# GEM STONES

By Gordon T. Austin

**Mr. Austin, a physical scientist with more than 30 years industry and Government experience, has been the gem stones commodity specialist since 1986. Mr. William Field, mineral data assistant, prepared the domestic production survey data.**

Production value of natural gem materials in the United States during 1990 was essentially unchanged at $52.9 million. The materials produced included faceting rough, lapidary rough, carving material, specimen material, natural and cultured freshwater pearls, mother of pearl, agatized coral, and coral.

The reported combined production value of synthetic and simulant materials was $20.5 million, about a 9% increase over that of 1989. Synthetic gems are laboratory grown and have essentially the same optical, physical, and chemical properties, and the same appearance as the natural gem that they represent. Synthetic gem materials produced in the United States include alexandrite, coral, diamond, emerald, garnet, lapis lazuli, quartz, ruby, sapphire, spinel, and turquoise. Simulants are laboratory grown gem materials that have an appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. The gem simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gem stones, would be classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced.

Wholesale and retail outlets, gem and mineral shops, gem and mineral show dealers, cutting factories, and jewelry manufacturers were the major purchasers of domestic gem materials.

## DOMESTIC DATA COVERAGE

The U.S. Bureau of Mines estimates of U.S. production were from the "Natural and Synthetic Gem Material Survey," a voluntary survey of U.S. operations, and from Bureau estimates of unreported production. Of the approximately 400 operations surveyed, 82% responded, accounting for about 95% of the total production, 92% of the natural production, and 100% of the synthetic and simulant production.

The 400 operations surveyed in 1990 were an increase of about 10% compared with the number of operations surveyed in 1989. The response rate was essentially the same as that of 1989. The Bureau estimated the production by nonresponding operations, by professional collectors, and by amateur or hobbyist collectors. The basis for these estimates were information from published data, conversations with gem and mineral dealers, analyses of gem and mineral shows and sales statistics, and from information informally supplied by collectors. In the formal voluntary survey and the informal surveys, the Bureau is totally dependent upon the cooperation of the producers, brokers, dealers, and collectors. Individuals and companies have been very cooperative and forthcoming with information. The Bureau is very appreciative of this cooperation.

## BACKGROUND

The history of production and preparation of gem stones begins with the wearing of items for personal adornment in prehistoric times; this preceded even the wearing of clothes. Amber was mined in the Baltic countries for use as a gem material before 25,000 B.C. Later, the Phoenicians in their writings described their trade routes to the Baltic for amber and to areas in Asia and Africa for other gem materials. The voyages of Columbus brought increased interest in gem deposits, especially emerald, in South America. The discovery of diamond in Africa in 1859 focused major interest on Africa. More recently, the discovery of diamond in Western Australia in 1967 has resulted in the development of one of the largest deposits in the world.

Commercial mining of gem materials has never been extensive in the United States. Although more than 60 gem minerals and materials have been produced commercially from domestic sources, most of the deposits are relatively small. In many instances, production rests in the hands of the numerous hobbyists and members of mineralogical and lapidary clubs. The Crater of Diamonds State Park near Murfreesboro, AR, is open to the public on a daily fee basis. Many gem-quality stones are found there each year.

### Definitions, Grades, and Specifications

Select rocks, certain varieties of mineral specimens, and some organic materials, such as pearl, amber, jet, and coral, are included in gem stones data. Customarily, diamond, ruby, sapphire, and emerald are considered the major gems.

The designation "gem stone" refers to a material appropriate for personal adornment. The most important qualities of gem stones are beauty, durability, uniqueness, and rarity. Beauty, indicated as splendor, purity, or attractiveness, is judged mainly according to the taste of the beholder and includes such appearances as luster, transparency, brilliance, and color. Luster of a mineral or stone is independent of color and is the surface appearance in reflected light. Apart from materials that have a metallic luster, the chief contributors to luster are transparency and refractive index. The perfection of polish enhances the luster of a stone. Visible imperfections impair the luster of transparent stones. However, defects, described as "jardens" or "inclusions," may enhance the beauty and value of natural rubies, sapphires, and other gem stones and may be used to identify the country of origin and even the mine. Durability is measured by the resistance of a stone to abrasion, pitting, chipping, or splitting. Resistance to abrasion is correlated with relative hardness, but intrinsic brittleness and toughness indicate resistance to wear in other aspects. Rarity is an essential qualification and is more important for some stones in determining their value than their physical characteristics.

Of the 1,500 mineral species, only about 100 possess all of the attributes required in gems. Silicates furnish the greatest number, including such minerals as beryl, topaz, tourmaline, and feldspar. Oxides such as corundum (ruby and sapphire) and quartz (amethyst, agate, etc.) comprise the second largest group. Sulfides, carbonates, and sulfates are of small importance; the phosphates yield only turquoise and variscite. An exception is pearl, essentially calcium carbonate, which is ranked high as a gem. Diamond, the best known gem stone, is an isometric crystalline form of the element carbon.

In general, gem materials are classified the same as minerals, that is, into group, species, and variety. Group refers to two or more gem materials that are similar in crystal structure and physical properties but have different chemical properties. Each individual member of the group is called a species. Varieties of species have similar crystal structure and chemical characteristics but differ in color. An example of this would be the hessonite variety of the grossular species of the garnet group.

### Products for Trade and Industry

Cutting and polishing of gem materials are done to obtain the most effective display of the material. No significant change is made in the fundamental properties, and the preparation is intended to enhance the desirable characteristics that are present initially. Gem materials are cut into gem stones in three main styles; cabochons, baroque, and faceted.

