe that the stone was, indeed, assembled. However, closer examination led to the conclusion that it was not.

Standard gemological testing proved that the stone was natural near-colorless beryl with a zone of emerald. As seen in figure 5, there are fractures that cross the planar interface between the colorless and colored areas. In our experience, such fractures would not be smoothly continuous if the interface was a cement plane joining two different pieces of material.

Although ruby or sapphire doublets are fairly common, true emerald doublets are rare. A stone similar in superficial appearance to the one we examined was described in the Gem News section of the Spring 1990 *Gems & Gemology* (p. 100); it turned out to be a beryl triplet.

Nicholas DelRe

Figure 4. The colorless and green zones in this 3.90-ct cabochon are readily apparent with immersion. Although they suggest that this might be an assembled stone, testing proved that it was natural near-colorless beryl with a zone of emerald.

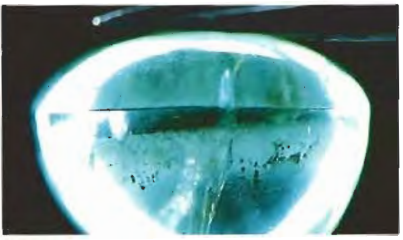


Figure 5. Fractures can be seen crossing the plane that separates the color zones in the emerald in figure 4. The continuity of these fractures proves the stone is not assembled.

More Banded LAPIS LAZULI

A reader of the entry on page 155 of the Summer 1990 issue was intrigued by the possibility of finding banded lapis rough, as he deals in Afghani minerals. Recently, he showed the East Coast lab a 4-oz. (113 g) specimen that he said was the only one he was able to find in a sizable lot of material he had just imported. The banding is very similar to that illustrated in the Summer issue (p. 155). In this particular specimen, the banding occurs in roughly one-third of the piece, which measures approximately 2 1/2 in. (6–7 cm). The material is of very fine color. *GRC*

MOONSTONE and IOLITE Beads

It seems to this editor that the popularity of beads as items of jewelry is cyclical. In the early 1950s, they were practically unobtainable and there was virtually no demand. Today,

Figure 6. The strong pleochroism of iolite is evident in the unusual flattened oval beads (largest, 11.65 × 16.50 mm) of this necklace.

Figure 7. Three colors of orthoclase moonstone (largest bead, 8.0 × 11.5 mm) are attractively combined in this necklace.

their popularity and the variety available are most impressive, as anyone who has attended the February Tucson shows will attest. There are now meetings of bead collectors as well as books covering both contemporary and antique examples.

Recently, the East Coast laboratory identified two bead necklaces of materials that no Eastern staff member recalled seeing before. Figure 6 shows the characteristic pleochroism of iolite in an attractive necklace of flattened oval beads that ranged from 5.40 × 6.35 mm to 11.65 × 16.50 mm. Figure 7 shows a necklace of three different colors of orthoclase moonstone in the form of lentil-shaped oval beads, which ranged from 4.5 × 9.5 mm to 8.0 × 11.5 mm.

The beads were identified by standard gemological tests. While iolite and moonstone are by no means uncommon, their use as beads is unusual. GRC

PEARLS

From Baja California

Figure 8 illustrates one of the most striking natural pearls that we have tested in the East Coast lab. This "bronze" pear shape had a lovely green overtone that gave an aura to the pearl. At 17.7 × 11.0 mm, it weighed 47 grains (there are 4 pearl grains to the metric carat). The pearl fluoresced a distinct pink to red to long-wave U.V. radiation (figure 9).

The owner stated that he had purchased the pearl in the fishing village of Mulege in Baja California (Mexico), selecting it from a large lot of multicolored pearls purportedly fished recently in the La Paz area of Baja. If the information he was given is accurate, this could signify that a "lost" source of fancy-colored natural pearls has again started to produce after more than half a century of dormancy.

From the earliest days of the Spanish occupation of Mexico, the Gulf of California was fished for pearls. Black and multicolored pearls were especially prized, and the name *La Paz,* from the capital of the province, was at one time synonymous with black pearls. The 400-year-old industry came to an abrupt end in 1938 when a mysterious malady struck all of the oyster beds in the Gulf of Cortez – in some cases hundreds of miles apart – simultaneously (see the Summer 1943 *Gems & Gemology* for further discussion of this bizarre occurrence).

Not until the early 1960s was there any sign of recovery of the beds (*The Gemmologist,* June 1962). To date, no great production has been reported. GRC

Figure 8. This 47-grain (17.7 × 11.0 mm) fancy-color pearl was reportedly fished from the waters near La Paz, Mexico.

Figure 9. The pink-to-red fluorescence to long-wave U.V. radiation proves natural color in the pearl shown in figure 8.

Uncommon Cultured

We seldom see cultured pearls as large as 17 mm in the lab. However, at the East Coast laboratory we received two in the space of a few months. Of particular interest was the great difference in the sizes of the two nuclei.

The first cultured pearl (approximately 17 mm in diameter) was in the center of a turn-of-the-century "star burst" pin (figure 10) that featured numerous old-mine-, rose-, and Swiss-cut diamonds set in silver and gold. We asked the client to remove the pearl for X-radiography and were surprised to learn from the X-radiograph that it was a cultured pearl with very thin nacre. In fact, the core was exposed near the drill hole. In spite of the thin nacre, the pearl did not fluoresce to X-rays, which indicated that it had a saltwater shell nucleus. It would be very unlikely for a 17-mm nucleus to be made of freshwater shell. The X-radiograph (figure 11) not only shows the very thin nacre but also some additional drill holes. The latter were made, perhaps, to introduce bleaching agents, since saltwater shell seldom approaches the whiteness of freshwater shell. This cultured pearl was undoubtedly a replacement for the original, since cultured pearls were probably not available at the time the pin was manufactured.

The other large cultured pearl was a button shape (figure 12) that measured nearly 17 mm in diameter. The X-radiograph (figure 13) shows a relatively small nucleus of freshwater shell, the fluorescence of which was visible down the drill hole.

GRC

Figure 10. The unusually large (17 mm) cultured pearl in this pin was found to have a very thin nacre. Because the pin appears to date from the turn of the century, the cultured pearl is probably a replacement for the original natural pearl.

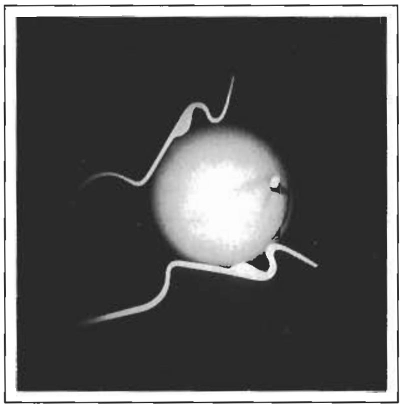


Figure 11. This X-radiograph of the cultured pearl in figure 10 clearly shows the thin nacre and some other drill holes, which were probably made to introduce bleach under the nacre to whiten the nucleus.

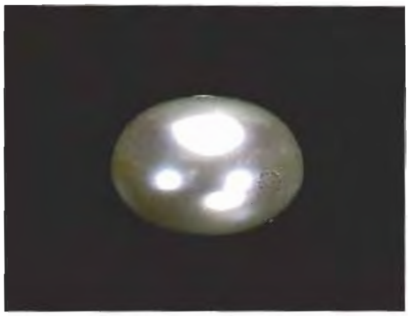


Figure 12. This unusually large (17 × 12 mm) button-shaped cultured pearl was found to have a surprisingly small nucleus.

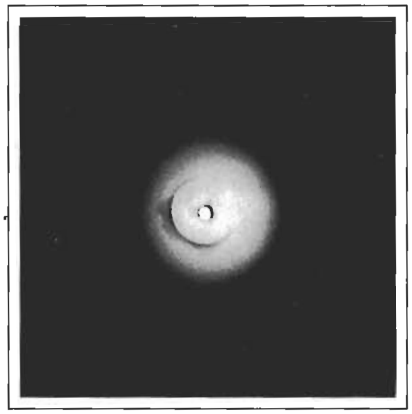


Figure 13. The relatively small nucleus of the cultured pearl in figure 12 is evident in this X-radiograph.

PERIOD JEWELRY

At various times, we have discussed period jewelry in this column. In addition to replacement pieces, such as the cultured pearl in the "star burst" pin described above, we have also looked at original pieces and reproductions.

There is, however, a fourth category: a piece in which an original section has been used in a more recent assemblage. Figure 14 shows a pin/pendant in which the center cluster ornament featuring a large emerald cabochon is surrounded by numerous old-mine-cut diamonds set in silver with gold backs, which strongly suggests that this section was manufactured before 1900. The brown pearls and pear-shaped pendant pearl in the piece are cultured, but of an unusual natural color. They are in a more modern section of the piece, which has tube-set round brilliants of the same recent vintage as those in the crown.

GRC

SYNTHETIC RUBY

"Manufactured" Mineral Specimen

The transparent, slightly purplish red 38.05-ct specimen shown in figure 15 was recently submitted to the

West Coast laboratory for identification. The refractive indices of 1.762–1.770, very strong red fluorescence to short-wave U.V. radiation, typical absorption spectrum, and easily visible curved striae and spherical gas bubbles proved that the material was a flame-fusion synthetic ruby. This cut and partly polished hexagonal prism was quite similar to one that we examined and subsequently described in this section of the Spring 1984 issue (pp. 49–50). Except for one large well-polished "prism face," this imitation was etched or abraded to resemble the surface characteristics of a natural crystal. *RK*

Flux Grown

The West Coast laboratory was asked to identify a 3.5-ct, orangy red, mixed-cut cushion shape. Standard gemological testing methods readily identified the material as synthetic ruby. The internal characteristics, however, proved to be quite unusual.

In addition to the flux "fingerprints," rain-like inclusions, and angular graining that are commonly seen in flux-grown synthetic ruby, this specimen showed some unusual color zoning: near-colorless straight, parallel bands sandwiched between areas of orangy red color (figure 16). *KH*

Figure 14. In this pin/pendant, the center "period" section containing a large cabochon emerald was combined with a more recently constructed outer piece featuring a crown and natural-color brown cultured pearls and cultured pearl pendant (10.5 × 14.8 mm).

Figure 15. Although this vaguely resembles a red beryl crystal, it is actually a flame-fusion synthetic ruby. The piece measures 23.09 × 11.83 × 10.22 mm

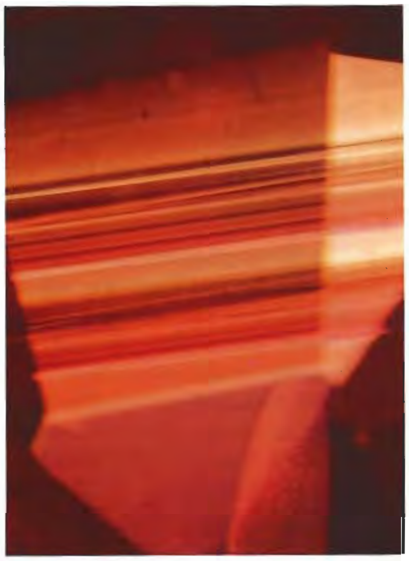


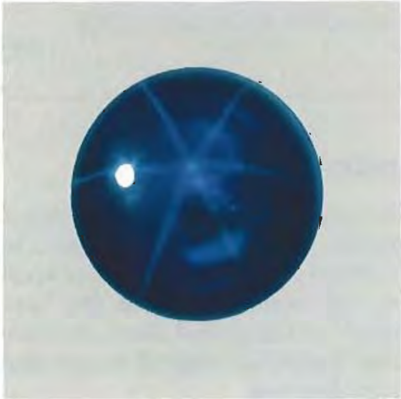
Figure 16. These straight, parallel, near-colorless and orangy red bands are not commonly seen in flux-grown synthetic rubies. Magnified 25×.

Diffused Star SAPPHIRE Update

The East Coast laboratory recently examined the 8.56-ct dark blue star sapphire shown in figure 17. Testing with immersion in methylene iodide determined that both the color and the asterism were produced by surface diffusion. Although this is not a new process (it was patented by Linde Air Products in 1954), we have not encountered such a dual diffusion-treated stone for many years (see, e.g., *Gems & Gemology*, Summer 1982, p. 107).

The dark color and weak asterism of the stone we recently examined fall short of the requirements for wide acceptance. One wonders if the shortage of good natural star sapphires has resulted because suitable

Figure 17. This 8.56-ct star sapphire is an excellent example of the diffusion of both color and asterism into the surface of an otherwise colorless or off-color stone.



rough is being heat treated to dissolve the rutile silk and provide a transparent blue for faceting. Perhaps this has prompted the return of the surface-diffusion process to satisfy the demand for star sapphires. Thus far, however, no commercial successes have been reported for this dual surface-diffusion process.

GRC

SYNTHETIC SAPPHIRE, with Triangular Inclusions

Typically, inclusions in flame-fusion synthetic corundum tend to appear round. Recently, the East Coast lab examined 34 calibrated French-cut blue stones in an Art Deco–style brooch. Twenty-eight of the stones were identified as natural sapphire; the six that flanked the near-colorless round brilliant-cut stone in the center were determined to be synthetic flame-fusion sapphires. These six synthetics contained an abundance of atypical triangular inclusions that, to the novice gemologist, could be quite misleading. Closer examination revealed that the inclusions were actually triangular cavities with gas bubbles (figure 18). These inclusions are described and illustrated in R. Webster's *Gems* (4th ed., 1983, p. 390).

Figure 18. Several synthetic sapphires mixed with natural sapphires in an Art Deco–style pin contained unusual, and possibly confusing, triangular inclusions that contain bubbles. Magnified 30×.

Nicholas DelRe

FIGURE CREDITS

Figures 1, 3–10, 12, 14, and 18 are by Nicholas DelRe. David Hargett contributed figures 2 and 17. The photomicrograph in figure 16 is by John I. Koivula. Figure 15 is by Shane McClure. The X-radiographs are by Robert Crowningshield.

A HISTORICAL NOTE

Highlights from the Gem Trade Lab 25, 15, and five years ago

SPRING 1966

The New York lab presented an illustrated discussion and comparison of the transparency to short-wave ultraviolet radiation of various synthetic and natural rubies. Solution-grown (flux) synthetics were determined to be slightly more transparent than flame-fusion synthetics.

A diamond set in a ring appeared to have discolored over time, acquiring a distinct brownish tinge that refused to be removed with cleaning. It was determined to be from someone who lived in an area that had extremely hard water. The discoloration was attributed to the iron staining that results from prolonged contact with such water. Boiling in strong acid removed the stains.

The Los Angeles lab had the opportunity to examine and photograph a most unusual natural pearl, on which the nacre was confined to one end. The other end was brown and had no nacre at all. With immersion and high magnification, the West Coast lab also resolved a lawsuit by proving that a blue sapphire with an unusual zone of natural blue color just under the table was indeed one piece and not a doublet.

SPRING 1976

Some of the rare gem materials and collectors' stones seen by the Los Angeles lab at this time were eosphorite, jeremejevite, pectolite, and a synthetic "powellite" that proved to be synthetic scheelite. An X-radiograph of a cultured pearl beautifully illustrated the procedure of drilling several holes at an angle through one common drill hole to reach different areas of heavy conchiolin with bleach to lighten the overall color.

The New York lab reported on their visit to the newly opened gem and mineral hall at the American Museum of Natural History.

SPRING 1986

In addition to a beautiful yellow danburite and three faceted radioactive ekanites, the West Coast lab reported on two particularly unusual items. The advent of laser technology enabled the cutting of all 26 letters of the alphabet from diamond; each measured 6.5 mm high by 4.5 mm wide and 2 mm thick. A 1,126-ct pinkish orange sapphire crystal, first seen at the 1983 Tucson show, was cut and the stones submitted for examination. The largest was 47 ct, far below the 200 ct that the owners had hoped to achieve. The crystal proved to be more heavily flawed, with more opaque areas, than expected when purchased.

GEMNEWS

JOHN I. KOIVULA AND ROBERT C. KAMMERLING, EDITORS

TUCSON '91

This past February the Gem News editors, along with countless others with an interest in gems and minerals, traveled to Tucson, Arizona, to attend the many concurrent trade shows taking place there. Following are some highlights of this year's event, based on the editors' observations and those provided by other GIA staff members.

Show exhibits of note. Although a number of associations hold annual shows in Tucson during February, the original stimulus for the event is the Tucson Gem & Mineral Show. Each year, TGMS highlights a featured mineral; for 1991 it was azurite. Special exhibits featured outstanding specimens from such institutions as the University of Arizona, Harvard University, and the American Museum of Natural History. The azurites displayed originated from such noted localities as Bisbee, Arizona; Chessy, France; Alice Springs, Australia; and Tsumeb, Namibia. The Sorbonne case also included other, rarer copper minerals such as lavendulan, tetrahedrite, and bornite. Other noteworthy exhibits were the Fabergé jeweled eggs from the Fersman Museum, Moscow, which had not been displayed previously outside the USSR, and the 75-ct Hooker Emerald, from the Smithsonian Institution.

DIAMONDS

Colored diamonds. Although Tucson is not thought of as a "diamonds" show, the number of diamonds offered there increases every year. Particularly notable this year were colored diamonds. These ranged from very small stones of desaturated color – mostly yellows and browns with gray to green overtones – to larger, finer stones with laboratory reports.

However, the majority of the colored diamonds offered appeared to have been treated, most commonly to green, blue, and yellow. The disclosure of treatment appeared to be almost consistently reversed: The fact that a color was natural was "disclosed."

Gem-quality synthetic diamonds from the USSR. Dr. Alexander Godovikov, of the Fersman Museum, allowed the editors and staff members of the GIA Research Department to briefly examine three gem-quality synthetic diamonds that had been manufactured in the Soviet Union (figure 1). All were yellow and small (4 mm on an edge), reportedly grown only for experimental purposes by the high pressure/high temperature method associated with the other known gem-quality synthetic diamonds, using an iron-nickel metal solvent-catalyst. According to Dr. Godovikov, however, the press used is different from the classical belt technology. It is apparently a hydrostatic press, with elements pushing in from six different directions. This reportedly lowers the cost of production. In the very limited time available to examine these synthetic diamonds, we did not see any of the color zoning or graining observed in other types of gem-quality synthetic yellow diamonds.

Figure 1. These three yellow gem-quality synthetic diamonds (a 0.29-ct octahedral crystal and two slices, 0.09 ct and 0.15 ct) were grown in Novosibirsk, Siberia, USSR. These samples do not exhibit the color zoning seen in the gem-quality yellow synthetic diamonds grown by Sumitomo and De Beers. Photo by Robert Weldon.

COLORED STONES

Madagascar apatite. In the Summer 1990 Gem News column, we mentioned having seen parcels of saturated bluish green to greenish blue rough apatite that was reportedly from Madagascar. The material was very similar in appearance to some of the tourmaline from Paraíba, Brazil.

This year we saw more of this intensely colored apatite, again identified by vendors as coming from Madagascar. A number of dealers, including Michael and Kathy Williams of House of Williams, Loveland, Colorado, were selling faceted material (figure 2); most of the stones were 1 to 2 ct. The Williamses reported that although large quantities of rough are available, relatively little has been faceted. This is probably due to the extreme sensitivity of the apatite to thermal shock–induced cleaving during fashioning. Mr. Williams has found that the Madagascar material is much more susceptible to such cleaving than is Mexican apatite.

Interesting bead materials. As in past years, a great number of materials were available in bead form. Among the more unusual was dolomite with alternating bands of very dark (blackish) green and light greenish white; the latter gave the appearance of fibrous streaks in the darker mass, producing a sheen at certain angles of observation. Also seen were cylindrical fluorite beads that prominently displayed the material's purple and colorless zoning. Another material available in beads of various shapes was a brecciated pyrite, naturally cemented together with various other materials (figure 3). A vague R.I. reading of 1.54 was obtained on some whitish binding material, indicating that it might be quartz or chalcedony. These may be similar to the pyrite-in-quartz beads described in the Winter 1986 Gem Trade Lab Notes section.

Cat's-eye beryllonite. One of the most unusual phenomenal stones seen was a cat's-eye beryllonite from Afghanistan (figure 4). The 8.49-ct stone, purchased for GIA's permanent collection, has a white body color and an exceptionally strong chatoyant band, so that it looks very much like the fibrous mineral ulexite. This stone,

Figure 2. Faceted blue apatite from Madagascar, like this 0.70-ct round brilliant cut, is similar in color to some of the tourmaline from Paraíba, Brazil. Photo by Maha Smith.

Figure 3. These approximately 15.5-mm disc-shaped beads are composed of a brecciated pyrite. Photo by Maha Smith.

Figure 4. The chatoyancy in this 8.49-ct beryllonite (15.70 × 9.45 × 6.60 mm) is an unusual phenomenon for this material. Photo by Maha Smith.

Figure 5. At 2.89 ct, this is the largest faceted clinohumite that the editors have seen. Stone courtesy of Bill Pinch. Photo by Maha Smith.

however, also exhibits interference colors at both ends which are somewhat reminiscent of an adularescent effect.

Large clinohumite. Clinohumite is a fairly rare collectors' gem from the Pamir Mountains of the Soviet Union. This year we saw an attractive medium dark brownish orange, oval modified brilliant-cut stone that, at 2.89 ct, is the largest that the editors have had the opportunity to examine (figure 5). Magnification revealed primary fluid inclusions and distinct growth zoning. All gemological properties were consistent with those reported in the literature for clinohumite.

Update on corundum. Sapphires, as always, were quite prevalent at Tucson. Many of the larger stones being offered were identified by presumed country of origin and appeared to be priced more on this criterion than on quality. There was again a wide variety of both blue and fancy-color sapphires from Montana. By some estimates, tens of thousands of carats were available. There were a fair number of the yellowish orange stones that some in the trade refer to as "padparadscha." Most prevalent were blue stones and yellow stones of approximately half a carat. Most of the material, with the exception of the blue sapphires from Yogo Gulch, is reportedly heat treated. There appeared to be a general effort to market the Montana sapphire as an American gem. For example, the firm Rio Grande Albuquerque offered Yogo blue sapphire in calibrated sizes separate from other blue sapphires in its Tucson show catalog.

A few dealers offered color-change sapphires. One firm had 19, ranging from under a carat to several carats.

In the 1990 Tucson report, we mentioned sapphire from Brazil. This year we received a number of independent reports of sapphire mining in Minas Gerais and saw several fine-quality stones of over 1 ct that were reportedly from this source. Some of the stones display a color change.

We also saw a large supply of bright red-orange sapphires from the Umba region of Tanzania, stones with a distinctly more saturated color than the so-called African "padparadschas" and with a darker tone than is generally seen in "padparadscha" sapphires.

Rubies from a number of sources were also seen. Cabochon-grade material recently produced in Mozambique is similar in appearance to ruby from Tanzania. It was also learned that the Greek-operated sapphire and ruby mine in neighboring Malawi ceased operation this year due to government intervention. A report on rubies and sapphires from Vietnam is provided in the entry on Vietnamese gem materials below.

Unusual colored stone cuts from Thailand. The Winter 1990 Gem News section carried a report that Thailand, long a colored-stone cutting center, is now fashioning large quantities of cubic zirconia for export. Apparently some of the precision cutting and newer cuts being used on this man-made material are also being applied to different natural gems. D. W. Enterprises of Boulder, Colorado, not only has CZ cut in Chanthaburi, Thailand, but also peridot, amethyst, aquamarine, and andalusite, among other gems. The resulting square and rectangular brilliant cuts are very efficient optically. In the case of andalusite, the cutting also enhances the eye-visible pleochroism of the finished gem (figure 6).

Figure 6. The pleochroism of this 1.78-ct andalusite (8.65 × 5.60 × 4.75 mm) is accented by the gem's rectangular brilliant cut. Photo by Maha Smith.

Figure 7. These brooches in 18k gold feature diamonds, pink tourmalines, and carved drusy agate. Gem carving by Dieter Lorenz, Germany; brooch designs by Susan Helmich, Monument, Colorado. Photo © Sky Hall.

Drusy gems in jewelry. Among the most interesting materials at Tucson this year were gems that could please both lovers of fashioned stones and lovers of minerals in their natural forms: Although their outlines were shaped by man (some also featuring carved areas), these gem materials prominently displayed natural drusy surfaces of minute individual crystals, the faces of which produced a multitude of scintillating reflections.

Among the gem materials fashioned in this manner, we saw drusy chrysocolla in quartz and drusy pale purple and dyed black quartz, as well as fine-quality lapis lazuli from Afghanistan that displayed broad areas of finely aggregated pyrite inclusions. Bill Heher of Trumbull, Connecticut, had what appeared to be the most extensive selection of these drusy gems: chrysocolla in quartz; white, gray, and orange agate; dioptase; hematite; psilomelane; pyrite; and rhodochrosite. Mr. Heher and others also had bright pink to purplish pink cobaltocalcite, reportedly from Zaire. Many of these gems had been carved in free-form shapes and set with other gem materials (figure 7).

Uralian emeralds. One of the more notable "new" materials to surface at Tucson this year was emerald and green beryl from the Ural Mountains of the Soviet Union. Barbara Lawrence, of Boston Findings, loaned GIA a few faceted specimens for study (figure 8). Most of the stones we saw were fairly small, approximately 1 ct and under. They are slightly yellowish green of light to medium tone and medium to high saturation.

Figure 8. A relatively new find of emeralds and green beryl from the Ural Mountains has entered the world gem market. These stones, the largest of which is 1.70 ct, are representative of a parcel of purportedly Uralian emeralds that were purchased in Israel. Photo © GIA and Tino Hammid.

Morganite from Mozambique. Morganite is again being produced in Mozambique, at Alto Ligonha in the border area adjacent to Malawi. The crystals are etched; some are naturally pink (in very light tones), and others are a "peach" color that can be heat treated to pink.

Brazilian opal. A few dealers were selling white opal from the deposit in Piauí State, Brazil. According to James T. Drew, Jr., of Star Gems (Brazil and New York), large, steady quantities of material are now being produced, with significant amounts sent to Hong Kong monthly for cutting.

David Stanley Epstein reports that black opal has also been found in Brazil, near Boi Morta, also in Piauí State. Some of this material seems to be rather porous and does not polish well; according to Mr. Epstein, a number of dealers treat it with Opticon. Some of the material has a very distinct, layered structure to its play-of-color, with blue at the base, followed by successive layers of green, yellow, orange, and—at the top—red.

Cultured pearls. Large quantities of cultured pearls were again available. Numerous sources at the show reported that last year's harvest in the Tahitian Islands was the best since culturing activities began there in earnest in the 1960s. Many strands of black cultured pearls were offered for sale, particularly in the 11 mm to 16 mm range. Strands of the more traditional white South Seas cultured pearls were also available in the same larger sizes.

Arizona peridot. Arizona is the major commercial source of peridot in smaller sizes. Large quantities of both rough and cut Arizona peridot were seen at Tucson. One vendor displayed almost 200 kg of "fairly clean" rough that he claimed would cut 1/4-ct stones.

Some exceptionally large peridots were also for sale this year, including a good-color 131.89-ct stone that was reportedly of Burmese origin.

Bicolored quartz. Amethyst crystals are commonly color zoned, with alternating purple and near-colorless triangular sections. In fashioning, these stones are usually oriented to mask the color zoning, producing a fairly uniform purple when viewed face-up.

The firm of Star Gems has chosen to emphasize rather than obscure this zoning in some of the Brazilian material they cut. The interesting bicolored gems that result are part amethyst and part rock crystal (figure 9).

Cat's-eye rose quartz. There are several varieties of quartz, including some that display optical phenomena. Although asteriated rose quartz is seen with some regularity, cat's-eye rose quartz is much less common. At Tucson, we saw one 8.35-ct oval single cabochon that displayed a strong chatoyant band across the length of its dome (figure 10). We carefully examined the stone to see if it exhibited any intersecting bands around the base—as might be expected were this an intentionally misoriented star stone—but saw none.

Rhodolite from Orissa. The Indian state of Orissa has gained a reputation as a producer of colored stones. In our Spring 1989 Tucson report, we noted almandine garnet coming from this locality; this year we saw rhodolites.

Figure 9. The color zoning was intentionally emphasized in cutting these bicolored quartzes (2.14 and 2.30 ct). Photo by Maha Smith.

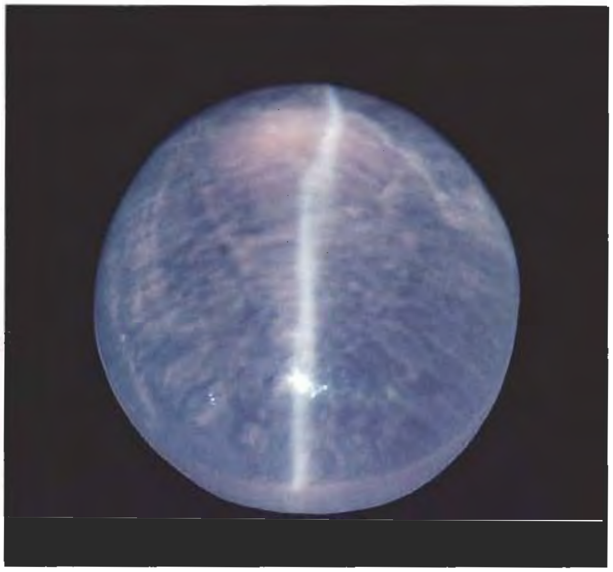


Figure 10. This 8.35-ct rose quartz cabochon displays distinct chatoyancy rather than the more common asterism. Photo by Maha Smith.

We obtained three of these stones (figure 11) for the GIA collection from Amar Jyoti Jain of Fine Gems, in New York. When viewed with fluorescent lighting, the garnets appear fine medium-dark reddish purple; with incandescent lighting, they look more purplish red, a color approaching that of some dark rubellite tourmaline. According to Mr. Jain, the stones come from a mine called Nakta Munda which was discovered in early 1990. The largest rough found will cut stones up to 20 ct, but there are few clean, good-color stones over 10 ct. Most of the better-quality material cuts stones no larger than 4 to 5 ct.

Gemological testing on the three rhodolites we obtained showed that all were within the published ranges for this type of garnet.

Figure 11. Orissa, India, is reportedly the source of these three rhodolite garnets (1.86–2.33 ct). Photo by Maha Smith.

Violet cat's-eye scapolite. Scapolite is actually a solid-solution series with end-members marialite and meionite. Considered a collectors' stone, it is seen most commonly as colorless to light yellow and pink to purple transparent gems. Because many of its gemological properties may overlap those of quartz, it may be confused with rock crystal, citrine, and amethyst. Scapolite is also seen in chatoyant form, with reported localities including Burma and Sri Lanka.

One of the more unusual stones we saw this year was a 7.87-ct dark violet cat's-eye scapolite (figure 12) that is strongly reminiscent of iolite. According to the owner, Mark Smith of Bangkok, the stone was mined in Burma. Like iolite, this scapolite also displays strong pleochroism, with dichroic colors of very light grayish blue and dark violet. The other gemological properties determined were consistent with those reported in the literature for the scapolite series. We resolved a uniaxial interference figure from this very dark stone by rigging a small portable polariscope to an intense fiber-optic light source. The birefringence, determined on a polished area of the stone's base, was 0.009. While this is within the range reported for scapolite, it is considerably lower than the 0.016 value reported in Arem's *Color Encyclopedia of Gemstones* for a cat's-eye scapolite of Burmese origin.

Figure 12. Burma is the reported origin for this 7.87-ct cat's-eye scapolite. Photo by Maha Smith.

Update on tanzanite. Reports in the trade press early this year indicated that the Tanzanian government had stepped in to halt the illegal production and distribution of tanzanite. Further clarification was obtained from a number of dealers at Tucson. They report that the Tanzanian army entered the Merelani area without prior notice, and removed as many as 25,000 illegal miners. The army is now patrolling the area and has made the legal miners erect barbed wire fences around their claims. The government has also encouraged patrols by small private armed forces hired by the mining companies; a representative of one mining company told a GIA staff member that they had 40 men under arms.

This activity, however, apparently has not affected the availability of material, as tanzanite was present at Tucson in the greatest ranges of size and color that either editor can remember seeing. In addition to a wealth of stones in the usual size range for jewelry applications, we saw some exceptionally large stones. Pala International of Fallbrook, California, reported that the 77.69- and 122.09-ct tanzanites in their stock were mined only in the second half of 1990. Also noted were some eye-clean, calibre-cut cabochons and the rare greenish material.

Abe Suleman of Tuckman International, Seattle, Washington, provided us with some additional information. Before the military involvement, four new tanzanite-producing holes were struck. Some of the crystals from these new finds have terminations with a pronounced green color due to strong pleochroism; this material heat treats to a "steely" blue color. Other material has a very light appearance that, contrary to expectations, heat treats to a good blue-violet color.

Paraíba tourmaline. The most talked-about stone of last year's show, the cuprian elbaite tourmaline from Paraíba, Brazil, was again at Tucson. Dealers indicated that little gem material has been found outside the hill that constitutes the original claim. Two dealers reported that, to minimize damage, the material is now heat treated at low temperatures (225° to 250°C) for as long as three days.

More on Vietnam gem finds. A number of items have appeared in the international jewelry press recently concerning rubies being mined in Vietnam. Carlo Mora and Saverio Repetto, of Fimo, a Swiss concern, report that they have formed a joint venture between one of their subsidiaries and a government-owned Vietnamese company to set up a cutting and evaluation operation in Ho Chi Minh City. They confirmed the discovery in 1987 of gem-quality rubies and pink sapphires in the Luc Yen area, north of Hanoi. Messrs. Mora and Repetto supplied us with several samples of material that they obtained in Vietnam (figure 13).

Preliminary gemological testing was carried out on 15 faceted stones ranging from 0.14 to 1.45 ct. The refractive index of the ordinary ray ranged from 1.768 to 1.776 and that of the extraordinary ray ranged from 1.760 to 1.768, with a corresponding birefringence of 0.008 to 0.009. The reaction to long-wave ultraviolet radiation ranged from weak to strong red with some zones (corresponding to blue color zones in the stones) being inert. The short-wave reaction was very weak to

Figure 13. These rubies (the largest is 0.36 ct) are reportedly from the Luc Yen area of Vietnam. Photo © GIA and Tino Hammid.

medium red. Magnification revealed a number of structural features, including strong transparent graining, strong color zoning in red and colorless and/or blue, and laminated twinning. Other internal features noted were secondary healing planes, orangy limonitic(?) staining in fractures, fine pinpoint inclusions in stringers and planes, and small transparent included crystals.

At Tucson, Messrs. Mora and Repetto, and their colleague Madeleine Florida, also supplied samples of sapphires that had been recovered from the Di Linh and East Nam Bo region of southern Vietnam (figure 14). They report that economically exploitable quantities of these blue sapphires as well as some zircon, red spinel, and pyrope garnet have also been found in the country. To date, however, Luc Yen is the only area in Vietnam where organized mining is taking place.

A detailed report on gems from Vietnam is being prepared.

ENHANCEMENTS

Plastic-treated ammonite. René M. Vandervelde of Korite Minerals Ltd. provided information about the iridescent fossilized ammonite mined in Alberta, Canada. He said that his firm continues to recover good quantities of material and showed one of the editors a large (approximately 10 in. [25 cm] in diameter), exceptionally fine specimen that had been mined recently. The material is recovered at depths below 30 ft. (about 10 m).

He also informed us that since 1989 other individuals had been selling some plasticized ammonite. It consisted of surface-collected material that had become unstable due to frost shattering. Apparently, when the Alberta government offered the entire province for mining bids in 1989, there was a rush to stake as much land as possible. The results have been very disappointing, and plasticizing the surface-collected ammonite was one way to salvage at least some of the bid money. By the end of 1990, most of the surface material had been collected, so there is less new plasticized material entering the market today.

Enhanced Paua shell. A number of iridescent shells are used as ornamental materials. One of these is the Paua shell, a type of abalone from the South Pacific. The natural body color is a light, silvery blue, although we have seen material that has been dyed a deeper blue and, in some cases, plastic coated.

One vendor at Tucson was selling a variation on this theme: material that had been dyed a rich green and plastic coated (figure 15). It was being marketed as "Ocean Emerald."

Colored Opticon for emeralds. The use of various substances to fill and thereby obscure surface-reaching fractures in emeralds is widespread. Although most often these substances are used in their natural—essentially colorless to light yellow—states, green oils may be used to impart a darker color to paler stones.

Today, in addition to the more "traditional" oils and natural resins, prepolymer synthetic resins are gaining in popularity, in part no doubt because they can be "set"

Figure 14. These sapphires (the largest is 0.38 ct) are reportedly from southern Vietnam. Photo © GIA and Tino Hammid.

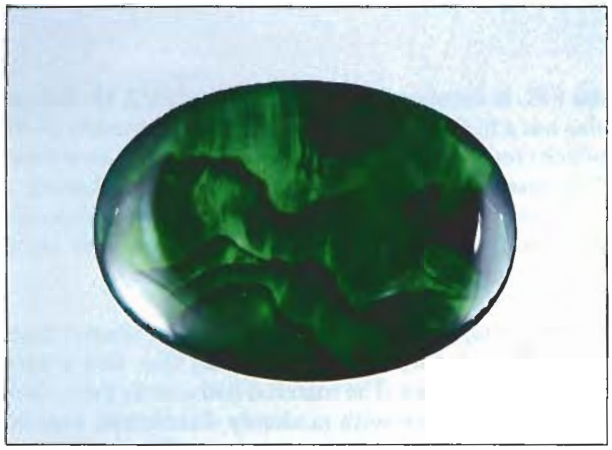


Figure 15. Green dye and a plastic coating have been used to enhance this 8.26-ct (24.90 × 17.90 × 3.47 mm) cabochon of Paua shell. Photo by Maha Smith.

(hardened) at the point of entry into the stone, thus sealing the liquid resin within the fracture and enhancing the treatment's durability. The best known of these materials is a colorless substance marketed under the trade name Opticon. At Tucson we learned for the first time, from two Brazilian dealers, that some treaters are adding a green coloring agent to the Opticon.

Heat treatment of ruby in Sri Lanka. To assist the GIA Research Department with its upcoming experiments in heat treating rubies, we approached various ruby dealers to learn more about the techniques used. Of particular interest, Sri Lankan dealers indicated that in their country virtually all rubies are heat treated by a very primitive method, using a blowpipe. The stated purpose is to "diffuse" the color (i.e., reduce color zoning) and remove blackish or violetish areas. The dealers we spoke with reported a 20% to 30% success rate.