Cabochons are cut in four operations: sawing, grinding, sanding, and polishing. Sawing, the initial step in cutting, is customarily done with a diamond saw to obtain a slab or slice of the desired size and thickness from the rough gem material. The cabochon outline is scribed onto a flat surface, most often using a template for making a standard size for jewelry mountings. Rough grinding of the stone may be by metal-bond diamond, silicon carbide, or aluminum oxide wheels or coated abrasive disks. In grinding, the hardness of the gem material determines the grit and hardness of the abrasive used. Multiple grinding steps starting with 80- to 100-mesh (grit) through 600-mesh abrasives are normally used. The scratches left by grinding are removed by progressively finer grinding and sanding. Disk or belt sanders use bonded to cloth abrasives, waterproof reinforced paper abrasives, or cloth charged with abrasive pastes. The final polish is obtained by using hard felt, wood, or leather laps, with various polishing agents such as fine diamond compound, tin oxide, tripoli, chromium oxide, cerium oxide, alumina, and rouge.

Polished irregular shapes are called baroque gems. An inexpensive method of polishing baroque gems consists of tumbling them in rubber-lined drums, using a grinding and polishing medium with or without water.

Facet cutting is employed ordinarily on transparent gem stones to increase brilliancy and appearance and is generally confined to the harder materials. Softer materials may be faceted, but extreme care must be exercised in cutting and polishing the stones and in their use in jewelry. The "round brilliant" cut, most commonly used in faceting, has 58 facets, 33 above the circle "girdle" and 25 below it, arranged in eightfold symmetry. The "round brilliant" and some other common cuts are illustrated in figure 1.

### Industry Structure

An estimated 80% to 85% of gem and natural industrial diamond is marketed through the Central Selling Organization (CSO) by the Diamond Trading Co. Ltd. and the Industrial Distributors Ltd. The CSO sells uncut gem diamonds on behalf of De Beers and most other major producers at sights (approved bidder viewings) in London, England, in Lucerne, Switzerland, and Kimberley, Republic of South Africa.

The CSO has been extremely successful at maintaining the rough diamond market for about 50 years. In modern times there has never been a decrease in CSO's price of rough diamonds. Table 9 illustrates the timing and the amounts of the average CSO price increases for rough gem diamonds from 1949 until the present. The compounded affect of these increases is a price increase of about 1,800% over the approximately 41.5 years. Thus, a piece of rough that sold for $100 in August 1949, would sell for about $1,800 in April 1990.

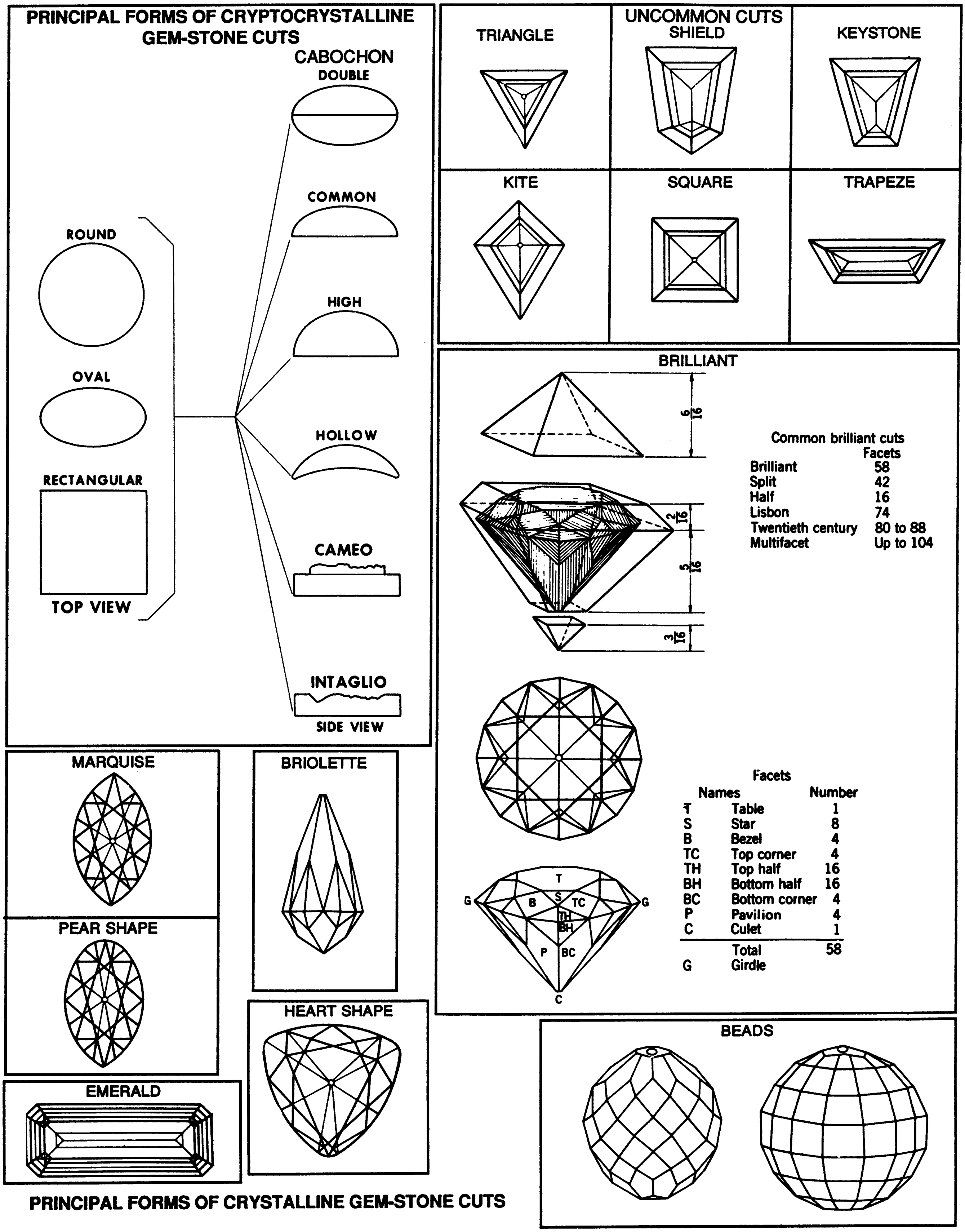
For more than 30 years, the major diamond cutting and polishing centers of the world were in Belgium and Israel, with a certain amount of the larger stones being cut in the United States. However, in the early 1980's, the development of a large cottage industry in India—today there is estimated to be more than 450,000 cutters—made a major impact on world diamond trade. Indian consumption of most of the world's small-gem, cheap-gem, and near-gem rough material in the manufacture of small stones resulted in annual cut-stone exports of almost $3 billion from April 1, 1988, to March 31, 1989. These small stones averaged less than one-fifth of a carat (0.20 carat). The availability of small inexpensive stones resulted in substantial changes in the design of jewelry. The utilization of small cut diamond stones (usually 0.07 to 0.14 carats each, called melee) to create a pavé effect (set close together to conceal the metal base) is but one example. Cutting and polishing of colored, synthetic, and simulant gem stones is centered in Thailand, India, Hong Kong, and Brazil, where cheap labor and favorable export laws ensure the lowest total costs for finished gems.

### Geology-Resources

Gem materials occur in a large variety of igneous, metamorphic, and sedimentary rocks and mineral deposits, usually as a small fraction of the total deposit. The origins are as varied as the occurrences. Principal formation of gem materials is by precipitation from watery solutions, by crystallization from molten rock, and by metamorphic processes. Approximately one-third of gem minerals is composed of silicate minerals, about one-fifth of alumina-silicates, and nearly one-seventh of oxides. The remaining compositional groups include the sulfides, phosphates, borosilicates, carbonates, and, in the single case of diamond, an element. The composition of selected gem materials is included as one of the items

FIGURE 1

**PRINCIPAL FORMS OF CRYPTOCRYSTALLINE AND CRYSTALLINE GEM STONE CUTS**



in table 2.

The United States has no defined large resources of major gem materials. Emerald deposits are known in North Carolina, as are ruby and sapphire. Historically, sapphires have been mined in Montana, and commercial mining once again is underway. Numerous other domestic deposits of gem minerals are known and have been mined for many years. However, no systematic evaluations of the magnitude of these deposits have been made, and no positive statements can be made about them.

Occasional finds of diamond have been made, but no great diamond pipes or alluvial deposits similar to those of Africa have been reported. Several companies are involved in diamond exploration in the Colorado-Wyoming State line area, in Michigan, Minnesota, Wisconsin, and Arkansas. Diamond-bearing kimberlites have been located, and bulk samples have been processed for diamond recovery. Results have not been made public.

World resources of gem materials are nearly all unevaluated. However, world gem diamond reserve is estimated to be about 300 million carats, including near-gem and cheap-gem qualities. Nearly all of the reserves are in Australia, Africa, and the U.S.S.R. (Siberia). The estimates for diamond reserves are of limited value because data needed for reliable estimates are not available from the producers. Reserve data on other gem materials are even less available than for diamond.

## Technology

*Synthetic Gems.*—The first synthetic gem produced was ruby, and later, by various melt techniques, sapphire, spinel, rutile, strontium titanate, and cubic zirconia. The Verneuil flame-fusion process, developed in 1902, consists of growing a single crystal in a simple, downward-impinging oxyhydrogen blowpipe flame. In manufacturing synthetic gems, pure oxides of aluminum and titanium, and as needed, moderating and coloring oxides, are charged at the top of a small furnace and melted as they pass through an oxygen-hydrogen flame. The molten material is solidified on a fireclay peg as a carrot-shaped single crystal known as a boule, usually ½ to 1 inch in diameter, 2 to 4 inches long, and weighing 75 to 250 carats. After cooling, the boule is heat treated and tapped at one end to relieve the internal strain that causes the boule to split into two vertical halves. The halves are then cut and polished into gems. Other melt techniques used are the Czochralski pulled-growth method for ruby, sapphire, spinel, yttrium-aluminum-garnet (YAG), gadolinium-gallium-garnet (GGG), and alexandrite; the Bridgman solidification method for sapphire; and skull melting for cubic zirconia and sapphire.

Solution techniques for manufacturing synthetic gems include flux methods for emerald, ruby, sapphire, spinel, YAG, GGG, and alexandrite; hydrothermal methods for emerald, quartz, and the colored varieties of quartz such as smoky, yellow, citrine, and amethyst; and the high temperature ultra-high-pressure presses used in the manufacture of synthetic diamond in which a molten metal is used as the solvent.

Other techniques involve solid- or liquid-state reactions and phase transformations for jade and lapis lazuli; vapor phase deposition for ruby and sapphire; ceramics for turquoise, lapis lazuli, and coral; and others for opal, glass, and plastics. However, the Verneuil, Czochralski, and scull melting processes are the melt techniques most often used for gem materials. The various synthetics and the method of production are shown in table 3.