More on diffusion-treated sapphires. Gem Source of Las Vegas, Nevada, and Bangkok, Thailand, was again offering blue diffusion-treated sapphires. Jeffery Bergman of Gem Source told one of the editors at the start of the show that he had on hand over 10,000 ct. He also stated that he is seeing a strong demand for calibrated stones, with strongest demand in the 2- to 10-ct range. A number of big stones were being offered, the largest being 21.60 ct; Mr. Bergman said that they were in the process of trying to treat a 37-ct stone. Current capacity is such that over a six-month period Gem Source could produce 100,000 ct of diffusion-treated stones of one carat or less.

In response to our question about the diffusion treatment of colors other than blue, Mr. Bergman stated that he had heard that other people had had some success in producing red colors with the diffusion process, but to date his own efforts had not been satisfactory. His attempts to diffuse chromium oxide into the stones had resulted in the simultaneous development of a blue color component due to the presence of the appropriate chromophores in the starting gem material. The end product has been stones with a purplish cast rather than the desired purer red. He speculated that he might get around this problem by beginning with very pale pink, approaching colorless, rough.

Figure 16. The Czochralski "pulling" method was used to produce these synthetic alexandrites, 3.63 ct. and 1.14 ct Photo by Maha Smith.

SYNTHETICS AND SIMULANTS

New synthetic alexandrite. J. O. Crystals of Redondo Beach, California, was marketing a new synthetic alexandrite made by the Czochralski "pulling" method. Two specimens (figure 16) were subsequently loaned to GIA for gemological examination.

The faceted stones are rather striking when observed face-up. According to Judith Osmer, each piece is carefully oriented in cutting to take advantage of the strong pleochroism in addition to the color change. These synthetic alexandrites are relatively lighter in tone than what we have come to associate with pulled synthetic alexandrite from other firms such as Kyocera; even in larger sizes this new material is of medium to medium dark tone.

Testing revealed properties generally consistent with those reported in the literature for pulled synthetic alexandrite. Ms. Osmer indicated that the smaller stones she has had cut appeared at first inspection to be quite clean, but some of the larger ones contained minute gas bubbles. Our subsequent examination of 1.14-ct and 3.64-ct faceted specimens revealed growth zoning in both and many minute bubbles in the larger of the two.

Update on Chatham production. Among the items of interest being shown by Chatham Created Gems of San Francisco, California, were some recently grown synthetic emerald crystals that were distinctly "cleaner" than the usual production-run material. These had a slightly flattened habit and weighed 40–60 ct. Also on display were two 1,000+-ct synthetic ruby crystals, with large areas of transparency, that were reportedly grown over a three-year period.

Thomas Chatham offered some statistics relating to production over the past year: 1 million carats of

Figure 17. These 8-mm silicon beads (left) are being marketed as a "lighter" alternative to hematite (right). Photo by Maha Smith.

synthetic ruby, with a 7% to 20% yield in cutting; and 1.4 million carats of synthetic emerald, with a 4% to 20% yield (13%–14% average). He reports manufacturing fewer than 20,000 ct per year of synthetic blue sapphire. Although the firm did produce minor amounts of synthetic "padparadscha" sapphire a few years ago, this production was largely experimental and relatively little of it ever reached the market. According to Mr. Chatham, there are currently no plans to manufacture it commercially.

More on synthetic emeralds. The Biron hydrothermal synthetic emerald, produced in Australia and once promoted as the "Pool Emerald," is now being marketed in the United States under a new name, Kimberley Created Emeralds, by the firm of the same name in New York City.

The firm of Aviv, Inc., of Houston, Texas, is now marketing Soviet hydrothermally grown synthetic emeralds under the name "Émsprit Emerald." Aviv reports that they are currently selling all of the material that they receive from the USSR, approximately 5,000 ct per month.

Man-made hematite simulant. Hematite is a popular gem material for intaglios and beads. To some extent, however, its use in the latter is restricted by its high density: With a specific gravity around 5.20, even relatively short necklaces of larger hematite beads can be very heavy. The most convincing of the man-made simulants, "Hemetine," offers no advantage in this area, having an S.G. of 4.00–7.00.

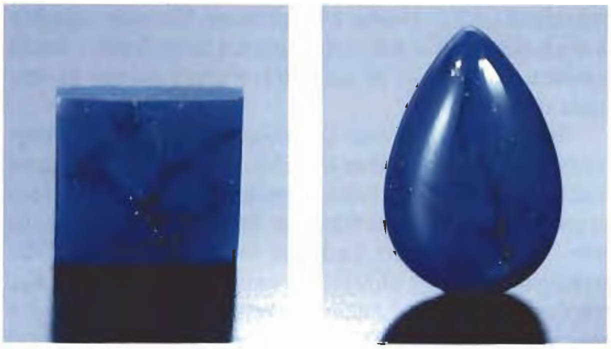
Gems Galore of Mountain View, California, has addressed this "weighty" issue by marketing jewelry items made of silicon, which is produced from a refined melt by the Czochralski method primarily for use in solid-state or semiconductor devices. Sold as beads, earrings, and cabochons under the name "Hemalite" (figure 17), this material has less than half the density of hematite. As we confirmed on a piece donated to GIA, the S.G. is consistent with that of silicon, 2.33. Silicon also has a higher Mohs hardness (7) than hematite (5–6), which could translate to greater "wearability" over time. The material is quite convincing visually, having a medium gray body color and metallic luster, although the natural material has a somewhat darker body color, close to black.

Imitation lapis lazuli. Also seen was a material marketed as "reconstructed" lapis lazuli that had a very natural appearance. The material had a fairly even, dark violetish blue color with randomly distributed, angular grains of pyrite. Two fashioned pieces (figure 18) were purchased for gemological testing. These revealed a spot R.I. of 1.55 and an S.G. of 2.31 ± 0.01. The material was inert to long-wave U.V. radiation and displayed a weak, chalky yellowish fluorescence to short-wave U.V. With magnification, we saw that the pyrite inclusions were raised slightly above the blue host material, indicating that the pyrite was the harder of the two. Some random, shallow whitish areas were also noted.

When placed over the end of a high-intensity fiber-optic illuminator, the material was semitranslucent, passing more light than is typical of natural lapis; only the pyrite inclusions were truly opaque. When viewed through a Chelsea filter while so illuminated, the stone became almost invisible: It apparently absorbed all those wavelengths of visible light passed by the filter's two transmission windows. The stone took on a slightly dark reddish brown cast, however, when viewed through the Chelsea filter with reflected light. The thermal reaction tester produced a weak acrid odor, whitish discolorations, and slight melting (all of which indicate that a plastic-type binder may be present). X-ray diffraction analysis revealed a strong pattern for barium sulfate ($BaSO_4$); it also confirmed that the metallic inclusions were pyrite. Infrared spectrometry identified the bonding agent as a polymer.

Gold in quartz doublets. Whitish vein quartz is the common host rock for gold. Occasionally, native gold in

Figure 18. These pieces of imitation lapis lazuli have a very natural appearance. Photo by Maha Smith.



its quartz matrix — "gold quartz" — is cut into tablets and cabochons for use in jewelry. This year, Canadian Placer Gold Ltd. of Vancouver, B.C., Canada, was marketing assembled stones fashioned from this material. These doublets (figure 19) consist of a relatively thin, flat top section of gold in quartz backed with a somewhat thicker layer of white ceramic. The pieces are sold both loose and as inlay (which protects the edges) in jewelry such as rings.

According to Mark Castagnoli, who fashions these assembled stones, most of the gold quartz he uses comes from mines in Sierra County, California, including the 16-to-1 and the Rush Creek, although some is from British Columbia's Caribou mine. Some of the material is extremely fine grained, bordering on chalcedony, and some pieces also have crystals of pyrrhotite.

Figure 19. A thin (approximately 1.5 mm) layer of gold in quartz is backed with white ceramic to produce this 17.10 × 5.00 × 3.50 mm assembled stone. Photo by Maha Smith.

More Soviet synthetics. Perhaps the greatest novelties at Tucson this year were synthetic gem materials from the Soviet Union. A large variety of these materials were available, some of which are totally new to the gemological community. Many of these materials, however, were only present in very small quantities.

Flux-grown synthetic spinel was available but only in the purplish red color previously reported in Gem News. However, other colors of synthetic spinel reportedly have also been produced.

Flux-grown synthetic alexandrite was also seen, the crystals being relatively small and flat (less than 5 mm thick). The color change is moderate, with a slightly brownish component reminiscent of that seen in natural alexandrite from Sri Lanka.

Hydrothermal synthetic beryl in a range of colors was seen. All of the crystals were small (less than a few centimeters long), with a typical flattened habit. Colors seen include green (synthetic emerald); purplish red, similar to natural red beryl; light blue, similar to natural aquamarine; violetish blue, resembling tanzanite; brownish green, reminiscent of andalusite and some tourmaline; a "turquoise" blue that looked like some Paraíba tourmaline; and an orangy pink that was quite similar in appearance to "padparadscha" sapphire.

A curiosity was an apparently flux-grown synthetic emerald overgrowth on tumbled aquamarine seeds. The material is not really gem quality but shows a beautiful combination of prismatic, basal, primary, and secondary pyramidal crystal faces on the overgrowth material.

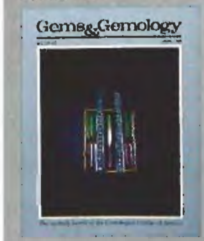
Several dealers were offering large quantities of synthetic quartz. Perhaps most noticeable was a medium dark cobalt blue, darker than the cobalt blue quartz previously grown. A rough crystal, several carvings, and faceted stones were loaned to GIA by Stephen Schwartz of Stephen Schwartz & Associates, Los Angeles. Mr. Schwartz reports that the greater depth of color is due to a different position of the cobalt ion in the quartz structure. Some of this material was rather deceptively advertised as "Siberian Blue Quartz." We saw tens if not hundreds of kilos of this material being offered, perhaps in part because of its alleged metaphysical properties.

Other colors of synthetic quartz seen were purple (synthetic amethyst), yellow (synthetic citrine), green (a tourmaline-like color), and a brownish orange reminiscent of dark, heat-treated citrine.

It was also reported by Peter Flusser of Overland Gems, Los Angeles, that gem buyers visiting crystal growers in the Soviet Union have been asked if they are interested in synthetic tanzanite or synthetic tourmaline, thus suggesting that these two materials can be readily grown. Some caution, however, is necessary in interpreting such an offer, as there is apparently no distinction in the Russian language between *synthetic* and *simulant*. Therefore, these inquiries may simply refer to imitation tanzanite and tourmaline, consisting of appropriate colors of synthetic beryl such as those mentioned above. Similar confusion in the past led to a "report" that extremely large gem-quality synthetic diamonds were being grown in the USSR. Clarification later revealed that the "synthetic diamonds" were in fact large CZ crystals.

Acknowledgments: The editors thank the individuals and firms who provided information for this special Gem News Tucson Report. In addition to those named in individual reports, we wish to thank Karin Hurwit of the GIA Gem Trade Laboratory, Santa Monica; Dr. Emmanuel Fritsch of the GIA Research Department; and Loretta Loeb, GIA collection curator.

Spring 1985



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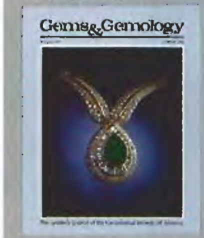

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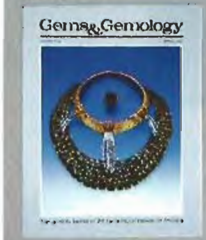

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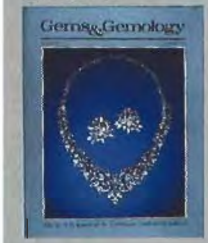

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THE MOST VALUABLE ARTICLE AWARD AND A NEW LOOK FOR GEMS & GEMOLOGY

By Alice S. Keller, Editor

Each year, *Gems & Gemology* brings you the most up-to-date information on natural gem materials, localities, synthetics, and treatments in our articles and regular features such as Gem Trade Lab Notes and Gem News. Last year saw the publication of some of our best articles to date, and you readers certainly let us know that in your balloting with comments such as "every article is important," "so many good articles this year," and "all of them are great!" It is obvious by your choices for first and second place that detection of treatments is a key concern. The remarkable article "Gemstone Enhancement and Its Detection in the 1980s," by Robert C. Kammerling, John I. Koivula, and Robert E. Kane, was clearly the winner from the outset of voting. Indeed, we have already sold hundreds of laminated copies of the detection chart that appeared in that article. The second-place winner, "The Identification of Blue Diffusion-Treated Sapphires," by Messrs. Kane, Kammerling, and Koivula, together with GIA researchers James E. Shigley and Emmanuel Fritsch, gave clear-cut explanations of the diffusion-treatment process and how the jeweler/gemologist can detect it. For third place, the winner is "Gem-Quality Cuprian-Elbaite Tourmalines from São José da Batalha, Paraíba, Brazil," by Drs. Fritsch and Shigley with George R. Rossman, Meredith E. Mercer, Sam M. Muhlmeister, and Mike Moon. The authors of these three articles will share cash prizes of $1,000, $500, and $300, respectively. The winner of the three-year subscription is Pinchas Schechter of Miami Beach, Florida. Congratulations! Photographs and brief biographies of the winning authors appear below.

I would also like to take this opportunity to thank Art Director Lisa Joko for updating the design of *Gems & Gemology* as we enter our second decade in the expanded format. We take our position as a leading force in gemology seriously, and feel that we should be as progressive in our "look" as we try to be in the information we provide. The editorial review and revision process remains as rigorous as ever, but we hope you like the new, more exciting graphics and even greater use of color.

FIRST PLACE

ROBERT C. KAMMERLING · JOHN I. KOIVULA · ROBERT E. KANE


John I. Koivula, Robert E. Kane, Robert C. Kammerling

As GIA's director of technical development, **Robert C. Kammerling** helps coordinate research and development activities between the Institute's various departments. He is also coeditor—with John Koivula—of the Gem News section of *Gems & Gemology*, coauthor—with Dr. Cornelius Hurlbut—of the book *Gemology*, as well as a regular contributor to numerous publications worldwide. A native of Chicago, Mr. Kammerling has a B.A. from the University of Illinois. **John I. Koivula,** GIA's chief gemologist, is world renowned for his expertise in inclusions and photomicrography. He is coauthor—with Dr. Eduard Gübelin—of the *Photoatlas of Inclusions in Gemstones.* Mr. Koivula also holds bachelor's degrees in chemistry and mineralogy from Eastern Washington State University. **Robert E. Kane,** also a prolific author, is manager of identification at the GIA Gem Trade Laboratory, Santa Monica. With 13 years of laboratory experience, Mr. Kane's research specialties include colored diamonds, rare collector gems, and the separation of natural, synthetic, and treated gems; he has also visited many of the major gem localities and key gem laboratories worldwide.

SECOND PLACE

ROBERT E. KANE · ROBERT C. KAMMERLING · JOHN I. KOIVULA · JAMES E. SHIGLEY · EMMANUEL FRITSCH

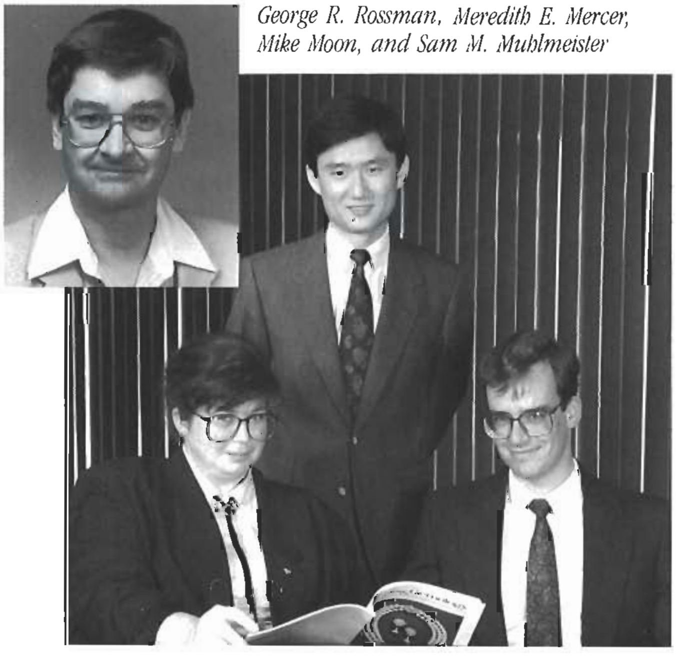
Photographs and biographies for Robert E. Kane, Robert C. Kammerling, and John I. Koivula appear above. A research scientist at GIA, **Emmanuel Fritsch** specializes in the application of spectroscopy to gemology, the origin of color in gem materials, and twinned crystals. A native of France, he received his Ph.D. from the Sorbonne in Paris. **James E. Shigley,** who received his doctorate in geology from Stanford University, is director of research at GIA. He has written several articles on natural, treated, and synthetic gem materials, and is currently directing research on the identification of these types of gem materials.

Emmanuel Fritsch and James E. Shigley

THIRD PLACE

EMMANUEL FRITSCH · JAMES E. SHIGLEY · GEORGE R. ROSSMAN · MEREDITH MERCER · SAM M. MUHLMEISTER · MIKE MOON

Photographs and biographies for Emmanuel Fritsch and James E. Shigley appear above. **George Rossman** received his B.Sc. from Wisconsin State University, Eau Clair, and his Ph.D. (in chemistry) from the California Institute of Technology, Pasadena, where he is now professor of mineralogy. His current research studies involve origin of color and the physical and chemical properties of minerals. **Meredith E. Mercer,** a research technician, runs heat-treatment and precious metals–testing projects for the GIA Research Department. She holds a master's degree in materials science and engineering from the University of California at Davis. **Sam M. Muhlmeister,** a research technician in GIA's Research Department, received bachelor's degrees in physics and mathematics from the University of California at Berkeley. His current projects include separating natural from synthetic gemstones on the basis of trace-element chemistry. **Mike Moon,** also a research technician, is a native of Korea. He is currently working on the Colored Diamond Project Database and the Fourier transform infrared spectrometer. He did his undergraduate work at Seoul National University and received a masters in metallurgy and materials science from Stevens Institute of Technology in New Jersey.



George R. Rossman, Meredith E. Mercer, Mike Moon, and Sam M. Muhlmeister

Gems & Gemology

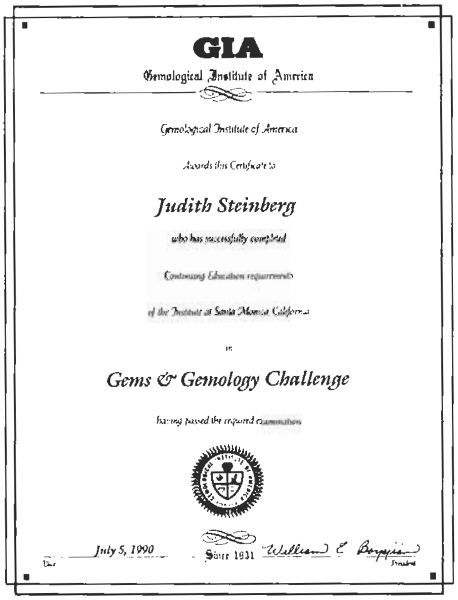
CHALLENGE

Gemology moves rapidly. From technological advances in synthesis and enhancements to new discoveries of mineral resources, it's a world that is constantly changing.