*Enhancement of Gem Stones.*—Enhancement of all types of gem materials through chemical and physical means has become much more commonplace and in the past few years has included a wider variety of gem materials. Irradiation by electromagnetic spectrum (X-rays, gamma rays, etc.) and by energetic particles (neutrons, electrons, alphas, etc.) is being used to enhance or change the color of diamonds, topaz, tourmaline, quartz, beryl, sapphire, zircon, scapolite, and pearls. Blue topaz is normally irradiated, but this does not imply that all of these gem materials are regularly irradiated.[1]

A number of gem materials can be enhanced by chemical treatment or impregnations. The treatments may alter the bulk of the gem material or only penetrate the surface. This includes bleaching, oiling, waxing, plastic impregnations, color impregnations, and dying. The treatments that alter only the surface of the gem material include surface coatings of various types, interference filters, foil backings, surface decoration, and inscribing. Chemical treatment is more widespread than the common dying of quartz, treatment of turquoise, and oiling of emeralds. Chemical treatment and impregnations have been used to enhance chalcedony, coral, ivory, pearl, tiger's eye, emerald, lapis lazuli, opal, ruby, sapphire, turquoise, beryl, quartz, jade, diamonds, and amber.[2]

TABLE 1

### CSO ROUGH DIAMOND PRICE INCREASES, BY PERCENTAGE

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. | 1949 | 25.0 | Nov. | 1967 | 16.0 | Aug. | 1973 | 10.2 | Sept. | 1982 | 2.5 |
| Mar. | 1951 | 15.0 | Sept. | 1968 | 2.5 | Dec. | 1974 | 1.5 | Apr. | 1983 | 3.5 |
| Sept. | 1952 | 2.5 | July | 1969 | 4.0 | Jan. | 1976 | 3.0 | Aug. | 1986 | 7.5 |
| Jan. | 1954 | 2.0 | Nov. | 1971 | 5.0 | Sept. | 1976 | 5.8 | Nov. | 1986 | 7.0 |
| Jan. | 1957 | 5.7 | Jan. | 1972 | 5.4 | Mar. | 1977 | 15.0 | Sept. | 1987 | 10.0 |
| May | 1960 | 2.5 | Sept. | 1972 | 6.0 | Dec. | 1977 | 17.0 | Apr. | 1988 | 13.5 |
| Mar. | 1963 | 5.0 | Feb. | 1973 | 11.0 | Aug. | 1978 | 30.0 | Mar. | 1989 | 15.5 |
| Feb. | 1964 | 7.5 | Mar. | 1973 | 7.0 | Sept. | 1979 | 13.0 | Mar. | 1990 | 5.5 |
| Aug. | 1966 | 7.5 | May | 1973 | 10.0 | Feb. | 1980 | 12.0 | | | |

TABLE 2

## GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWELRY

| Name | Composition | Color | Practical size[1] | Cost[2] | Mohs | Specific gravity | Refraction | Refractive index | May be confused with— | Recognition characters |
|---|---|---|---|---|---|---|---|---|---|---|
| Amber | Hydrocarbon | Yellow, red, green, blue | Any | Low to medium | 2.0–2.5 | 1.0–1.1 | Single | 1.54 | Synthetic or pressed, plastics | Fossil resin, soft. |
| Beryl: | | | | | | | | | | |
| Aquamarine | Beryllium alluminum silicate. | Blue green to light blue | Any | Medium to high | 7.5–8.0 | 2.63–2.80 | Double | 1.58 | Synthetic spinel, blue topaz | Double refraction, refractive index. |
| Emerald | do. | Green | Medium | Very high | 7.5 | 2.63–2.80 | do. | 1.58 | Fused emerald, glass, tourmaline, peridot, green garnet, doublets | Emerald filter, dichroism, refractive index. |
| Emerald, synthetic | do. | do. | Small | High | 7.5–8.0 | 2.63–2.80 | do. | 1.58 | Genuine emerald | Flaws, brilliant, fluorescence in ultraviolet light. |
| Golden | do. | Yellow to golden | Any | Low to medium | 7.5–8.0 | 2.63–2.80 | do. | 1.58 | Citrine, topaz, glass, doublets | |
| Morganite | do. | Pink to rose | Any | do. | 7.5–8.0 | 2.63–2.80 | do. | 1.58 | Kunzite, tourmaline, pink sapphire | Refractive index. |
| Calcite: | | | | | | | | | | |
| Marble | Calcium carbonate | White, pink, red, blue, green, or brown | Any | Low | 3.0 | 2.72 | Double (strong) | 1.49–1.66 | Silicates, banded agate, alabaster gypsum | Translucent. |
| Mexican onyx | do. | do. | Any | Low | 3.0 | 2.72 | do. | 1.6 | do. | Banded, translucent. |
| Chrysoberyl: | | | | | | | | | | |
| Alexandrite | Beryllium aluminate | Green by day, red by artificial light | U.S.S.R. (small), Sri Lanka (medium) | High | 8.5 | 3.50–3.84 | Double | 1.75 | Synthetic | Dichroism, inclusions in synthetic sapphire. |
| Catseye | do. | Greenish to brownish | Small to large | do. | 8.5 | 3.50–3.84 | do. | 1.75 | Synthetic, shell | Gravity and translucence. |
| Chrysolte | do. | Yellow, green, and/or brown | Medium | Medium | 8.5 | 3.50–3.84 | do. | 1.75 | Tourmaline, peridot | Refractive index, silky. |
| Coral | Calcium carbonate | Orange, red, white, black, or green | Branching, medium | Low | 3.5–4.0 | 2.6–2.7 | do. | 1.49–1.66 | False coral | Dull translucent. |
| Corundum: | | | | | | | | | | |
| Ruby | Aluminum oxide | Rose to deep purplish red | Small | Very high | 9.0 | 3.95–4.10 | do. | 1.78 | Synthetics, including spinel | Inclusions, fluorescence. |
| Sapphire | do. | Blue | Medium | High | 9.0 | 3.95–4.10 | do. | 1.78 | do. | Inclusions, double refraction, dichroism. |

See footnotes at end of table.

TABLE 2—Continued

## GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWELRY

| Name | Composition | Color | Practical size[1] | Cost[2] | Mohs | Specific gravity | Refraction | Refractive index | May be confused with— | Recognition characters |
|---|---|---|---|---|---|---|---|---|---|---|
| Corundum—Continued | | | | | | | | | | |
| Sapphire, fancy | Aluminum oxide | Yellow, pink, white, orange, green, or violet | Medium to large | Medium | 9.0 | 3.95–4.10 | Double | 1.78 | Synthetics, glass and doublets | Inclusions, double refraction, refractive index. |
| Sapphire and ruby stars | do. | Red, pink, violet blue, or gray | do. | High to low | 9.0 | 3.95–4.10 | do. | 1.78 | Star quartz, synthetic stars | Shows asterism, color on side view. |
| Sapphire or ruby synthetic | do. | Yellow, pink, or blue | Up to 20 carats | Low | 9.0 | 3.95–4.10 | do. | 1.78 | Synthetic spinel, glass | Curved strae, bubble inclusions. |
| Diamond | Carbon | White, blue-white, yellow, brown, green, pink, blue | Any | Very high | 10.0 | 3.516–3.525 | Single | 2.42 | Zircon, titania, cubic zirconia | High index, dispersion, single refraction, hardness, cut, luster. |
| Feldspar: | | | | | | | | | | |
| Amazonstone | Alkali aluminum-silicate | Green | Large | Low | 6.0–6.5 | 2.56 | — | 1.52 | Jade | Cleavage, sheen, vitreous to pearly, opaque, grid. |
| Labradorite | Alkali aluminum-silicate | Gray with blue and bronze sheen color play | do. | Low | 6.0–6.5 | 2.56 | — | 1.56 | do. | Cleavage, sheen, vitreous to pearly opaque, grid. |
| Moonstone | do. | White | do. | Low | 6.0–6.5 | 2.77 | — | 1.52–1.54 | Glass or white onyx | Blue sheen, opalescent. |
| Garnet | Complex silicate | Brown, black, yellow, green, ruby red, or orange | Small to medium | Low to high | 6.5–7.5 | 3.15–4.30 | Single straine | 1.79–1.98 | Synthetics, spinel, glass | Single refraction, anomalous strain. |
| Jade: | | | | | | | | | | |
| Jadeite | do. | Green, yellow, black, white, or mauve | Large | Low to very high | 6.5–7.0 | 3.3–3.5 | Crypto-crystall | 1.65–1.68 | Onyx, bowenite, vesuvianite, grossularite | Luster, spectrum, translucent to opaque. |
| Nephrite | Complex hydrous silicate | do. | do. | do. | 6.0–6.5 | 2.96–3.10 | do. | 1.61–1.63 | do. | Do. |
| Peridot | Iron magnesium silicate | Yellow and/or green | Any | Medium | 6.5–7.0 | 3.27–3.37 | Double (strong | 1.65–1.69 | Tourmaline chrysoberyl | Strong double refraction, low dichroism. |
| Opal | Hydrous silica | Colors flash in white, gray, black, red, or yellow | Large | Low to high | 5.5–6.5 | 1.9–2.3 | Isotropic | 1.45 | Glass, synthetics, triplets | Play of color. |
| Pearl | Calcium carbonate | White, pink, or black | Small | do. | 2.5–4.0 | 2.6–2.85 | — | — | Cultured and imitation | Luster, structure, X-ray. |

See footnotes at end of table.

TABLE 2—Continued

## GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWELRY

| Name | Composition | Color | Practical size[1] | Cost[2] | Mohs | Specific gravity | Refraction | Refractive index | May be confused with— | Recognition characters |
|---|---|---|---|---|---|---|---|---|---|---|
| Quartz: | | | | | | | | | | |
| Agate | Silica | Any color | Large | Low | 7.0 | 2.58–2.64 | — | — | Glass, plastic, Mexican onyx | Cryptocrystalline, irregularly banded, dendritic inclusions. |
| Amethyst | do. | Purple | do. | Medium | 7.0 | 2.65–2.66 | Double | 1.55 | do. | Refractive index, double refraction, transparent. |
| Cairngorm | do. | Smoky | do. | Low | 7.0 | 2.65–2.66 | do. | 1.55 | do. | Do. |
| Citrine | do. | Yellow | do. | Low | 7.0 | 2.65–2.66 | do. | 1.55 | do. | Do. |
| Crystal, rock | do. | Colorless | do. | Low | 7.0 | 2.65–2.66 | do. | 1.55 | do. | Do. |
| Jasper | do. | Uniform or spotted red, yellow, or green | do. | Low | 7.0 | 2.58–2.64 | — | — | do. | Opaque, vitreous. |
| Onyx | do. | Many colors | do. | Low | 7.0 | 2.58–2.64 | — | — | do. | Uniformly banded. |
| Rose | do. | Pink, rose red | do. | Low | 7.0 | 2.65–2.66 | Double | 1.55 | do. | Refractive index, double refraction, translucent. |
| Spinel | Magnesium aluminum oxide. | Any | Small to medium | Medium | 8.0 | 3.5–3.7 | Single | 1.72 | Synthetic, garnet | Refractive index, single refraction, inclusions. |
| Spinel, synthetic | do. | Any | Up to 40 carats | Low | 8.0 | 3.5–3.7 | Double | 1.73 | Spinel, corundum, beryl, topaz, alexandrite | Weak double refraction, curved striae, bubbles. |
| Spodumene: | | | | | | | | | | |
| Kunzite | Lithium aluminum silicate | Pink to lilac | Medium | Medium | 6.5–7.0 | 3.13–3.20 | do. | 1.66 | Amethyst, morganite | Refractive index. |
| Hiddenite | do. | Yellow to green | do. | do. | 6.5–7.0 | do. | do. | | Synthetic spinel | Do. |
| Tanzanite | Complex silicate | Blue | Small | High | 6.0–7.0 | 3.30 | do. | 1.69 | Sapphire, synthetics. | Strong trichroism. |
| Topaz | do. | White, blue, green | Medium | Low to medium | 8.0 | 3.4–3.6 | do. | 1.62 | Beryl, quartz | Refractive index. |
| Tourmaline | do. | All, including mixed | do. | do. | 7.0–7.5 | 2.98–3.20 | do. | 1.63 | Peridot, beryl, corundum, glass | Double refraction, refractive index. |
| Turquoise | Copper aluminum phosphate | Blue to green phosphate | Large | Low | 6.0 | 2.60–2.83 | do. | 1.63 | Glass, plastics | Difficult if matrix not present, matrix usually limonitic. |
| Zircon | Zirconium silicate | White, blue, or brown, yellow, or green | Small to medium | Low to medium | 6.0–7.5 | 4.0–4.8 | Double (strong) | 1.79–1.98 | Diamond, synthetics, topaz, aquamarine | Double refraction, strongly dichroic, wear on facet edges. |