Over the last year, *Gems & Gemology* has brought the profession in-depth coverage and insight into these changes like no other journal in the field. We've met our 1990 challenge. Now, together with GIA's Continuing Education Department, *Gems & Gemology* would like to challenge you.

The following 25 questions are based on articles published in the four 1990 issues of *Gems & Gemology.* We encourage you to refer to those issues to find the *single best answer*; then mark the appropriate letter in the card provided in this issue (photocopies or facsimiles of this card will not be accepted). Mail the card with your answers by Monday, August 26, and be sure to include your name and address. All entries will be acknowledged with a letter and an answer key.

If you score 75% or better, you will receive a GIA Continuing Education Certificate testifying to your accomplishment. Score a perfect 100%, and you will also receive a special acknowledgment in the Fall issue. Good luck!



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Note: Questions are taken from only the four 1990 issues. Choose the single best answer for each question.

1. Although always potentially damaging, diamond grit–impregnated tweezers should be limited to careful use with
   - A. diamonds only.
   - B. man-made gems.
   - C. diamonds and corundum.
   - D. stones with a Mohs hardness of 8 or greater.

2. Of the rubies and sapphires entering the market in the 1980s, 95% are believed to have been enhanced by
   - A. dyeing.
   - B. irradiation.
   - C. heat treatment.
   - D. surface coatings.

3. In the late 1980s, Colombia's share of world emerald production was approximately
   - A. 25%.
   - B. 30%.
   - C. 40%.
   - D. 49%.

4. The color of Guatemalan jadeite with the greatest commercial potential is
   - A. white.
   - B. "blue."
   - C. "black."
   - D. variegated green.

5. The most expensive Majorica imitation pearl color to produce is
   - A. gray.
   - B. black.
   - C. white.
   - D. cream rosé.

6. The known history of the Dresden Green diamond begins in
   - A. 1672.
   - B. 1726.
   - C. 1741.
   - D. 1746.

7. The color in hydrothermally grown synthetic aquamarine from the USSR is the result of
   - A. irradiation.
   - B. heat treatment.
   - C. a high copper content.
   - D. a charge-transfer process.

8. The primary coloring agents for Paraíba tourmalines are
   - A. iron and copper.
   - B. titanium and iron.
   - C. manganese and copper.
   - D. manganese and titanium.

9. The following color in Paraíba tourmaline is not likely to be the result of heat treatment
   A. light blue
   B. bluish purple
   C. turquoise blue
   D. "emerald" green

10. Most tsavorite comes from
   A. Kenya.
   B. Zaire.
   C. Tanzania.
   D. South Africa.

11. The Dresden Green diamond was determined to be a rare
   A. type Ia diamond.
   B. type Ib diamond.
   C. type IIa diamond.
   D. type IIb diamond.

12. While of some use in determining sapphire provenance, EDXRF does not always distinguish sapphires from Kashmir from those originating in
   A. Myanmar.
   B. Thailand.
   C. Australia.
   D. Sri Lanka.

13. So-called "Alaskan black diamond" is actually
   A. hematite.
   B. melanite.
   C. chalcedony.
   D. cassiterite.

14. The most useful microscopic features for identifying that a sapphire is of Kashmir origin are
   A. "snowflakes" and "feathers."
   B. "snowflakes" and pargasite crystals.
   C. tourmaline crystals and "fingerprints."
   D. well-formed rutile needles and color zoning.

15. A good means of identifying that blue sapphires have been diffusion treated involves
   A. U.V. fluorescence.
   B. use of the refractometer.
   C. immersion in methylene iodide.
   D. use of a hand-held spectroscope.

16. The only totally new synthetic gem material introduced commercially during the 1980s was synthetic
   A. diamond.
   B. tanzanite.
   C. cubic zirconia.
   D. cat's-eye alexandrite.

17. In the past decade, the technique that probably brought the most new solutions to gem identification problems was
   A. X-ray spectroscopy.
   B. Raman spectroscopy.
   C. infrared spectroscopy.
   D. the electron microprobe.

18. The nucleus of a Majorica imitation pearl is made from
   A. glass.
   B. plastic.
   C. "pearl essence."
   D. mother-of-pearl.

19. The largest California diamond reported to date was about
   A. 3.90 ct.
   B. 6.74 ct.
   C. 17.83 ct.
   D. 32.99 ct.

20. Currently, the annual production of synthetic cubic zirconia exceeds
   A. 50 million carats.
   B. 100 million carats.
   C. 500 million carats.
   D. one billion carats.

21. All of the following are characteristic features of diffusion treatment in blue sapphires except
   A. dense concentrations of rutile silk.
   B. localization and blotchiness of color.
   C. concentrations of color along facet junctions.
   D. dark concentrations of color in surface-reaching breaks.

22. During the 1980s, the gem material that enjoyed the greatest resurgence of interest was
   A. jade.
   B. pearl.
   C. emerald.
   D. diamond.

23. The most obvious means of separating natural or other synthetic emeralds from "Emeraldolite" is
   A. magnification.
   B. refractive index.
   C. specific gravity.
   D. visual appearance.

24. Bluish gray colors were commonly produced in saltwater cultured pearls in the 1980s through
   A. bleaching.
   B. irradiation.
   C. heat treatment.
   D. diffusion treatment.

25. In the 1980s the highest average mining grade of diamonds was found in the
   A. Argyle mine, Australia.
   B. Jwaneng mine, Botswana.
   C. Kalimantan mine, Borneo.
   D. Jagersfontein mine, South Africa. ○

GEMOLOGICAL ABSTRACTS

DONA M. DIRLAM, EDITOR

COLORED STONES AND ORGANIC MATERIALS

The beryl suite of gems. B. Jones, *Rock & Gem*, Vol. 20, No. 12, December 1990, pp. 36–42.

In a detailed description of the major beryl producing areas of the United States, the author focuses on the New England states and southern California. Mr. Jones begins by describing some of the varieties of beryls, such as maxixe, morganite, aquamarine, and heliodor. Goshenite is also mentioned, but not in great detail.

Then, the author turns to beryls from southern California, particularly, San Diego County's Pala district. Here he talks about Pala's three major sources: the White Queen mine on Hiriart Hill and the mines on Tourmaline Queen Mountain and Pala Chief Mountain. While the Himalaya mine today is noted for producing the best-quality tourmalines from southern California, it has also produced fine-quality morganite. On rare occasions, the two gems occur in the same specimen.

America's earliest sources for beryl, Jones explains, were in New England, particularly in Maine, New Hampshire, and Connecticut. No longer a major producer of beryls, New England does remain as the historical locality for these gems. This locality has been overshadowed by the major discoveries of beryls in Brazil. Maine pegmatite crystals, Jones tells us, were astoundingly big, although impure and opaque. Some crystals weighed more than 20 tons and were so large that miners had to actually tunnel into them during the mining process. Jones concludes with a detailed description of the various mines of distinction throughout New England. Five photographs, three in color, help illustrate this article. *Ron Conde*

Gem-quality chrysoprase from Haneti-Itiso area, central Tanzania. K. A. Kinnunen and E. J. Malisa, *Bulletin of the Geological Society of Finland*, Vol. 62, No. 2, 1990, pp. 157–166.

Gem-quality, apple-green, Ni-bearing chalcedonic silica occurs as veins in silicified serpentinite in the Hanetiand hydrated opals (3.8–4.9 wt.% physically absorbed water) present blue iridescence due to a less dense packing of silica spheres; they occur in claystones. The infrared, X-ray diffraction, and DTA patterns all show that the substitution of Al for Si in the tetrahedral network is a function of the Al_2O_3 content.

R. A. Huddlestone

DIAMONDS

Electron microscopic study of inclusions in small diamonds occurring in Liaoning. X. Xiao and G. Liu, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 361–363.

Inclusion minerals in small diamonds from Liaoning province, China, were found to consist of Al-rich chromite, K-feldspar, and quartz. The mineralogic composition of these phases is similar to that of acidic igneous rocks. These phases are quite different from the peridotitic-suite and eclogitic-suite mineral inclusions that are commonly found in diamonds. *JES*

The end of an era. R. Scott, *British Jeweller & Watch Buyer,* Vol. 58, No. 6, February 1991, pp. 32–35.

It is the end of an era for a "breed of 'garimpeiros,' or prospectors" who still work the old diamond mines in the Brazilian rain forest region called Chapada Diamantana which became a national park in 1985. The old prospectors are allowed to continue their antiquated mining activities, but the end of the era is due to two factors: (1) because the work is labor intensive and the money meager, most young people will not go into the business; and (2) the new breed of prospector has also brought the new technology that is more lucrative but more damaging to the environment. Accompanied by seven black-and-white and color photographs, this is an interesting article on one lifestyle that is dying and another that is replacing it. *RT*

Lifetime Achievement Award, William Goldberg. D. Federman, *Modern Jeweler,* Vol. 89, No. 12, December 1990, pp. 35–44.

Modern Jeweler has awarded its seventh Lifetime Achievement Award to diamond dealer William Goldberg. His lifetime devotion to the American diamond trade is as well known as his strict cutting standards. David Federman chronicles Mr. Goldberg's rise from a failed diamond cutter to a giant in the diamond business. Also included are discussions of successes he has had with diamonds such as the Queen of Holland and the Premier Rose. Special attention is placed on his six-year term as president of the Diamond Dealers' Club (of which he is now treasurer) and his tireless resolve at trying to raise the New York diamond trade to the level of Antwerp and Tel Aviv. There is an interesting special segment focusing on William Goldberg's top diamond cutter, Herbert Lieberman, and his experience with a 255.61-ct rough diamond that later became the 89.01-ct Guinea Star. *CPS*

Nitrogen-defect aggregation characteristics of some Australasian diamonds: Time-temperature constraints on the source regions of pipe and alluvial diamonds. W. R. Taylor, A. L. Jaques, and M. Ridd, *American Mineralogist,* Vol. 75, No. 11/12 1990, pp. 1290–1310.

This 20-page article is an in-depth study of the conditions of formation of 50 diamonds from northwest (Argyle, Ellendale) and eastern (Copeton) Australia, as well as from Kalimantan, Borneo. Using Fourier transform infrared spectroscopy (FTIR), the authors determined total nitrogen concentrations and the amounts of A nitrogen aggregates (a pair of substitutional nitrogen atoms), B nitrogen aggregates (presumably four clustered nitrogen atoms), and platelets (an extended defect presumably of carbon atoms) in these stones. A aggregates turn into B aggregates plus platelets with time of residency in the earth's mantle (ranging from 0.4 to 1.6 billion years), increasing temperature (ranging from 1050° to 1300°C), and increased nitrogen concentration (which ranged from 10 to 1220 ppm for the stones in this study). The Argyle eclogitic diamonds, known to have a relatively short residence time in the mantle (0.4 billion years) and to have been submitted to an average temperature of 1255°C during that time, were used to refine the thermodynamic constants of the nitrogen aggregation reactions.

Ellendale diamonds, although geographically close to those from Argyle, were found to be significantly younger. Remarkably, some diamonds from Ellendale (northwest Australia) and Kalimantan seem to have a similar time-temperature history, which strongly suggests that those diamonds share a common origin and have been dispersed only by recent tectonic processes.

The authors conclude that a diamond population can be characterized by its nitrogen content, extent of aggregation of A aggregates, and extent of platelet degradation. In some favorable cases, such information may help determine the geographic origin of some diamonds. Since the method used is nondestructive, this process could potentially be extended to some faceted gem-quality diamonds. *EF*

Silicon carbide cluster entrapped in a diamond from Fuxian, China. I. S. Leung, *American Mineralogist,* Vol. 75, No. 9/10, 1990, pp. 1110–1119.

Silicon carbide occurs in both hexagonal (alpha-SiC) and cubic (beta-SiC) polymorphs. The hexagonal form (moissanite) is a rare accessory mineral in some kimberlites, while the cubic form (which has no accepted mineral name) has been reported from a sedimentary shale and a carbonaceous chondrite meteorite, but has never been fully characterized. An inclusion in a small

(1.3-mm in diameter) octahedral diamond crystal from the Fuxian diamond mine near Dalian, Liaoning Province, was found to contain SiC, and represents a well-documented occurrence of both SiC polymorphs. The inclusion contains four blue-green, hexagonal SiC crystals overgrown by younger, colorless grains of cubic SiC. This multicrystalline cluster is surrounded by a thin layer of K-Al-Si-rich glass that contains minute calcium carbonate and calcium sulfate crystals. The phases were all characterized by petrographic, SEM-EDX, and single-crystal X-ray diffraction techniques.

The inclusion is bounded by unusual curved surfaces, which suggests that the included minerals formed before they became entrapped in the growing diamond crystal. The presence of SiC polymorphs in natural diamond provides evidence that SiC may be an important carbon-bearing mineral in the earth's mantle. Estimates by other researchers indicate that the source of the Fuxian kimberlite in which the SiC inclusion may have crystallized may be deeper than 250 km and in a reducing geological environment. *JES*

GEM LOCALITIES

Colored pectolites, so-called "Larimar" from Sierra de Baoruco, Barahona province, southern Dominican Republic. K. Bente, R. Thum, and J. Wannemacher, *Neues Jahrbuch für Mineralogie Monatshefte,* No. 1, 1991, pp. 14–22.

White, greenish, light bluish, and blue pectolite from the Sierra de Baoruco have been studied in detail by a variety of instrumental analysis methods. Properties include $\alpha \sim 1.59$, $\gamma \sim 1.63$; $\underline{D}$ 2.84g/cm^3, H.$\leq$ 6. Chemical analyses and cell parameters are given for the four varieties. The pectolites form part of the alteration products in a picritic basalt of Upper Cretaceous age; it is believed that they formed at a temperature below 240°C. The greenish tints are related to color centers, while the blue color is probably due to vanadium.

R. A. Huddlestone

Gemstone prospects in Central Nigeria. J. Kanis and R. R. Harding, *Journal of Gemmology,* Vol. 22, No. 4, 1990, pp. 195–202.

The authors describe several gem localities in central Nigeria, from which a number of gem materials have begun to emerge over the past 10 years. Published material on the region, however, is limited, and this account is based to some extent on recent visits by the senior author, Mr. Kanis. Among the localities described is the Rafin Gabas Hills district in western Plateau State, from which greenish and yellowish gem-quality beryl and "blue to very deep blue" aquamarine have been produced over the last eight years. Topaz and quartz are also found, accompanied by a variety of accessory minerals. As mining exhausts surface deposits, the difficulty of hard-rock mining may make further exploitation impractical.

Not far away, near the town of Keffi, are tourmaline-bearing pegmatites, of which there are some 20 known. Although mining is sporadic, the potential for significant production exists. A wide variety of colors of gem-quality tourmaline have already been produced.

The Jemaa district in southwest Kaduna State has yielded sapphire for more than 20 years, but only since the development of heat treatment have the stones been of much commercial value. The sapphires are basalt related, with deposits similar to those of Australia, Thailand, and Kampuchea. The same deposits also contain deep red to orange and near-colorless gem-quality zircon.

The authors describe the regional and local geology for each of these deposits, including accessory minerals. Complete chemical analyses for four zircon samples (inductively coupled plasma emission spectroscopy and neutron activation analysis) are provided. Locality photographs also accompany the text. *CMS*

INSTRUMENTS AND TECHNIQUES

Bead buyers and parcel pickers filter set. R. K. Mitchell, *Journal of Gemmology,* Vol. 22, No. 4, 1990, pp. 212–214.

Mr. Mitchell describes and evaluates a set of four filters marketed by Hanneman Gemological Instruments for parcels of stones or strings of beads to see if they contain a single kind of gem material. In general, the author found that the filters were to some extent useful but, as with all such filters, considerable care must be exercised, especially if the stones or beads are different colors within the same gem species. They cannot be relied on to provide evidence in every case. *CMS*

Gemmological visual aids. J. Eadie, *Journal of Gemmology,* Vol. 22, No. 4, 1990, pp. 207–209.

The author describes visual aids for teaching crystallography to gemologists. These include models for demonstrating axes of symmetry, twinning, and light vibration and polarization. Both students and teachers of gemology will appreciate such three-dimensional aids. Six photographs illustrate the three models described. *CMS*

"Letter to the Editor" from Dr. H. A. Hänni, *Journal of Gemmology,* Vol. 22, No. 4, 1990, pp. 250–251.

Dr. Hänni's letter is in response to readers' requests that he provide absorption spectra to illustrate points made in his 1990 *Journal of Gemmology* article on Kashmir sapphires. Accordingly, he provides representative polarized spectra for Kashmir, Ceylon, Burma, and Pailin sapphires over the range of 300 to 500 nm. *CMS*

Reappraisal of infrared spectroscopy of beryl. C. Aurisicchio, O. Grubessi, and P. Zecchini, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 421–423.

The present study involves a detailed investigation of the infrared spectra of beryls, which have a complex crystal chemistry. Main substitutions involve divalent and trivalent ions for Al in the octahedral site, and Li ions for Be in the tetrahedral site. Both substitutions require the entry of alkali (Na,K,Cs,Rb) ions along the "channels" in the crystal structure, which are made up of six-membered rings of Si tetrahedra. Water molecules may be present at several positions along these same channels. The effects of these substitutions on the unit-cell dimensions allows for the definition of three beryl series according to the ratio of (c/a) unit-cell dimensions. These three series are the "octahedral," "tetrahedral," and "normal" beryls. Absorption bands in the 3800–3400 and 1200–500 wavenumber regions are correlated with these three beryl series. Assignments are suggested for absorption bands based on the observed substitutions. Only more research will determine whether this three-beryl series will have direct gemological significance. *JES*

Water in beryl—a contribution to the separability of natural and synthetic emeralds by infrared spectroscopy. K. Schmetzer and L. Kiefert, *Journal of Gemmology,* Vol. 22, No. 4, 1990, pp. 215–223.

Infrared spectra obtained from 75 samples of natural emerald and 28 samples of synthetic emerald (flux and hydrothermal) were obtained and studied by the authors with the intent of finding additional criteria to distinguish between natural and synthetic material. Features in the range of 3500 to 3800 cm^{-1} associated with H_2O and OH in beryl were found to be useful in making this distinction in all cases studied. With spectra grouped into five types, four could be used to make a positive identification. One spectral type, however, appeared in both natural and synthetic low-alkali emeralds, including natural emeralds from Nigeria and Colombia and hydrothermally grown synthetic emeralds from Lechleitner and Russia.

The authors discuss the advantages of KBr pellets, for which powder is scraped from emerald samples, to obtain infrared spectra. However, a minimum of 0.5 mg of powder is required, making this method less than ideal for gemological purposes. It should be used only when all other nondestructive methods fail and only with the permission of the owner. Spectral graphs accompany the text, as does a useful table of significant spectral features correlated with locality and compositional information for the samples studied. *CMS*

JEWELRY MANUFACTURING ARTS

'All that glitters': Part IV. E. Weber, *Jewelers' Circular-Keystone,* Vol. 162, No. 2, February 1991, pp. 142–145.