[1] Small—up to 5 carats; medium—up to 50 carats; large—more than 50 carats.
[2] Low—up to $25 per carat; medium—up to $200 per carat; high—more than $200 per carat.

The oldest and most common method of gem material enhancement is heat treating. Heat treatment of gem materials was used in Greece and Rome well before the Christian Era. Heat treatment can cause color change, structural change, and improve clarity. In the past, heat treatment was common for quartz and gem corundum. Today, materials that are heat treated to enhance their appearance include sapphire, topaz, beryl, tourmaline, quartz, zircon, amber, diamond, and zoisite.[3]

***Mining.***—Gem materials mining operations can range from the most primitive to the most sophisticated. In hard rock, at shallow depths, an operation by one, two, or three persons may be mined by prybar, pick, shovel, and baskets for carrying material. A larger operation may include drilling, blasting, and minimum timbering. Mechanized hauling and hoisting is done only at the larger mines.

Diamond mining in the kimberlite pipes of Africa and the U.S.S.R. and the lamproite pipes of Australia represent the ultimate in that huge quantities of ore must be mined to extract small quantities of diamond produced at as low a cost as possible.

Placer mining for gem stones ranges from small-scale, simple procedures to huge complicated operations. In some areas, digging is by hand, and sorting and recovery is by panning, screening, or sluicing. Diamond miners in the larger placer operations use bucket dredges and heavy-duty excavating equipment, as, for example, in Australia, Brazil, the Republic of South Africa, Namibia, and the U.S.S.R.

***Processing.***—Most gem stone material is broken or crushed where necessary and concentrated by various combinations of hand picking, washing, screening, or jigging. In large-scale operations, mineral benefication methods employ mechanization and the latest technology in all steps from primary crushing and screening to the final recovery processes. Diamond recovery, in particular, makes use of standard gravity methods, grease belts, electrostatic separation, skin-flotation, magnetic separation, separation by X-ray luminescence, and separation by optical sorting.

TABLE 3

SYNTHETIC GEM STONE PRODUCTION METHODS

| Gem stone | Production methods | Company | Date of first production |
|---|---|---|---|
| Ruby | Flux | Chatham | 1950's |
| | | Kashan | 1960's |
| | | Knischka | 1980's |
| | | J.O. Crystal (Ramaura) | 1980's |
| | Zone melt | Seiko | 1980's |
| | Melt pulling | Kyocera (Inamori) | 1970's |
| | Verneuil | Various producers | 1900's |
| Star ruby | do. | Various producers (Div. of Union Carbide) | 1900's |
| | Melt pulling | Kyocera | 1980's |
| | | Nakazumi | 1980's |
| Sapphire | Flux | Chatham | 1970's |
| | Zone melt | Seiko | 1980's |
| | Melt pulling | Kyocera | 1980's |
| | Verneuil | Various producers | 1900's |
| Star sapphire | do. | Linde | 1940's |
| Emerald | Flux | Chatham | 1930's |
| | | Gilson | 1960's |
| | | Kyocera | 1970's |
| | | Seiko | 1980's |
| | | Lennix | 1980's |
| | | U.S.S.R. | 1980's |
| | Hydrothermal | Lechleitner | 1960's |
| | | Regency | 1960's |
| | | Biron | 1980's |
| | | U.S.S.R. | 1980's |
| Alexandrite | Flux | Creative crystals | 1970's |
| | Melt pulling | Kyocera | 1970's |
| | Zone melt | Seiko | 1980's |
| Cubic zirconia | Skull melt | Various producers | 1970's |

## ANNUAL REVIEW

### Production

In 1990, all 50 States produced at least $1,000 worth of gem materials. Ten States accounted for 95% of the total value of natural gem material produced. The States, in order of declining value of production, were Tennessee, Arkansas, Arizona, Montana, California, Oregon, Alabama, North Carolina, Utah, and Texas. Certain States were known for the production of a single gem material (i.e., Tennessee for freshwater pearls and Arkansas for quartz). Other States produced a variety of gem materials. Arizona produced the greatest variety of gem materials. Production included agate, amethyst, antlerite, azurite, chrysocolla, fire agate, garnets, jade, malachite, obsidian, onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. California, Idaho, Montana, and North Carolina also produced a variety of gem materials. North Carolina was the only State to have produced all four of the major gems: diamond, emerald, ruby, and sapphire.

The average production value of natural gem materials for the past 10 years was $20.7 million per year, with a high of $52.9 million in 1990 and a low of $7.2 million in 1982. The value of production for the past 10 years must be separated into two trends. The first trend was the period between 1981 through 1985, during which time approximately 24 operations reported production. Production average $7.4 million per year and was generally level. During the second trend, 1986 to the present, production averaged $34.0 million and was the result of an increase of 1,567% in the number of producers surveyed.