Each segment of this continuing series focuses on a specific aspect of antique jewelry, giving clues to identification by analyzing specific examples. The topic for this installment is commemorative and historic antique jewelry.

Images or emblems of royalty are frequently found in antique jewelry. The likenesses are usually carved cameos or painted miniatures, mounted in gold as brooches, pendants, bracelets, or rings. Often the borders are further embellished with engraving, enameling, or gems. Many of these were presented as royal gifts for special service or allegiance, or to commemorate an historic event. Mourning jewelry also can have historic significance if it relates to royalty or famous persons.

Dates and/or inscriptions are almost always present, and many times the jewel will be placed in a special presentation box. Both of these factors provide positive clues to pinpoint time of manufacture.

The examples discussed here were drawn from the 18th through the 20th centuries and include such widely different personalities as Louis XVI, Queen Victoria, and D. H. Lawrence. Including the cover insert, 11 color photos illustrate the text. Although figure 2 has been printed upside-down, it does not detract from this otherwise intriguing article. *EBM*

Chatelaines. R. Krieger, *Vintage Fashions,* Vol. 2, No. 2, 1991, pp. 14–19.

The author of this interesting article briefly describes the evolution of the chatelaine from nothing more than a bunch of keys up to its present-day manifestation as the purse. Originally, the chatelaine (a French word meaning "mistress of the castle") was a clasp from which useful household items such as keys, seals, scissors, and the like were suspended on short chains. Chatelaines first came into use in the Middle Ages, but they gained status as jewelry during the 18th and 19th centuries when they were worn by both men and women as ornamental pieces from which charms or watches might be hung. This article describes different styles of chatelaines and the various objects that might be attached to them. For example, elaborately engraved or enameled watches were frequently suspended from the center chain, which would be engraved or enameled to match. The text is illustrated with 12 photos, all but two of which are black and white. Unfortunately, most are out of focus, but, nevertheless, they pique one's interest. *EBM*

Copyrights: When someone's got designs on your designs. D. Bottorff, *American Jewelry Manufacturer,* Vol. 38, No. 11, November 1990, pp. 63–65.

In one of the better articles on design copyright, Bottorff provides important information. She notes three significant changes in the copyright law: (1) U.S. citizens can enforce the copyright of their design in foreign countries; (2) within the U.S., it is no longer required that designers stamp or affix the copyright symbol to their work; and (3) transfer of ownership of copyright from a designer to the manufacturer must be done in writing—a manufacturer does not automatically obtain the copyright by purchasing the design. Bottorff provides a succinct process for copyrighting a design via the U.S. Register of Copyrights, Washington, DC, 20599. She also briefly mentions the American Jewelry Design Council, an organization of designers who hold the concept that as soon as jewelry is seen as an art form, designers will be more motivated to protect their work. *RT*

Favourite snuff bottles: The George and Mary Bloch Collection. G. Bloch and M. Bloch, *Arts of Asia,* Vol. 20, No. 5, 1990, pp. 90–98.

Mary and George Bloch began collecting snuff bottles in 1983 after a chance meeting with Sotheby's snuff bottle expert provided the catalyst for this new venture. In this article, the Blochs discuss 43 of their pieces, all of which are illustrated with color photographs of the front and back views. Of particular interest are those snuff bottles made from organic materials: a series of intricate ivories from the 18th century; a luminous red amber bottle; and several made of bamboo, hornbill, gourd, and tangerine skin. In virtually all cases, these are carved with intricate, significant symbols.

The Bloch collection also contains many more traditional materials, such as chalcedonies, whose variable inclusions and coloring provide the source of the design, and jadeite and turquoise. By observing the dates assigned to various bottles, one can document the use of specific gem materials.

The Blochs have put together a collection in which each acquisition becomes an opportunity to learn more about the pieces one already possesses. It is fortunate that in a time when many collectors are very secretive about their collections, the Blochs are willing to share their expertise in such detail.

Lisa S. Routledge

Glass beads of China. P. Francis, Jr., *Arts of Asia,* Vol. 20, No. 5, 1990, pp. 118–127.

As any gemologist knows, glass has long been used to imitate natural stones: The earliest documented use of glass in China was to imitate green and white nephrite. But much like the early synthetic gems, glass was considered a rarity in China and was highly prized for its own unique qualities.

The use of glass soon moved beyond that of jade simulant, and its manufacture reached a peak with the spectacular "Eye" beads in the late Chou period (481–221 B.C.). China's importance as a beadmaker has only recently been noted, as researchers struggle to make sense of the evidence of 3,000 years of production and trade of glass beads. Francis, an expert on the history and development of beads, reviews the evidence for glass beads from China, drawing on collections outside China as well as on translations of Chinese literature. What results is a remarkable overview of the topic, which provides a framework for future work.

Lisa S. Routledge

Traditional body ornaments from the Naga Hills. A. Herle, *Arts of Asia,* Vol. 20, No. 2, 1990, pp. 154–166.

The remote hills of Northern India near Tibet and Burma (Myanmar) are home to the Naga tribes, once head hunters, an agricultural people who have remained separate from their Hindu neighbors. Body ornaments of ivory, brass, and many organic materials such as conch shell and hornbill ivory express personal status, clan membership, and prowess at war.

Festivals held to celebrate the planting and harvesting of crops, and the fertility-related taking of heads, were occasions for displaying a multitude of ornaments. Not just a gorgeous display of personal status, it was believed that this self-adornment would win the favor of the crop spirits and ensure a good harvest. The author concludes by noting that a significant collection of historic documents and pictures of artifacts from Nagaland exists at Cambridge University and is accessible by an interactive video-disc. Thirty-two photographs illustrate the article. *Lisa S. Routledge*

SYNTHETICS AND SIMULANTS

Detection of synthetic emeralds by thermal conductance. P. G. Read, *Journal of Gemmology,* Vol. 22, No. 4, 1990, pp. 233–234.

The author discusses the usefulness of thermal conductance testers in the separation of synthetic from natural emeralds. Tests were done with an Alpha-test meter, which provides a digital readout of conductance values. Five readings per sample were obtained and averaged for a variety of natural and synthetic emeralds. While not exhaustive, the report indicates that, in most instances, readings from synthetic emeralds are significantly lower than those from most (but not all) natural emeralds. *CMS*

Optical absorption spectra of synthetic tourmalines. M. N. Taran and A. S. Lebedev, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 457–458.

Tourmalines synthesized in hydrothermal solutions were doped with various transition metal ions (Fe, Ti, Cr, Ni, Cu, Co, and Mn). Optical absorption spectra in the range 400–1000 nm are presented for these synthetic tourmalines. Absorption bands recorded are assigned here to various causes. It is interesting to note that the spectrum of the Cu-doped synthetic tourmaline exhibits the same absorption features as have been reported for the copper-containing blue tourmalines from Paraíba, Brazil. *JES*

Thermal diffusivity of isotopically enriched ^{12}C diamond. T. R. Anthony, W. F. Banholzer, J. F. Fleischer, Lanhua Wei, P. K. Kuo, R. L. Thomas, and R. W. Pryor, *Physical Review B*, Vol. 42, No. 2, 1990, pp. 1104–1111.

General Electric recently grew colorless gem-quality synthetic diamonds. These type IIa synthetic diamonds have a reduced concentration of ^{13}C in order to achieve a superior thermal conductivity. To produce such high-purity material, a synthetic diamond thin film was first grown by chemical vapor deposition from a gas enriched in ^{12}C. The resulting film was then powdered and used as a carbon source in a classic high-pressure diamond synthesis process to grow two crystals (0.92 and 0.95 ct), each containing 99.9% ^{12}C (as compared to 98.96% ^{12}C and 1.04% ^{13}C in natural diamond). According to the authors, these crystals would be an E color on the GIA diamond-grading scale. Their thermal conductivity is 50% higher than that of natural type IIa diamonds.

Although the purpose of this material is purely industrial (increase in thermal conductivity to facilitate miniaturization of integrated circuits), this new type of synthetic diamond could surface on the gem market. *EF*

TREATMENTS

A jeweler's guide to emerald oiling. T. Themelis and D. Federman, *Modern Jeweler*, Vol. 89, No. 5, May 1990, pp. 65–69.

Mr. Themelis of Gemlab Inc. (a firm that offers an emerald oiling service) and Mr. Federman discuss the many aspects of emerald oiling, including the many types of oils, epoxy resins, dyes, plasticizers, and hardeners used today, as well as inherent problems that occur with certain types of fillers. They cover the cleaning of a previously treated stone (which sometimes must be done repeatedly to ensure that all of the old filling is gone) and describe in detail Themelis's four-step treatment process. Several helpful care and handling tips are given, and a proper disclosure section is also added to assist jewelers who deal with emeralds and many other gems treated in this fashion. Unfortunately, the section on detection is too limited and the photographs are not as helpful as they could have been, but the information on the different filling materials and filling processes is very good. The article also contains several before-and-after photographs of treated emeralds. *CPS*

MISCELLANEOUS

The Hillman Hall of Minerals & Gems, The Carnegie Museum of Natural History. R. A. Souza, W. E. Wilson, R. J. Gangewere, J. S. White, and J. E. King, *Mineralogical Record*, Vol. 21, No. 5, 1990, pp. 1–32.

This is an excellent, detailed review of the founding and history of the Carnegie Museum in Pittsburgh and the genesis of the Hillman Hall of Minerals and Gems. This article and its 52 accompanying photographs (primarily by Harold and Erica Van Pelt) is so comprehensive that it has also been bound for sale as a separate volume.

Gangewere and Souza recount the early acquisitions of the mineral and gem collection, and describe the succession of curators who helped develop the Division of Mineralogy. A trustee of the museum, Henry L. Hillman, established the Hillman Foundation to support a new mineral exhibit designed to present "minerals in a manner of sculpture and shown for their beauty as well as physical properties and economic uses." The Hillman Hall opened to the public in 1980, culminating 11 years of specimen acquisition, planning, and construction.

After the detailed history, Souza describes the hall itself. Following the natural flow of the floorplan, the reader is led from one specialized display to another, concluding like a grand finale in the Masterpiece Gallery. The Van Pelt photographs illustrate the "Highlights of the Collection" and are accompanied by detailed descriptions of the specific specimens shown. *LBL*

The Pre-Columbian civilizations of Peru. M. Jaquet, *Aurum*, No. 36, Winter 1989, pp. 62–69.

This article highlights the major societies that existed in Peru before the Spanish conquest, the evolution of their gold-working technology over 3,000 years, and their contributions to what we think of as Pre-Columbian art.

The Chavin people (1200–200 B.C.) worked gold by hammering nuggets into sheets and then embossing the pure metal. The Nazca society (200 B.C. to 700 A.D.) is famous for their gigantic animal silhouettes visible from the air. Although they discovered gold casting, they continued to hammer out thin medallions and heads. The Mochicas (200 B.C. to 700 A.D.) existed at the same time as the Nazca, but lived in northern Peru while the Nazca spread through the southern desert. Their jewels were the most inventive of the era, with breast pendants and ear jewelry of hammered and welded gold.

The Chimú empire (1000–1450 A.D.) was an extension of the Mochicas. They excelled at gold craftsmanship and used techniques such as welding, plating, alloying, filigree, and lost wax to create incomparable works that have been recovered from tombs. The Incas (1200–1532 A.D.) considered gold "the Sweat of the Sun." The artisans, many from the conquered Chimú, used gold to cover temple walls and decorate gardens. Unfortunately, most works were melted down by the Spanish conquerors.

Sixteen beautiful photographs show intricate details of the workmanship and use of gemstones such as lapis lazuli, chrysolite, pearls, emeralds, and turquoise. The author concludes this fascinating article with a discussion of various treatments and techniques that the ancient Peruvians had mastered in their use of gold. *Peter Solomon*

THANK YOU!

The Gemological Institute of America extends its sincerest appreciation to all of the people and firms who contributed to the activities of the Institute through donations of gemstones and other gemological materials. We are pleased to acknowledge many of you below.

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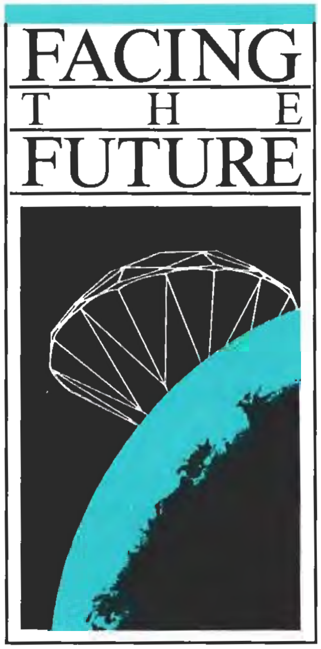

1991
INTERNATIONAL GEMOLOGICAL SYMPOSIUM

PROGRAM ABSTRACTS, PANELS, AND POSTER SESSION PRESENTATIONS

INTERNATIONAL GEMOLOGICAL SYMPOSIUM

Program Abstracts, Panels, and Poster Session Presentations

The International Gemological Symposium, which takes place in Los Angeles June 20–24, 1991, will be a unique combination of academic and social events. It is being hosted by the Gemological Institute of America in conjunction with the Conclave of the American Gem Society. No less than four types of program activity have been designed to enrich the experience—each with its own imprint on the total event. Drawing from among the most talented gemologists, jewelers, manufacturers, retailers, and suppliers the world over, Symposium is a once-in-a-lifetime happening.

There will be two General Sessions—the opening and closing ceremonies—featuring addresses by internationally recognized authorities. In a special videotaped presentation, Nicholas Oppenheimer, Chairman of the Board of the Central Selling Organisation, will give a special welcome message and tribute to the future of the diamond industry. The keynote speech, delivered by noted author and social forecaster, John Naisbitt, will set the tone for the Symposium theme: FACING THE FUTURE. The closing ceremony will feature Gerald Rothschild, former managing director of I. Hennig & Co. diamond brokers. The capstone will be delivered by Maurice Tempelsman, distinguished international diamond industry leader and financier. GIA President William Boyajian will deliver the valedictory remarks.

Bounded by these exciting features we find the true heart of Symposium—the Presentations, Panel Discussions, and Poster Session. Individual Presentations will be made by scores of speakers who will focus their expertise in diamonds, colored stones, pearls, jewelry, economics, precious metals, marketing, and related specialties. In Panel Discussions, key figures will dialogue on the most important, sometimes controversial, issues facing the industry today in gem identification, quality analysis, evaluation, and appraisals, among other topics. The Poster Session is a noncommercial marketplace of exhibits where everyone can interact with authors presenting the very latest research findings and technological advances in gemology, gem identification, and sources, as well as jewelry fashion, design, marketing, and manufacturing. What follows are the abstracts of feature Presentations, a description of the Panels and the prominent individuals who will be participating, and topics and authors for the dozens of displays in the Poster Session. There has never been an event like this in the history of gems and gemology.

D. Vincent Manson
Chairperson, International Gemological Symposium

ABSTRACTS OF FEATURE PRESENTATIONS

At the core of Symposium are the 72 presentations that will be given in four concurrent series of sessions Friday and Saturday, June 21 and 22. These sessions cover the critical areas in the gem and jewelry industry: Diamonds, Colored Stones, Economics and Marketing, and Jewelry. The abstracts of these presentations are provided here grouped in these four main categories. An alphabetical index to the individual speakers appears on the last page of this program.

DIAMONDS

SYNTHETICS AND TREATMENTS □

Emmanuel Fritsch, *GIA*

Synthetic Diamond Thin Films: The Potential Impact on the Gem Trade

The production of thin films of synthetic diamond or "diamond-like" carbon at low pressure is a new technology that has significant potential applications in the gem and jewelry industry. This presentation will briefly discuss the most prominent processes currently in use and will emphasize the types of products resulting from this technology that may have an impact on the gem trade. Included will be current means of identification. Also offered will be a realistic perspective on what can be expected from this new technology in coming years.

Zvi Yehuda, *Diamond Research Laboratory, Israel*

Fracture Filling of Diamonds

For many years, the diamond trade had sought an enhancement to improve the appearance of low-clarity diamonds. In 1983, Zvi Yehuda developed a process of filling surface-reaching separations in polished diamonds with a material that makes the separations less apparent. This treatment withstands normal wear and cleaning, and there is no noticeable weight gain. The treatment can usually be detected by the presence of interference colors (often blue and orange) when the filled break is viewed down its length. Recently, Mr. Yehuda has made available a related enhancement for emeralds.

Alan T. Collins, *King's College London*

The Artificial Coloration of Diamond by Radiation Damage

Modern technology has made treated diamonds more attractive, more abundant, and less costly. Consequently, jewelers today are more likely to encounter colored diamonds than their colleagues of a generation ago. Distinguishing between "natural" color and irradiated stones is now a critical issue. This presentation will discuss the origin of color in diamonds as well as artificial coloration by radiation damage and thermal annealing. In many cases, this treatment can be detected by absorption spectroscopy. The optical absorption spectra of natural-color and laboratory-irradiated diamonds will be compared, and research in the area discussed.

James E. Shigley, *GIA*

Gemological Properties of Gem-Quality Synthetic Diamonds Grown by High-Pressure Methods

The past decade has seen rapid advances in the technology of diamond synthesis, including the introduction of gem-quality synthetic diamond to the marketplace for industrial purposes. Diamond growth in the laboratory takes place under very different conditions from those present deep in the earth. As a result, synthetic diamonds have distinctive gemological properties by which they can be identified. This presentation will review the gemological properties of high-pressure synthetic diamond, with emphasis on those key features that can be used to distinguish them from natural diamonds of similar color and quality. Past technical advances will be reviewed briefly, and some thoughts presented on possible future developments that may influence the jewelry industry.

DIAMOND MARKET PERSPECTIVES ☐

Eli Izhakoff, *Diamond Dealers Club, New York*

An Overview of the Diamond Market

The world diamond markets are tightly interwoven. This presentation provides a global picture of the diamond industry, with a focus on supply and demand. The world's supply of rough will be discussed, with emphasis on changes in output at various mines, the impact of Australia's production, the role of the "open market" and the CSO, and the USSR as a major producer. Future trends in world demand include expanded markets in the Far East, changes in the U.S. and Western European markets, and the potential for new markets in Eastern Europe.

S. N. Sharma, *Hindustan Diamond Co., India*

India's Role in the World Diamond Market

India has been involved in diamonds since ancient times. After a brief period of dormancy, it revived as a major cutting and polishing center for diamonds in the 1960s. It now supplies over 70% of the world's requirement of finished diamonds, or approximately 11 million carats annually. The diamond industry in India is highly labor intensive and export oriented. A dominant feature is private entrepreneurship, characterized by internal trading in rough and polished diamonds. Given the large work force and the competitive pricing of the product, India will continue to be strongly linked to the future of the world diamond market.

Sylvain Zucker, *International Diamond Council*

Antwerp and the European Economic Community

The 6,000 cutters in Antwerp operate in conjunction with key organizations such as the Hoge Raad voor Diamant (HRD—Diamond High Council), the Diamantclub van Antwerpen, and the Belgian Federation of Diamond Bourses, affiliated with the World Federation of Diamond Bourses (WFDB). The historical development of Antwerp as the world's most prominent diamond center is discussed, as are the larger, high-quality stones and the more difficult shapes that have long been Antwerp's mark of distinction. The presentation will include production and distribution figures, as well as the opportunities and challenges presented by the European Economic Community.