The reported production value of synthetic and simulant gem materials was $20.5 million in 1990. The reported value of production increased 9%. The average value of production of synthetic and simulant gem materials for the past 5 years was $16.2 million, with a high of $20.5 million in 1990 and a low of $10.3 million in 1986. Thirteen firms, five in California, four in Arizona, and one each in Massachusetts, Michigan, New Jersey, and Ohio, produced synthetic and simulant gem material. The six States, in order of declining value of production, were Massachusetts, California, New Jersey, Michigan, Ohio, and Arizona.

Arizona is well known for the widest variety of gem materials produced by any State. In 1990, gem material production included agate, amethyst, antlerite, azurite, chrysocolla, fire agate, fluorite, garnet, jade, jasper, malachite, obsidian (Apache tears), onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. Yet, turquoise, peridot, petrified wood, and azurite/malachite accounted for more than 90% of the total value of gem material produced. Arizona was the largest producer of turquoise, peridot, and petrified wood in terms of dollar value in the United States. It was also the world's largest producer of the first two gem materials. Additionally, there are four manufacturers of synthetic or simulant gem materials in Arizona that produce about $100,000 worth of material each year.

Arkansas is famous for the production of quartz crystals. Yet, Arkansas is second in value of production of freshwater pearls and shells and the only State in the United States that has had any sustained diamond production.

For the past 19 years hobbyists have found from 300 to 1,500 diamonds per year at the Crater of Diamonds State Park. Since 1972, about 13,000 diamonds have been recovered; this amount of diamond production is insufficient to classify the United States as a diamond-producing country. Still, the potential to become a diamond producer may be there, and efforts were underway to evaluate this potential more fully. The program to evaluate the diamond deposit was halted by legal actions after completing three exploration drill holes. The program is currently on hold, awaiting the outcome of the litigations.

Gem material production from California includes a variety of materials. California is the leading tourmaline producer in the United States and the only producer of benitoite. Additionally, California produces agate, alabaster, beryl, dumortierite, fire agate, garnet, gem feldspar, jade, jasper, kunzite, lepidolite, obsidian, quartz, rhodonite, topaz, and turquoise. Yet, even with this long list of gem materials, most people think of California in terms of its State gem benitoite, the production of high-quality tourmalines, and its fine orange spessartine garnets.

In May 1989, Pala International reported the discovery of the largest gem tourmaline pocket found in the Himalaya Mine during the past 12 years. The pocket yielded about 500 kilograms of tourmaline; 50% was carving or cabochon grade, less than 1% was faceting grade, and the remainder was specimen grade.

California also has four manufacturers of synthetic or simulant gem materials. The State is the second largest producer of synthetics and simulants in terms of value of total production.

Colorado is not known as a gem material producing State, but it does hold some gem stone honors. For 4 or 5 years prior to 1988, Colorado had the only commercially operated amethyst mine in the United States. It has the only commercially mined deposit of lapis lazuli in the United States and one of the few dig-for-fee topaz deposits currently operating. Additionally, the State was the first to commercially produce turquoise and still has commercially operated turquoise mines. The State also produced the United States' finest gem-quality rhodochrosite and a quantity of high-quality rhodonite.

Many different locations in the State produce aquamarine, the Colorado State gem stone. The best known locations and the locations with the longest history of continued production (since about 1884) are Mount Antero and White Mountain in Chaffee County. Mount Antero, at 14,269 feet, may be the highest gem stone location in the United States. White Mountain, separated from Antero by a small saddle, is only slightly lower at 13,900 feet.

Star garnet, the Idaho State gem stone, leads the list of gem materials produced in the State. Idaho is one of two places that produce significant amounts of star garnet; India is the other. These almandite garnets are translucent, purplish-red stones that show four- or six-ray stars when cabochon cut or are transparent deep red stones that can be faceted. The primary sources of Idaho star garnet are the placer deposits on the East Fork of Emerald Creek and its tributary gulches in Benewah County. Additionally, the placers of Purdue Creek in Latah County yield star garnets. Currently, garnets that do not cut stars also are commercially mined from areas in Clearwater County. These garnets range from purplish rose-red to a highly prized "special pink." Gem-quality garnets occur at several other locations in Idaho and are mined periodically by hobbyists or professional collectors for the gem stone market.

Opal is the second largest contributor to the total value of gem material produced in Idaho. The varieties produced include precious, yellow, blue, pink, and common. The Spencer opal mine is the largest producer. At the Spencer Mine, precious opal occurs as one or more thin layers within common opal that have partially filled gas cavities within a rhyolite-obsidian flow. About 10% of the material is thick enough to cut into solid gems; the remainder is suitable for making doublets and triplets. The Spencer Mine is also the source of the pink opal, which occurs as either pink common opal or pink bodied precious opal.

In recent years, an increasing amount of gem material (smokey quartz, aquamarine, topaz, and garnets) has been recovered from the Sawtooth batholith. A significant portion of the batholith lays within the Sawtooth National Recreation Area, administered by the Forest Service, U.S. Department of Agriculture. Herein lies a possible problem. The Forest Service may prohibit the collection of gem and mineral specimens from the National Recreation Area under CFR Title 36, 269.9b, which prohibits the removal of "natural features of the land." Additionally, all mining is prohibited in a recreation area. It appears that material is still being collected from the area, but this may stop in the future. Hopefully, collectors and the Forest Service can arrive at some mutual understanding where hobbyists can collect material or possibly collect controlled amounts for the commercial market.

In the U.S. gem stone industry, Maine and tourmaline are almost synonymous. In 1822, Maine's Mount Mica was the site of the first gem stone production in the United States. In September 1991, Plumbago Mining Corp. was actively mining the Mount Mica pegmatite for gem material and mineral specimens. Over the years, Mount Mica produced hundreds of pounds of fine-quality gem and mineral specimen tourmaline.