Attention will also be paid to the current and future role played by the International Diamond Council (IDC), a committee created by the WFDB and the International Diamond Manufacturers Association to establish universally accepted norms for the grading of polished diamonds.

Moshe Schnitzer, *Israel Diamond Exchange*

The Diamond Industry in Israel

The history of the Israeli diamond industry is intertwined with that of the creation of the state of Israel. Almost half a century ago, Israel pioneered new manufacturing methods, thus facilitating greater efficiency in cutting while shortening the traditionally long period of apprenticeship. Recently, Israel has also stepped up research and development in automation, and it is now one of the biggest users of automatic polishing and laser cleaving. Today, diamonds constitute about one-third of Israel's total industrial exports. The establishment of joint ventures and financial self-sufficiency, as well as continued expansion in automation, are all challenges to be met by the Israeli diamond industry in the years ahead.

Hertz Hasenfeld, *Hasenfeld & Stein, New York*

New York's Role in the International Diamond Market

In the context of the rich and diverse history of the New York diamond market, this presentation identifies the unique and specialized roles of the New York diamond manufacturer, importer, dealer, and broker—the key players on the supply side. It discusses New York's manufacturing specialities—larger well-cut stones, mostly sold with GIA reports, as well as the myriad of goods offered by its network of dealers. Attention will be given to the manufacturing, dealing, and financial strengths of the New York market and what it offers to its customers. The presentation will also review the international markets served, and how cutting is adapted to accommodate each area, along with a glimpse into future trends of this strong and vital center of diamond activity.

DIAMOND SOURCES ☐

Al Levinson, *University of Calgary, Canada*

Geographic Origins of World Diamond Sources Now and in the Future

Historically, first India and then Brazil were the main sources of diamonds. South Africa emerged as the leading producer following discovery of diamonds there in the 1870s. Today, five countries—South Africa, Zaire, the USSR, Botswana, and Australia—each contribute about 10% of the world's supply of diamonds; the latter three sources were only discovered within the last 30 years. Four countries produce approximately 1%–2%, and about a dozen supply minor amounts.

This presentation will report on the relative amounts of gem and industrial diamonds produced at the various sources today, distinguishing between primary (pipe) and secondary (alluvial) deposits. Emphasis will be placed on the geologic constraints that determine where diamonds are found, and predictions will be made regarding possible locations of new major producing areas.

A. J. A. Janse, *Mintel Pty., Australia*

Diamond Sources in Africa

For more than a century, Africa has been a world leader in diamond production. Within Africa, however, there are great differences from one deposit to the next in terms of geology of the occurrence, mining and recovery, methods used, and even types of diamond produced. The indicators for continued production in Africa, both off-shore and in kimberlite, are promising. This presentation reviews the history of diamond mining in Africa, and examines the geologic and economic factors that will determine the future of the gem on this continent.

Arnold S. Marfunin, *IGEM Academy of Sciences, USSR*

Diamond Sources: Russia

Following the 1954 discovery of the Yakutian Diamondiferous Province in Central Siberia, the USSR emerged as a major diamond-producing nation. Since then, there have been ongoing efforts to locate new deposits, optimize production, and foster industries based on national diamond resources; however, Yakutia remains the economic core of diamond production in Russia. This session reviews the geology and geography of the Siberian deposits, outlines Soviet exploration, production, and trading method and highlights the use of Russian diamonds in science and technology, as well as in jewelry. It also reports progress in the development of potentially significant diamond deposits in the Arkhangel'sk region in the European north of the USSR.

Robert E. Kane, *GIA Gem Trade Laboratory*

Diamond Sources in Australia

Extensive exploration by several mining companies resulted in the discovery of diamonds in the Kimberley region of Western Australia, the Ellendale deposit in 1976 and then the spectacular Argyle AK-1 pipe in 1979. The Argyle mine became fully operational in 1985, and by the end of the following year was the world's leading producer of diamonds in terms of total rough production. This slide presentation will briefly review the occurrence of diamonds in lamproites in Australia and then discuss in detail mining and recovery at the AK-1 pipe and associated alluvial deposits. The nature of the diamonds produced, including Argyle's spectacular pinks, and the marketing of the Australian diamonds will also be examined.

DIAMOND CHARACTERIZATION ☐

Basil Watermeyer, *Johannesburg, South Africa*

Optimizing Diamond Weight Recovery through Faceting Design

Many considerations need to be invoked in producing a faceted diamond from a piece of rough. Addressed here are, specifically, the influence of rough shape and cut design with regard to maximizing both yield and appearance. Traditionally, rough diamonds have been processed as round brilliants with a small percentage being fashioned into fancy cuts. However, using brilliant-cut faceting designs appropriate to the shape of the rough will result in a much greater number of stones being converted into fancies with significantly increased weight retention and no loss of brilliance. The economic merits of using these designs are discussed together with marketing techniques to promote them.

Edward Schwartz, *GIA Gem Trade Laboratory*

Clarity Grading of Diamonds

The GIA diamond-grading system has gained in recognition and use throughout the international jewelry community since its introduction to the trade in the early 1950s. Now, a full generation within the industry has been educated, either formally or by association, in the use of GIA clarity-grading terminology. This presentation will highlight the importance of maintaining alignment on grading concepts within the trade through the next decade and beyond. The participant will learn how GIA's Gem Trade Laboratory applies the grading system to larger sizes and fancy cuts, about eye visibility and its relation to clarity grades, and about the nature of some of diamond's more unusual clarity characteristics such as graining.

D. Vincent Manson, *GIA*

Proportion Considerations in Round Brilliants

A brief historical review of the role of proportions in the design of a round brilliant-cut diamond looks at early faceting procedures and the relative importance of brilliance, fire, and sparkle. Special attention is given to the insights provided by Tolkowsky's analysis in the 1920s. Since that time, few new ideas have been presented; yet there has been increasing emphasis on the role of proportions in quality analysis. Today, there is wide acceptance of a narrow range for table diameter, crown angle, and pavilion depth for round brilliants, considered in conjunction with symmetry and polish.

Recent research has shown, however, that the application of modern light theory together with three-dimensional ray tracing to produce photo-realistic images promises to provide new insights and understanding. The results of such innovative techniques are presented and some of the implications discussed. Other factors that could be analyzed include special shapes and the influence of color.

James Lucey, *GIA*

The Basics of GIA's Color Nomenclature

The human eye recognizes millions of color sensations; yet attempts to describe them often seem vague and inarticulate. In the world of gemstones, lack of adequate color communication skill is a serious hindrance, since appreciation of beauty and accurate quality description depend so much on color. This informative presentation will show how to break down all color perceptions into three components—hue, tone, and saturation—and how to quantify each one individually. It will describe the shorthand method of color description and its application in the jewelry industry. Understanding the basics of GIA's color nomenclature will also help the jeweler-gemologist understand recent developments in the market for fancy-color diamonds.

John King, *GIA Gem Trade Laboratory*

Grading Fancy-Color Diamonds

Fancy-color diamonds have fascinated mankind over the centuries. Now, more than ever, this fascination has resulted in a growing market for these unique stones. Essential to this market is a grading system capable of accurately describing color. In this presentation, the complexities of color grading fancy-color diamonds—and, in particular, developments at GIA's Gem Trade Laboratory for color determinations—will be addressed.

COLORED STONES

COLORED STONE SOURCES ☐

Eckehard J. Petsch, *International Colored Gemstone Association*

Overview of Colored Stone Sources

Colored stones come from virtually every part of the world, and new sources are continually being found and developed. Some of the most important gem-producing regions—Brazil, Sri Lanka, Africa—always seem to surprise us with new and different gem materials. The flow of these stones to the marketplace is altering as new cutting and trading centers—in Bangkok, Seoul, Taipei, and the industrial free zone in China near Hong Kong—are emerging. Trade organizations now play a critical role in promoting colored stones, and will undoubtedly grow in importance in the future.

Vladimir S. Balitsky, *USSR Academy of Sciences*

Gemstone Occurrences in the USSR

The historic deposits of various gems in the USSR include areas of middle Asia, Kazakhstan, the Urals, Siberia, the

Kola Peninsula, and the Far East. The systematic study of those occurrences, however, has only been undertaken during the last 30 to 40 years. At present, over 100 deposits of gem materials such as emerald, scapolite, amethyst, demantoid garnet, jadeite, spinel, amber, tourmaline, agate, nephrite, rhodonite, and onyx are being explored. Dr. Balitsky will review the geology of some of these deposits and describe the various gems they produce.

Ron Ringsrud, *Constellation Colombian Emeralds, Los Angeles*

Emeralds and Other Gems from Colombia

For over 400 years, Colombia's mines have been supplying the world with emeralds. Although Muzo is the largest producer, Cosquez, Chivor, Gachalá, and Peñas Blancas also contribute to Colombia's output. Strip mining with bulldozers is still the main mining method, although economic and environmental factors are bringing tunneling into greater use. Increased world demand for emeralds has tripled the price per carat over the last 10 years. Also during this time, marketing and distribution processes and channels in Colombia showed their weakness and inability to respond to this surge in demand. In the past two years, however, emerging organizations and market structures in Bogotá have foreshadowed a new vitality and maturity for the 1990s. In addition, increased exploration throughout Colombia, much of it based on international scientific cooperation, shows promise of other gem materials, notably sapphires, and new sources of emerald in the future.

Henry Ho, *World Jewels Trade Center, Bangkok*

The Gem Riches of Southeast Asia

Southeast Asia has long been a significant producer of high-quality sapphires, rubies, spinels, and other colored gems. Today, fine gems are emerging from Cambodia and Vietnam as well as from both historic and new mining operations in Burma, Sri Lanka, and Thailand. This presentation gives a brief historic review and then describes current locations and exploration and mining techniques. It also reviews the quality and quantity of gems being produced and sold on today's market, and, especially, the increasingly important role of Thailand as a major processing and distribution center.

Daniel Sauer, *Amsterdam Sauer, Brazil*

Brazil: An Everlasting Source of Gemstones

Sometime in the future, we will see fine amethyst selling for hundreds of dollars a carat and beautiful agates set in 18K gold. These many years hence, Brazil will still be a major—if not the major—producer of fine gem materials due to its unique combination of gem resources and a socio-political system that promotes prospecting and mining.

The Upper Precambrian Atlantic Pegmatite Province, which covers five states (including Minas Gerais), together with the Mesozoic basalts of the Paraná basin, which covers large portions of southern Brazil, will supply the market with fine gems for years to come. These include economic quantities of emerald, aquamarine, tourmaline, topaz, alexandrite, chrysoberyl, and opal, as well as large quantities of amethyst, citrine, heliodor, almandite, and chalcedony. In fact, the relatively new alexandrites from Hematita and the unusual new tourmalines from Paraíba represent entirely new "gem belts."

Key to the successful development of these supplies is the *garimpeiro*, the independent miner of Brazil who must constantly feed his obsession with striking it rich. As long as the government continues to recognize the importance of this activity and the miners receive the strong support of gem dealers and jewelers, new occurrences will be found and old ones expanded.

Campbell R. Bridges, *Bridges Exploration Ltd., Kenya*

Colored Stone Occurrences in Africa

The African continent contains numerous deposits of traditional gem materials such as emerald, ruby, sapphire, turquoise, spinel, and the like; it is the unique source of recently discovered vibrant gems such as tanzanite and tsavorite. Other commercial gems include aquamarine, iolite, chrome tourmaline, peridot, rhodolite, and pink and orange garnets. Africa has also produced a host of collectors' stones. This presentation will give reasons for the abundance of gem deposits in Africa, a historical perspective, specific geology of major occurrences, mining methods, and salient gemological characteristics and properties. Future likely trends will also be explored in terms of production and marketability.

Grahame Brown, *Allgem Services, Australia*

Australian Colored Gemstones

The production and export of Australian colored gemstones has been dominated by three gem species: opal, sapphire, and chrysoprase. Australia's potential for colored gems is considerable. Economically important deposits of gem-quality nephrite, amethyst, emerald, turquoise, zircon, garnet, topaz, and feldspars occur in remote, inhospitable regions within the states of South Australia, Western Australia, and the Northern Territory. This presentation will review and illustrate the occurrence, location, historical production, and current yield of Australia's colored gem resources. In addition, the significant gemological features of colored stones from these various deposits will be presented.

William Larson, *Pala International, California*

Gemstones of North America

Over the years, North America has produced a number of gem materials, including diamond, sapphire, red beryl, amethyst, peridot, turquoise, and tourmaline. Today, the most economic gem deposits are the pegmatites of San Diego County, California. In operation since the late 19th century, mines in this area continue to produce thousands of carats of tourmaline annually. This presentation will review the major gem minerals mined in North America with special attention given to the pegmatite gems of San Diego County. Exploration continues throughout the U.S. and Canada, with prospects for significant future production in San Diego County; Sawtooth, Idaho; the turquoise districts of Arizona, Nevada, and New Mexico; the Mount Mica tourmaline area of Maine; the red beryl deposits in the Wah Wah Mountains of Utah; and the peridot deposits in Arizona.

Peter C. Keller, *Bowers Museum, California*

Future Colored Stone Sources

Historically, countries such as Colombia, Burma, South Africa, and Sri Lanka have dominated the world's supply of fine gems. As economic and political conditions change in these and other third-world nations, the dependable flow of fine gems may dwindle and other sources may be identified. This presentation examines such potentially important sources as Vietnam, East Africa, Pakistan, the USSR, Afghanistan, and China.

GEM IDENTIFICATION ☐

Kenneth Scarratt, *Gemmological Association of Great Britain*

New Developments in Gem Identification

Laboratories engaged in commercial gemstone identification have been faced with a great number of challenges, particularly over the past 20 years. New synthetics and treatments of gemstones, new mines, new gem materials, and even changing nomenclature have transformed gem-testing facilities from basic microscope and simple instrument establishments to laboratories packed with sophisticated equipment. This presentation will address both the basic and advanced techniques employed in dealing with present-day identification problems, as well as prospects for new developments in gem identification.

John I. Koivula, *GIA*

Inclusions: A Vital Means of Gem Identification

Gemologists deal on a daily basis with the identification of a variety of materials. It is fortuitous that the vast majority of these gems contain light-microscope resolvable inclusions. Inclusions are still the primary means of separating natural from synthetic, and treated from untreated, gems. This presentation discusses the strengths and weaknesses of using inclusions in gem identification, and speculates on their importance in the future of gemology.

Alan Jobbins, *Journal of Gemmology, United Kingdom*

Jade and Its Identification

The history of the use of jade and its recognition in 1863 by Damour as two distinct minerals, nephrite and jadeite, will be briefly outlined. Detailed discussion will include the identification of these materials using such routine gemological methods as magnification and heavy liquids. The use of laboratory equipment such as X-ray diffraction and U.V. radiation to identify species as well as simulants and various treatments will also be discussed. Possible future applications of sophisticated technology to separations and treatment detection will be covered as well.

C. W. Fryer, *GIA Gem Trade Laboratory*

Pearl Identification

Of key concern in the pearl industry is not only the separation of imitation, cultured, and natural pearls, but also the identification of color enhancements. This presentation will briefly discuss visual methods of separating natural from cultured pearls, as well as the use of X-radiography and X-ray fluorescence, currently the only nondestructive means of positive identification. The different treatments and their detection will also be covered. The application of new technology to pearl identification in the future will be explored.

PEARLS

Shigeru Akamatsu, *K. Mikimoto & Co., Japan*

Pearl Research

To understand and possibly improve the color of cultured pearls, pearl pigment secreted in the nacre layer and its appearance mechanism have been investigated by chemical, biological, and culture-technological means. Following the development of various analytical instruments, we now know that pigment appearance is decided by genetic causes. Recent progress in biotechnology has also provided explanations for the mechanism of color appearance. This information is particularly useful in identifying natural, untreated pearls and in enhancing the overall quality of cultured pearls.

Koji Wada, *National Institute of Aquaculture, Japan*

Cultured Pearl Production and Future Prospects

In the 1960s and 1970s, pearl culturing in Japan was affected by conflicts with fishing concerns, industrial pollution, and the overstocking of oysters in the pearl farms. However, recent research in pearl culturing has paved the way for the production of larger, better-quality round pearls. This presentation will address recent improvements in pearl-culturing techniques, the challenges that still must be met, and the physiologic, metabolic, and genetic characteristics of pearl oysters that will control successful culturing in the future.

Shunsaku Tasaki, *Tasaki Shinju Co., Japan*

Pearl Marketing

Cultured pearls are known worldwide for their intrinsic beauty. In the more than 50 years that they have been available, they have been subjected to many cycles of supply and demand. This presentation will review the rise in demand during the 1970s and the 1980s, current problems in marketing and distribution, and future prospects.

Alex Edwards, *Adachi Pearls, California*

Pearl Grading

Like diamonds, cultured pearls can be evaluated on the basis of certain factors—i.e., luster, blemish, color, shape, and size. Once a pearl is quality graded, knowledge of key market variables such as production, prices at membership auctions, and consumer demand enable the assignment of value. This presentation will review pearl-grading systems that have been used in the past and focus on the steps that have led to developing a workable quality- and value-grading system for Akoya cultured pearls internationally. Such a system has real benefits for buying, selling, and appraising pearls.

John R. Latendresse, *American Pearl Co., Tennessee*

Freshwater Cultured Pearls

Historically, the major producers of cultured freshwater pearls are Japan, which has greatly reduced production in recent years, and China, which primarily provides the lower-quality "krispie" cultured pearls. The past decade has witnessed a number of developments in the culturing of freshwater pearls in the U.S. Realization that the culturing techniques used in Japan were not directly transferable to the different species of mollusks native to North America led to development of new methods. Pearls of one, two, and three years' cultivation can be harvested simultaneously from a single mollusk. A number of new shapes have been developed that lend themselves to original jewelry designs. Advances are also being made in the production of round cultured pearls in the U.S.

COLORED STONE TREATMENTS

Kurt Nassau, *Lebanon, New Jersey*

An Overview of Colored Stone Treatments

Reported as early as the first century A.D., treatments have been used to produce simulants and, most recently, to improve color and/or quality. Today, aquamarine, carnelian, topaz, zircon, sapphire, and ruby, among others, are routinely heat treated. Irradiation is used to color materials such as pearls, quartz, tourmaline, and, most important, blue topaz. There are also a number of miscellaneous treatments, such as dyeing, plastic impregnation, glass-filling of surface-reaching fractures, and diffusion treatment. This presentation will review the key gem treatments and means of identification, discuss the importance of treatment terminology, and explore possible future developments.

Terrence S. Coldham, *Sapphex Pty., Australia*

Heat Treatment

For centuries, certain gem materials have been known to be improved by heat treatment; recently, almost every gem species has become a target for treatment. The heat treatment of corundum, in particular, has evolved rapidly, causing important changes in the marketplace. Almost all corundum is now heat treated using various methods depending on whether it is of igneous or metamorphic occurrence and its locality of origin. A number of indicators can be used to identify that a stone has been heat treated, but they are not present in all heated stones. The future will undoubtedly see the more widespread use of heat treatment in the gem industry.

Robert C. Kammerling, *GIA*

Fracture Filling of Emeralds

Among the gemstone enhancements that have gained notoriety lately are those that improve apparent clarity through the filling of surface-reaching fractures. Although the use of oil is a fairly established practice, recently other substances such as synthetic resins have become popular as filling materials in emerald. This presentation will briefly review current filling practices and then focus on the filling of emeralds and detection criteria. It will also examine potential new applications of filling procedures to other gem materials.

George R. Rossman, *California Institute of Technology*

Gemstone Irradiation

Commercial procedures for gemstone irradiation represent mature technologies. Gem materials such as topaz, diamond, quartz, and tourmaline are commonly irradiated to produce stable colors. A variety of other minerals can be treated, but only a few of them develop desirable colors with long-term stability. In many cases, the detailed atomic-level changes induced by irradiation are poorly understood. Methods for identifying radiation treatment in different stones range from highly reliable to nonexistent.

SYNTHETICS AND SIMULANTS

Dennis Elwell, *Hughes Aircraft Co., California*

An Overview of Manmade Gemstones

Manmade gemstones have a long and interesting history. Today, the key techniques used for gem synthesis are flame fusion, pulling from a melt, and high-temperature solution growth (flux growth and hydrothermal). This presentation will examine these methods and some of the materials grown by each. Possible future developments will be explored.

Thomas Chatham, *Chatham Created Gems, California*

Laboratory-Grown Emeralds

Research leading to today's sophisticated processes of crystal growth began in the mid-1800s. However, Carroll Chatham's achievement of a flux-grown synthetic emerald was a major breakthrough in gem synthesis. More recently, hydrothermally grown synthetic emeralds have entered the market. Today, there are five major companies producing flux-grown and hydrothermally grown synthetic emeralds. Only the visual identification of inclusions provides conclusive proof of the origin of any emerald, natural or laboratory grown. Mr. Chatham presents his view that, like cultured pearls in the 1960s, the "created emerald" industry is on the verge of tremendous growth.

Judith A. Osmer, *J. O. Crystal Co., California*

Laboratory-Grown Ruby

Following an overview of the history and techniques used to produce laboratory-grown ruby, a detailed comparison will be made between naturally occurring ruby and ruby grown by solution. The similarities in growth parameters and gemological properties will be illustrated. Estimates of current production and projections for future increases will be made in the context of the marketing issues associated with these laboratory marvels.

Joseph F. Wenckus, *Ceres Corp., Massachusetts*

Cubic Zirconia: The Great Impostor

Cubic zirconia (CZ) is the most widely accepted diamond simulant available today. Since the introduction of CZ in 1977, production has grown dramatically, with present annual output estimated to be in excess of 250 tons. Faceted CZ has also become the world's most effective simulant. With improved crystal-growth methods and gem-cutting techniques, even the professional jeweler now finds it very difficult to determine if the mounted gem is natural or manmade. The discussion will include a brief history of the CZ skull-melting process, current production technology, techniques for the separation of natural diamond and CZ, new developments in colored CZ, and some insights into the unusual, and often controversial, business of diamond simulants.

Shane McClure, *GIA Gem Trade Laboratory*

Distinguishing Natural Rubies, Emeralds, and Alexandrites from their Synthetic Counterparts by Means of Inclusions

Establishing whether a gem material is natural or synthetic poses risks for today's jeweler-gemologist both professionally and financially. In making the distinction, it is as important to know the characteristics of the natural gem as it is to know those of the synthetics. Since a synthetic by definition possesses approximately the same chemical, optical and physical properties as its natural counterpart, inclusions are often the only means to provide a definitive identification. This presentation highlights those inclusion characteristics that are distinctive of natural rubies and emeralds, as well as the alexandrites recently discovered near Itabira in Minas Gerais, Brazil.

ECONOMICS AND MARKETING

WORLD MARKETS

Martin Rapaport, *Rapaport Diamond Report, New York*

The Impact of the Global Economy on Diamond Prices

Gems are an international commodity. As such, economic problems in one major consumer country can have a profound impact on demand—and, therefore, pricing—in other major consumer countries. Diamonds provide an ideal example of the effect of the new global economy on gems and jewelry. This presentation will define the international diamond market, discuss how prices are negotiated in that market, and explain the importance of arbitrage. Key factors in pricing are interest, inflation, and foreign currency rates, government regulation, and liquidity and wealth in the global economy. This presentation will conclude by reviewing these factors and looking ahead to where the market will be in the year 2000.

Michael C. Barlerin, *World Gold Council, New York*

Gold and Jewelry

This presentation will review the key trends in gold jewelry consumption from the 1960s through the 1980s. It will then address demand trends in the primary developed markets and emerging trends in the developing, i.e., price-driven markets. Gold jewelry is playing an increasingly important role in the gold market, with a strong correlation between the price of gold and the consumption of gold jewelry. This relationship will be explored, as will current and potential future developments in consumer markets worldwide.

Carl Pearson, *London*

The World Diamond Market

The 1970s and 1980s witnessed tremendous changes in rough supplies, diamond manufacturing, and the composition of polished demand. Major increases in production in Africa and Australia have been absorbed by an expansion in the world cutting industry and the growth of consumer markets, especially in the Far East. The flexible response of the diamond market to political, economic, and technical changes in many ways has been the key to its success.

The 1990s, however, will provide a new set of challenges to the industry. The new decade has already brought a slowdown in the diamond market and reduced profitability in the wake of the global economic downturn and the Gulf War. But consumer markets will gradually revive, with new market opportunities in Eastern Europe, the Middle East, and the Far East. Recent market declines in the U.S. and Japan are likely to be reversed.

Diamond production will increase more slowly in the 1990s than in the 1980s, but producers will attempt to develop their cutting and jewelry manufacturing potential. Their success in these fields is expected to be limited, given the highly competitive and specialized nature of the cutting industry worldwide and the poor record of diamond and jewelry industries in producer countries.

This overview of supply and demand will also discuss how the diamond market has responded to changes in jewelry manufacturing and retailing. An assessment of future prospects will focus on identifying longer-term trends in the market and how these may evolve under different economic scenarios.

Thomas Andruskevich, *Tiffany & Co., New York*

Practical Considerations in Entering the International Jewelry Market

Expanding a business into the international arena—like expansion within a neighborhood or across one's own country—first requires a clear understanding of the demographics of the proposed market. The selection of management, preferably local, of the new enterprise is also critical, as is the development of an appropriate pricing structure vis a vis local competitors and other company locations. A substantial investment will usually be required, and there might not be a payback for several years. Given current world economic fluctuations, and developments such as the European Economic Community, future international expansions will depend on a clear understanding of very complex issues.

MARKETING CHALLENGES IN THE '90s □

Russell Shor, *Jeweler's Circular-Keystone, Pennsylvania*

The Impact of the New Global Economics

Two major economic challenges face the American jewelry industry: foreign-made jewelry and market competition. The dollar volume of imported jewelry sales in the United States is 50% and rising. Increased purchases in world centers by Asian, European, and Japanese buyers is driving up the price of diamonds and colored stones. This presentation will review the implications of changes in international production with a focus on the competitive outlook. It will also look at structural changes in the U.S. market. Key financial and management issues to be discussed include margins, cash flow, memoranda, and credit.

Charles Septer, *Service Merchandise Co., Tennessee*

Catalog Showrooms and the Jewelry Industry

For the past several years, catalog showrooms have been one of the most important sources of diamond and colored-stone jewelry for the middle-class American consumer. This presentation will look at the marketing strategies of catalog showrooms and the services they offer both the patron and the trade. It will also examine how catalog showrooms select merchandise and the promotional events unique to this aspect of the industry. Finally, Mr. Septer will look at the future of catalog showrooms as a vital link between diamond and colored-stone suppliers and the consumer.

Thomas Tivol, *Tivol Jewelers, Missouri*

The Independent Upscale Retailer

The independent upscale retailer in the 1990s will (1) have knowledge of his marketplace demographics (social groupings) and purchase-display attitudes, (2) develop public-relations events specifically for social groupings using customer referrals within each group, (3) choose to lose sales on products that will damage the retailer's image or from customers whose buying habits prevent them from becoming goodwill ambassadors of the business, and (3) distinguish himself (or herself) from all competition in all areas by adopting the position *opposite* of "I shall do what is necessary to make the sale."

Robert L. Bridge, *Ben Bridge Jeweler, Washington*

Retail Chains in the Jewelry Industry

The rise of retail jewelry chains since 1970 has drastically changed the complexion of the jewelry industry. This presentation will look at the market effects of this phenomenon first as it developed from 1970 to 1982, and then as it has evolved since 1985, when the move toward consolidation of chains began. The conclusion will examine the possible long-term effects that the continued evolution of jewelry chains could have on the retail sector.

Judy Laughren, *Diamond Promotion Service, New York*

Diamonds: Markets and Merchandising

The myth, magic, and mystique of diamonds is centuries old. Their popularity in the last 50 years is due in large part to the worldwide marketing efforts of De Beers and the Central Selling Organisation in London. This presentation will provide a historical perspective on diamond marketing, with emphasis on the United States market. Existing diamond jewelry market conditions will be reviewed and current product trends identified. Concluding remarks will focus on recent changes in the current market, both inside and outside the jewelry industry, providing some thoughts for future directions.

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PRODUCT KNOWLEDGE AND INFORMATION SYSTEMS IN THE JEWELRY INDUSTRY

Dennis Foltz, *GIA*

Demographics and the Jewelry Industry

In the 1990s, dramatic changes in almost every aspect of society will impact on the jewelry industry. The flow of information will be faster, issues will be more complex, and the need for consumer-oriented training will be more acute. The workforce will also be smaller, with lower skill levels but higher expectations. We can also expect new educational methods and technology to provide more effective training alternatives. Strength and growth in the jewelry business will require recognition of these trends and appropriate responses in terms of both resources and personnel. This presentation will examine these developments and explain how industry leaders can meet the challenges and create opportunities by implementing educational programs that support corporate objectives.

Earl Lynch, *Diamond Promotion Service, New York*

Training and Education: The Key to Success in the Future

This presentation examines the development of education and training in the United States and then focuses on the vital role it plays in the jewelry industry and especially in successful retail marketing. The informed consumer in the jewelry marketplace of the '90s places increasing demands on the sales force to be knowledgeable about materials and manufacturing. This translates into an even greater need for more and better training. Yet there are problems with education today that need to be addressed. These problems are examined and successful future directions are identified.

John Sinkankas, *Peri Lithon, California*

The Role of Gemological Literature in Research and as an Aid to the Jeweler

In the jewelry business and its supporting fields of research, it is no longer feasible to depend on the traditional "one-on-one" apprenticeship used in the past. With the information explosion, students, graduates, and even established professionals and interested laymen must increasingly turn to book and periodical literature to keep abreast of developments. This presentation discusses how to best accomplish this and offers specific suggestions for the formation of a useful reference library.

Dona Dirlam, *GIA*

Databases for the Jewelry Industry

As our rapidly changing industry moves into the 21st century, the rate at which jewelers will be challenged by new developments will escalate. No longer can the professional rely on the occasional perusal of a trade or technical journal to stay informed. Obtaining, evaluating, storing, and retrieving this vast quantity of information will occupy an increasing amount of the professional's energy. Databases will play an important role as sources of all types of information. This talk will review the history of databases and the opportunities offered by those that are relevant to gemology and the jewelry, specifically diamond, industry.

Harold and Erica Van Pelt, *Photographers, Los Angeles*

Gem and Jewelry Photography

One of the greatest revolutions of the last 25 years has been the use of color in print. This has presented new advertising opportunities for colored gems, but the gems themselves pose unique challenges for the photographer. This highly visual presentation will describe some of the photographic techniques now in use to maximize the impact of color in gems and jewelry. It will also examine the new technology in color reproduction that can be used in conjunction with fine photography for the production of effective catalog and print advertising.

JEWELRY

PERIOD JEWELRY ☐

Derek J. Content, *Glyptic Arts Ancient Jewelry, Maine*

Ancient Jewelry: Its Lasting Heritage

Despite their lack of modern tools, ancient artists created jewelry of outstanding beauty, often incorporating engraved quartzes, garnets, or other gem materials. These pieces transcend their period and constitute a continuing source of inspiration for modern jewelers. This presentation will give an overview of some ancient jewelry engraved gems recently available in the marketplace. Attention will also be paid to forgeries and their detection.

Diana Scarisbrick, *London*

Ancestral Jewels

In contrast to the nobility of other countries, who have suffered the depredations of war and revolution, the members of the British aristocracy have been able to preserve their wealth over a long period. This is due to the unique combination of inheritance laws and an unbroken run of political stability since 1688. As a large proportion was invested in jewelry, the hereditary collections of the great English families present a panorama of the best European craftsmanship over several hundred years. This survey will focus on national taste, the pieces made by celebrated jewelers such as Rundell and Bridge, Garrard, Lacloche, Cartier, Chaumet and Hennell, and the prices now obtained for them at auction. The fine work produced continues to be a source of inspiration.

David J. Callaghan, *Hancock's & Company, London*

Period Jewelry: Overview

Period jewelry is the product of available materials combined with the designer's talent, daring, and ingenuity. The key to its allure lies in its overall craftsmanship and quality. This overview will describe metal techniques and the use of gems in period jewelry, and will show examples of motifs derived from ancient and antique jewels. The current dilemma posed by reproductions will also be addressed, including their impact on the current and future market for period jewelry.

Roger Harding, *Gemmological Association of Great Britain*

Crown Jewels

The British crown jewels housed in the Tower of London have recently been catalogued. Scepters, orbs, and parts of some of the crowns date from the 17th century; important gems from these pieces will be described. In the 19th and early 20th centuries, large diamonds such as the Kohinoor and the Cullinans were added to the collection, reflecting historical aspects of the British Empire. There were also additions of colored gemstones, and the extent to which these represent standards of excellence still current today will be discussed.

MATERIALS AND METHODS IN JEWELRY ARTS □

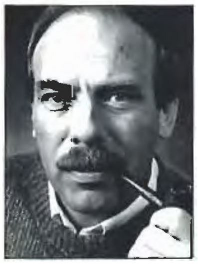
Gerhard Becker, *Friedrich August Becker, Germany*

Gem Art Objects

The gem trade has shown increasing interest in carved gemstones and gem art objects. Today, gem art objects range from bowls and vases of chalcedony and other opaque gem materials, through fine cameos and intaglios, to beautifully detailed figurines of tourmaline and other transparent gems. This presentation will provide a brief historical perspective on gemstone art objects, followed by a description of modern techniques and new developments in technologies such as ultrasonic carving.

Bernd Munsteiner, *Idar-Oberstein, Germany*

Gem Carving—Gem Designer



In recent years, the art of gem carving has achieved new levels of creativity that bring a unique character to cutting gem materials such as aquamarine, amethyst, heliodor, and rutilated quartz. One of the premier gem designers in the world today, Mr. Munsteiner will briefly review the development of gem carving and sculpture. He will then describe recent technical advances in this area and the opportunities presented by gem carving for the creation of provocative pieces of jewelry.

Sandro Sebastianelli, *Sebastianelli Sandro & Co., Italy*

Jewels of the Seas—Cameos and Coral

The art of working coral and carving cameos from natural seashells in Torre del Greco has been perfected throughout the ages. These traditions have brought fame and fortune to this small seaside town. Sculpting, engraving, and other techniques used by Italian carvers will be discussed and illustrated and methods of distribution described. Contemporary drawings by the students of the Italian Institute of Design in Milan and Rome will complete the presentation.

Paul V. A. Johnson, *Goldsmiths' Hall, United Kingdom*

Precious Metals Testing in the Jewelry Industry

"All that glisters is not gold" wrote William Shakespeare, and in our context perhaps no truer words have been written. But, how can we tell and why do we need to know? The British Hallmarking system originated in 1364; to this day it serves as an effective guarantee to the consumer and ensures fair trading. The history and current practices of hallmarking will be discussed with particular reference to the analytical techniques involved. In countries where no hallmarking systems exist, there is evidence of often widespread underkarating. Reference will be made to available testing techniques and facilities, and to possible future developments that may help the jeweler faced with an underkarating scenario.

Carl P. Denney, Jr., *Johnson and Matthey, New York*

Platinum and Its Application in the Jewelry Industry

Although platinum has played a prominent role in jewelry manufacturing in the West for much of this century, today demand for platinum is dominated by the Japanese. There is also a developing trend toward the use of platinum in other world markets. An overview will identify present techniques used in the design and manufacture of platinum and platinum/gold combination jewelry. The presentation will also examine the marketing and promotional opportunities presented by platinum. Prospects for the future include international standards for platinum jewelry and karat platinum alloys.

JEWELRY IN THE 20th CENTURY AND BEYOND □

John D. Block, *Sotheby's, New York*

The Auction Market and Its Position in the Jewelry Industry

The importance of gem and jewelry sales through auction houses has increased dramatically in the last decade. The significance of auctions as a marketplace and the opportunities they present to the public, as well as to the jewelry trade, will be examined. The information provided by auction houses, such as sales figures and types of jewelry offered, has been used as a barometer for trends in the jewelry market. This sheds light on future developments in the industry, and opens the discussion on creating new markets and how the auction houses attract buyers.

Penny Proddow, *R. Esmerian, Inc., New York*

Contemporary Jewelry Fashions in America

The American jewelry industry has passed through many phases in the 20th century, moving from almost total dependence on European jewelers and artisans for technology and design to original work that set jewelry fashions worldwide. Art Nouveau, Art Deco, Streamline and Postwar styles, as manifest in American jewelry, reveal a country finding its own jewelry identity, so to speak, characterized by a dextrous use of metals, bold design, and a growing preference for quality stones.

Vivienne Becker, *London*

The European Perspective

This presentation will look at the evolution of European jewelry design in the 20th century, leading to an informed speculation about future design developments. Using slides of some of the most spectacular milestone jewels from each decade, Ms. Becker will trace the major art and design movements and their influence on jewelry, starting with Art Nouveau and continuing through the Edwardian (or Garland) Style, Art Deco and Modernism, the Machine Age, the sophisticated '50s, and the "new" jewelry of the '60s, up to present-day design and designers. Throughout, she will contrast the work of individual artist-jewelers with that of the major houses such as Cartier or Boucheron. This will lead to an assessment of developing trends, shifts in the market, and varying attitudes toward jewel buying and wearing. The presentation will close with a look at some entirely new European designs for the future.

Morihiro Nagahori, *Nagahori Corp., Japan*

Jewelry Trends in Southeast Asia

In the last two decades, Southeast Asia has emerged as an important jewelry market both for production and consumption. The jewelry trade in Hong Kong, Thailand, Singapore, Korea, Taiwan, and particularly Japan will be discussed with emphasis on its growth, strengths, and weaknesses. Japan has played an increasingly important role in jewelry design; key designers and design trends will be addressed. Prospects for the future, including expanded production and distribution, will be highlighted with a closing view on the role of the jeweler in the coming decade.

PANELS AND PANELISTS

On Sunday, June 23, men and women on the cutting edge of the industry will meet in a series of panels to present their perspectives on critical issues affecting diamonds, colored stones, gem identification, research, marketing, and jewelry history and appraisals. Following a brief presentation by each panelist on the issue at hand, the discussion will be open to a question-and-answer session with members of the audience. Below is a short description of each panel, sample questions that are likely to be addressed, and the names and affiliations of the panelists scheduled to participate.

Diamonds: Manufacturing, Markets, and Worldwide Distribution

The major developments in the diamond industry take place in a relatively small number of key hubs that strongly influence the overall character of the market. This panel of industry leaders will provide insights into their market centers and address questions such as: How will new technologies influence cutting styles and production? What future changes in national demand can we expect and what opportunities do they present?

Jean-François Moyersoen, *Gemstone Price Reports, Belgium* ♦ **Eli Haas,** *Diamstar International, New York* ♦ **Abraham Fischler,** *Hoge Raad voor Diamant, Belgium* ♦ **Michael Mitchell,** *Argyle Diamonds, Australia* ♦ **Jacques Mouw,** *Interdiam, Los Angeles* ♦ **Edward Asscher,** *Royal Asscher Diamond Co., The Netherlands* ♦ **Hidetako Kato,** *Japan Jewellery Association*

Diamond Grading: The "Four C's" and Quality Analysis

The importance of objective quality analysis of diamonds has escalated in recent years, and it is likely that grading laboratories will play an even greater role in the industry in the future. What are the dynamics of international standardization in quality analysis? How does the global village influence specific issues of quality analysis?

Glenn R. Nord, *GIA Board of Governors, California* ♦ **Richard T. Liddicoat,** *GIA* ♦ **William E. Boyajian,** *GIA* ♦ **Thomas C. Yonelunas,** *GIA Gem Trade Laboratory* ♦ **Yoshiko Doi,** *Association of Japan Gem Trust* ♦ **Kenneth Scarratt,** *Gemmological Association of Great Britain*

Colored Stones: Identification and Quality Analysis

Gemological laboratories worldwide are faced with new natural gem sources and increasingly sophisticated synthetics and treatments. They are also constantly seeking to improve their usefulness to the international community. Among the many questions that they face today and in the future: What are the advantages of standardized gemological nomenclature and the obstacles to its development in the international marketplace? What are the difficulties of determining locality of origin and the pros and cons of issuing origin reports?

Kenneth Scarratt, *Gemmological Association of Great Britain* ♦ **Jean-Paul Poirot,** *Chambre de Commerce et d'Industrie de Paris* ♦ **Adi Peretti,** *Gübelin Gemmological Laboratory* ♦ **Robert Crowningshield,** *GIA Gem Trade Laboratory* ♦ **Ulrich Henn,** *German Foundation for Gemstone Research* ♦ **William Sersen,** *Asian Institute of Gemological Sciences*

Colored Stones: Research on Treatments and Synthetics

With the rapid new developments in gemology, the trade depends on the gemological research community to report on materials and enhancements and apply advanced technologies to meet the everyday requirements of the jeweler-gemologist. What new commercial treatments or synthetics might we expect in the near future? What are the prospects for improved practical identification techniques?

Karl Schmetzer, *Germany* ♦ **Peter G. Read,** *P. G. Read Consultancy Services Ltd, United Kingdom* ♦ **James Shigley,** *GIA* ♦ **Henry Hänni,** *SSEF Laboratory* ♦ **Kurt Nassau,** *New Jersey* ♦ **Vladimir S. Balitsky,** *USSR Academy of Sciences*

Research: Advanced Instruments and Identification

Many of the identification problems that face the gemologist today cannot be successfully addressed using readily available methods and instrumentation. As in the past, the jewelry industry must adapt technology and instrumentation from other disciplines. What recent technological developments in other areas are likely to have an impact on the jewelry industry in the 1990s? How can the jeweler-gemologist benefit from these advances?

Bernard Lasnier, *Institut de Géologie, France* ♦ **Gordon Brown,** *Stanford University, California* ♦ **George R. Rossman,** *California Institute of Technology* ♦ **Kurt Nassau,** *New Jersey* ♦ **Emmanuel Fritsch,** *GIA*

Colored Stones: Sources, Distribution, and Marketing

With the increased importance of colored stones in the jewelry industry, numerous questions of supply, distribution, and marketing arise. For example: What role should producers have in marketing colored stones? What are the advantages and difficulties of standardizing quality-analysis procedures?

Douglas Parker, *William Kuhn Co., New York* ♦ **A. E. T. Ellawala,** *Ellawala Exports, Sri Lanka* ♦ **Roland Naftule,** *NAFCO Gems, Arizona* ♦ **Maurice Roditi,** *Emerbras, Brazil* ♦ **Anant Hassan Salwala,** *Thai Lapidary International Co., Thailand*

Retail Marketing in a Global Economy

Changing international patterns of supply and demand, for example, the greatly increased purchasing activity in Japan in the 1980s, will inevitably affect supply and demand in local markets. How does the retail jeweler accommodate these changes? What inventory adjustments can be made to respond to rapid and complex economic changes?

Michael Roman, *Jewelers of America, New York* ♦ **William Chaney,** *Tiffany & Co., New York* ♦ **Helene Fortunoff,** *Fortunoff, New York* ♦ **Roger Marks,** *Jewelers of America, New York* ♦ **Ralph Destino,** *Cartier, New York*

Jewelry for the Connoisseur and Its Marketing in the '90s

Given the increasingly sophisticated consumer of the '90s, can we identify the importance of integrity and quality in influencing the customer's purchasing decision? How do the marketing concepts used to appeal to the jewelry connoisseur translate into useful techniques for the mainstream retailer?

Shintaro Uyeda, *Uyeda Jeweller, Japan* ♦ **Michael Kazanjian,** *Kazanjian Brothers, Los Angeles* ♦ **Joseph H. Samuel,** *J. and S. S. DeYoung, Massachusetts* ♦ **Ralph Esmerian,** *R. Esmerian, New York* ♦ **Peter Schneirla,** *Tiffany & Co., New York*

Jewelry: History, Identification, Appreciation, and Evolving Design

Many elements are involved in the evolution of design. How can the designer maximize his creativity within the realities of the jewelry industry? And how can the retail jeweler best utilize the range of design elements—historic through avant garde—that are available?

Wilma Vigano, *Platinum Guild International* ♦ **Martin Gruber,** *Nova Stylings, California* ♦ **Michael Bondanza,** *Michael Bondanza, New York* ♦ **Diana Scarisbrick,** *London* ♦ **Vivienne Becker,** *London* ♦ **Leonardo Poli,** *La Nouvelle Bague*

Gems and Jewelry: Evaluation, Appraisals, Ethical and Legal Questions

The jewelry world faces an increasingly complex appraisal climate. What are the legal responsibilities of the appraiser? Why do different situations call for different appraisal procedures? What is happening with legislation and licensing? What is the best way to establish correct values? These and many additional important questions will be addressed.

Donald A. Palmieri, *Gemological Appraisal Association, Pennsylvania* ♦ **Anna M. Miller,** *A. M. Miller and Associates Appraisals, Texas* ♦ **Patti Geolat,** *Geolat and Associates, Texas* ♦ **Cosmo Altobelli,** *Altobelli Jewelers, California* ♦ **Joseph W. Tenhagen,** *Joseph W. Tenhagen Gemstones, Florida* ♦ **Joel A. Windman,** *Jewelers Vigilance Committee, New York*

POSTER SESSION—A MARKETPLACE OF NEW IDEAS

A common mode of scientific and technical communication, a poster session presents information visually using written text, photographs, graphic aids, and other displays, within a standard-size booth. At Symposium, approximately 90 poster session presentations are scheduled on a wide range of gemology- and jewelry-related topics. Presenters will be available to discuss their "posters" (as indicated here by abbreviated titles) on Sunday, June 23, although the "posters" will be available for viewing that Friday and Saturday as well.

COLORED STONES

•Acuña, Gabriel and R. Ringsrud, *Constellation Colombian Emeralds, Los Angeles*
Mining and marketing of emeralds in Colombia

•Austin, Gordon T., *U.S. Bureau of Mines, Washington, DC*
Gem production in the United States

•Balitsky, Vladimir S., *Institute of Experimental Mineralogy, USSR*
Characteristics of synthetic iron-bearing quartz

•Balitsky, Vladimir S. and T. M. Boublikova, *Institute of Experimental Mineralogy, USSR*
Synthetic malachite

•Boehm, Edward W., *Gübelin Gemmological Laboratory, Switzerland*; and Y. Melas, *GIA*
Red spinel: History, identification, and market potential

•Bowersox, Gary, *Gem Industries, Honolulu*
Gems of Afghanistan and Pakistan

•Bridges, Campbell, *Bridges Exploration, Kenya*
Tsavorite

•Brown, Grahame, *ALLGEM Services, Australia*
Biron synthetic pink beryl

•Carmona, Charles I. and J. E. Cole, *Guild Laboratories, Los Angeles*
Endangered species used in jewelry

•Chai, Bruce H. T., *CREOL, University of Central Florida*; and E. Fritsch, *GIA*
Synthetic alexandrite and its variations

•Chai, Bruce H. T., *CREOL, University of Central Florida*; and E. Fritsch, *GIA*
Synthetic blue gehlenite

•Coeroli, Martin, *EVAAM, Tahiti, French Polynesia*
Tahiti cultured pearls

•Barbosa, H. D. , *Brazil*; and B. C. Cook, *Nature's Geometry*, California
Copper tourmaline of Paraíba, Brazil

•Gauthier, Jean-Pierre, *University Claude Bernard Lyon, France*
Optical phenomena in opal, diopside, and mother-of-pearl

•González, Estuardo, *Los Angeles*
Guatemala's jadeite

•Gunawardene, Mahinda, *MANYGEMS GmbH, Germany*
Gems of Sri Lanka

•Hänni, Henry A., *Swiss Foundation for the Research of Gemstones SSEF, Switzerland*; and K. Schmetzer, *Germany*
Burma-type rubies from Morogoro, Tanzania

•Harlow, George E., *American Museum of Natural History, New York*
Jadeite and related jades from Guatemala

•Henn, Ulrich and H. Bank, *German Foundation for Gemstone Research, Germany*
Gem corundum from Malawi

•Henn, Ulrich and H. Bank, *German Foundation for Gemstone Research, Germany*
Color and pleochroism of Cu-bearing tourmalines

•Henn, Ulrich and H. Bank, *German Foundation for Gemstone Research, Germany*
Green and pink hydrogrossular from South Africa

•Hoover, Donald B., *Hoover Associates, Denver*; and A. F. Theisen, *University of New Hampshire*
Fluorescence spectra of Cr^{3+}-bearing gem minerals

•Illenberger, Stephen P. and C. A. Mark, *The Gemstone of the Caribbean, Florida*
Blue pectolite

•Johnston, Chris and M. E. Gunter, *University of Idaho*; and C. R. Knowles, *Idaho Geological Survey*
Ponderosa mine sunstone

•Juchem, Pedro Luiz, *Centro de Gemologia/UFRGS, Brazil*
Gemstones of Rio Grande do Sul, Brazil

•Kim, Won-Sa, *Chungnam National University, Korea*
Korean amethyst

•Kremkow, Cheryl and N. R. Barot, *International Colored Gemstone Association, California*
World gem mining report

•Lebedev, Alexander S., *Institute of Geology and Geophysics, USSR*
Russian hydrothermal synthetic emerald

•Liu, Guobin, *Institute of Geochemistry, China*
Synthetic gem materials from China

•Loeb, Loretta B., *GIA*
The GIA reference gem collection

•Marfunin, A. S., *Moscow State University, USSR*
Radiation centers in gemstones

- Mendis, D. P. J., M. S. Rupasinghe, and C. B. Dissanayake, *Institute of Fundamental Studies, Sri Lanka*
  Gem deposits of Sri Lanka
- Moon, Anthony R. and M. R. Phillips, *University of Technology, Australia*
  Titania precipitation in sapphire
- Muhlmeister, Sam, *GIA*; and B. Devouard, *France*
  Trace element chemistry of natural and synthetic rubies
- Ottaway, Terri L. and F. J. Wicks, *Royal Ontario Museum, Canada*
  The Muzo emerald deposit, Colombia
- Panjikar, Jayshree and K. T. Ramchandran, *Gemmological Institute of India, Bombay*
  Rubies from India
- Reshetnjak, N. B., V. Bukanov, V. S. Balitsky, G. V. Bondarenko, *Institute of Experimental Mineralogy, USSR*
  Raman spectroscopy of gemstones
- Ringsrud, Ron, *Constellation Colombian Emeralds, Los Angeles*
  A social history of Colombia's emerald-mining region
- Robert, Dominique and D. Marsan, *CRISMATEC, France*
  New colors for synthetic garnets
- Roskin, Gary, *GIA*
  Harvesting the Japanese coral
- Rupasinghe, Mahinda S., R. A. P. Rupasinghe, C. B. Dissanayake, and O. A. Ileperuma, *Institute of Fundamental Studies, Sri Lanka*
  Classification of heat-treatable corundum
- Salomao, Elmer P., *Departamento Naçional da Producão Mineral, Brazil*
  Gemstone production in Brazil
- Sapalsky, Cristina and T. Calderon, *Gemmological Institute of Spain, Madrid*
  Optical study of Spanish sphalerites
- Sauer, Daniel A., *Amsterdam Sauer Co., Brazil*; and J. P. Cassedanne, *Federal University of Rio de Janeiro, Brazil*
  Aquamarines in Brazil
- Spencer, R. J. and A. A. Levinson, *University of Calgary, Canada*; and J. I. Koivula, *GIA*
  Fluid inclusion study of Mexican opals
- Stark, Karen B., *GIA*
  Malaya garnet
- Taijing, Lu, *Institute of Physical and Chemical Research, Japan*; and I. Sunagawa, *Tohoku University, Japan*
  Texture formation in geode chalcedony
- Themelis, Ted, *Accredited Gemologists Association, California*
  Sapphires from Brazil
- Troup, Gordon J., D. R. Hutton, and J. R. Pilbrow, *Monash University, Australia*
  Gemstones and magnetic resonance spectroscopy (EPR, ESR)
- Troup, Gordon J., J. R. Pilbrow, and D. R. Hutton, *Monash University, Australia*
  ESR instrumentation for gemmology
- Wang, Fuquan, *Geological Museum of China, Beijing*
  Gem localities in China
- Webb, Gayle, B. J. Barron, and F. L. Sutherland, *The Australian Museum, Sydney*
  The ruby problem, Barrington Volcano, Australia
- Zoysa, E. Gamini, *Sri Lanka*
  Gem deposits of Sri Lanka

DIAMOND

- Boro, Serge and M. Feinberg, *Lazare Kaplan International, New York*
  New breakthrough in diamond identification
- Bosshart, George, *Gübelin Gemmological Laboratory, Switzerland*
  Green diamonds
- Bronstein, Alan, H. Rodman, *Aurora Gems, New York*; and S. Hofer, *Colored Diamond Laboratory Service, Connecticut*
  Aurora collection of colored diamonds
- Chapman, John G., *Argyle Diamonds, Australia*
  Argyle's pink and champagne diamonds
- Devries, Robert C., *P-T-X, New York*
  Laser luminescence of synthetic diamond crystals
- Hatleberg John N., *Big Gems, New York*
  Replicas of famous diamonds
- Hofer, Stephen, *Colored Diamond Laboratory Services, Connecticut*; and N. Hale, *Hale Color Consultants, Phoenix*
  Color measurement of "white" diamonds
- Kaplan, George and M. Feinberg, *Lazare Kaplan International, New York*
  The "ideal cut" diamond
- Peretti, Adolf, *Gübelin Gemmological Laboratory, Switzerland*; and W. Boguth, *Switzerland*
  Color description of colored diamonds
- Schachter, Michael, *Maico Industries, New Jersey*
  The "Dream cut" diamond
- Watermeyer, Basil, *South Africa*
  Modern brilliant diamonds
- Zezin, Roman B., E. P. Smirnova, *Gemmological Center of the USSR, Moscow*; and G. V. Saparin, *Moscow State University, USSR*
  New growth mechanism of natural diamonds
- Zezin, Roman B. and V. F. Nasedkin, *Gemmological Center of the USSR, Moscow*
  Color effects in natural diamonds
- Zezin, Roman B. and V. F. Nasedkin, *Gemmological Center of the USSR, Moscow*
  Formation of color centers in diamonds under mechanical treatment

GENERAL GEMOLOGY

- Ashbaugh, Charles E. III, *GIA*
  Gamma-ray spectroscopy in gemology
- Bernardin, John E., *El Sobrante, California*
  Minimizing extinction in faceted gemstones
- de Goutière, Anthony, *de Goutière Jewelers, Canada*
  Wonders within gemstones
- Dele, Marie-Louise, *University of Lille, France*; and J-P. Poirot, *Service Public du Controle des Diamants, France*
  Raman spectroscopy in gemology
- Hanneman, W. William, *Hanneman Gemological Instruments, California*
  Fundamental gemology
- Koivula, John I., *GIA*
  Illumination techniques
- Landais, Edmond, *Association Française de Gemmologie, Paris*
  Automated Brewster angle refractometer
- Omoumi, Heideh, D. G. W. Smith, and D. P. Leibovitz, *University of Alberta, Canada*
  A gemological database software program
- Piat, Daniel H., *Association Française de Gemmologie, France*
  Synthetic stone manufacturer's policy
- Read, Peter G., *Gemmological Association of Great Britain*
  Gem databank
- Rubin, Howard, *GemDialogue Systems, New York*
  Gem color description system
- Shida, Junko, *Gemmological Association of All Japan*; and I. Sunagawa, *Tohoku University, Tokyo*
  Laser tomography in gemology

GEMSTONE MARKETING

- Chamberlin-Bowersox, Bonita, *Gem Industries, Honolulu*
  Merchandising challenges for colored gemstones in the '90s
- Downing, Paul B., *Majestic Gems and Carvings, Tallahassee*
  Opal: identification and value
- Drucker, Richard B., *Gemworld International, Chicago*
  Pricing gemstones
- Hendry, David W., Jr., *Card 'N' Tag Systems, California*
  Color imaging and teleconferencing
- Humphrey, David, *Geo Design, California*
  The gem merchant of the 21st century
- Marcusson, Cynthia R., *Cynthia Renee and Company, California*
  Market guidelines for colored gemstones
- Michelsen, Sofus S., *Center for the Study of Gemstone Evaluation, New Jersey*
  Gemstone pricing index
- Streight, S. Gordon, *Streight Jewellery Products, Australia*
  Jewelry appraisal software
- Torsuwan, Rangsan and A. Sawadisevee, *Silom Precious Tower Co., Thailand*
  International gemstone marketplace
- Underwood, Thom, *Accredited Gemologists Association, California*
  A career gemologist in the 1990s

JEWELRY

- Denney, Carl P., Jr. and S. Bragoli, *Johnson Matthey, New York*
  Platinum as a jewelry metal
- Forester, Nanette, *American Lapidary Artists, Los Angeles*
  Lapidarists of North America
- Marfunin, A.S., *University of Moscow, USSR*
  Gold as a phenomenon of artistic culture
- Mercer, Meredith E. and S. Armstrong, *GIA*
  Tabletop karat-gold testing methods
- Misiorowski, Elise B., *GIA*
  Pink diamonds in jewelry
- Serras, Helen, *Glyptography Center, Maryland*
  English glyptography masters
- Stuart, Martin A., *Martin Stuart and Company, Los Angeles*
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