Mount Mica is not the only large producer of high-quality tourmalines. Dunton Mine of Newry Hill is the most prolific gem tourmaline producer in Maine. Since its discovery in 1898, the mine has produced tons of gem- and specimen-grade tourmaline. Other mines and quarries in a three county area produce gem- and mineral specimen-grade tourmalines. These include the Bennett, BB #7, Emmons, Harvard, Tomminen, Waisenen, Black Mountain and Red Hill Quarries, and Nevel Mine in Oxford County. It also includes the Mount Apatite Quarries in Androscoggin County and the Fisher and Porcupine Hill Quarries in Sagadahoc County.

Maine also produces fine-quality beryls—aquamarine, heliodor, and morganite. Pegmatites in Oxford, Androscoggin, and Sagadahoc Counties regularly produce fine-quality blue and blue-green aquamarine, rich yellow and gold colored heliodor, and rose and peach colored morganite. In 1989, the largest rose colored morganite on record was found at the Bennett Quarry near Buckfield in Oxford County.

In 1989, Plumbago Mining Corp. opened the most significant commercial amethyst mine in the United States near the town of Sweden in Oxford County. Reported production in the first year of operation was about 5,000 pounds of gem-quality and specimen-grade amethyst. The gem material has good deep purple color, but is mostly small pieces. An officer of the company did report the cutting of a 12-carat stone from the material and that some material recovered would yield stones as large as 20 carats.

Montana produces many different gem materials, some suited to faceting, while others are better suited to the cutting of cabochons, carvings, or objects of art. The gem materials that come to mind when Montana is mentioned are sapphires and Montana moss agate, with Dryhead agates a very close third. Yet, amethyst, amazonite, azurite, covellite, cuprite, garnet, onyx, opal, petrified wood, rhodochrosite, rhodonite, smokey quartz, sphalerite, and wonderstone (banded rhyolite) are also produced or have been produced in the State for use as gem material.

Since 1865 Montana has produced sapphires. In recent years, it appears that the Montana sapphire has gained in popularity, and because of the improved popularity, production has increased significantly. Currently, commercial sapphire production is from deposits on the Missouri River in Lewis and Clark County, the Rock Creek area in Granite County, and from the Yogo Gulch area in Judith Basin County. Additionally, there are dig-for-fee sapphire operations on the Missouri River and Rock Creek.

Until 1989, the value of Nevada's gem material production was essentially dependent upon the production of turquoise and opal, and the production of turquoise was, and still is, declining. In 1989, Nevada reported the first major production of nephrite jade.

The Nevada jade is from a deposit near Tonopah. The material varies in color from different shades of green to black, and some is mottled with off-white to tan markings. The reported quality is from fine gem to carving-grade. Mine run jade is available from fist-size pieces to individual boulders that weigh more than 1 ton. The jade is very similar to good to fine Wyoming jade.

Nevada has been a major producer of turquoise since the 1930's, and until the early 1980's, the State was the largest turquoise producer in the United States. Estimates indicate that over the years, 75 to 100 different mines and/or prospects have produced sizable quantities of turquoise. Production varied from a few thousand dollars worth of material at some properties to more than a million dollars at others. Estimates of total production to date are between $40 to $50 million.

Precious opal production from deposits in the Virgin Valley area began in about 1906. The opal from Virgin Valley is comparable to any in the world for its vivid play of color and is unsurpassed in terms of the size of material available. The material varies in color from deep pure black to brown to yellowish-white to white to colorless. The play of color includes all the colors common to precious opal—red, blue, green, yellow, orange, and so on. The opal occurs primarily as replacement of wood, or sometimes, the replacement of cones of conifer trees. The uses of the opal are greatly restricted because of a severe problem with crazing. Currently, two mines in Virgin Valley are open to individuals on a dig-for-fee basis during the summer months. The operators of these mines also mine the deposits for their own inventories.

North Carolina is the only State in the United States where all four major gem materials, diamond, ruby, sapphire and emerald, are found. During 1988 was the last time all four major gem materials were found in the same year. The diamond was found in a gold placer mine, rubies and sapphires were recovered from the Cowee Valley, and emeralds were found near Hiddenite and Little Switzerland.

Production of ruby and sapphire from the Cowee Valley in Macon County began in 1895 when the American Prospecting and Mining Co. systematically mined and washed the gravels of Cowee Creek. Today some dig-for-fee operations are in the Cowee Valley. Many people pay to dig or purchase buckets of gravel to wash to recover gem corundum, garnets, and other gem materials.

Every year there is publicity concerning the discovery of large and valuable rubies and sapphires at one or more of the mines in Cowee Valley. No doubt large corundum crystals and pieces of corundum are found each year. Similarly, valuable rubies and sapphires may be found, but the number of large and valuable gems and the values of these gems often are over-stated. During the period when commercial mines operated in the area, gem material was found that would cut fine-quality 3- to 4-carat stones. Today, the amount of quality gem material has greatly declined. Most of the rubies found are not of top color or clarity and on average are suitable for cutting stones of a carat or less. The sapphires tend to be larger than the rubies and high-quality sapphires are more abundant than high-quality rubies.

In 1875, emeralds were discovered near what is now Hiddenite, with the first attempts at commercial mining of emeralds in the Hiddenite area in 1881. Other attempts at mining were made in the 1920's, the 1950's, the 1970's, and the latest ended in 1990. At different times the emerald deposits in the Hiddenite area have produced large emerald crystals, and some significant stones have been cut from Hiddenite material. Yet, to date, it has not been possible to maintain an economically viable mine operation on any of the deposits. This includes the last attempt that would have mass mined the deposit and used a berylometer to sort the emerald from the waste rock. The berylometer worked well, but the amount of emerald present did not support the project.

Historically, Oregon has been known for the production of various picture and scenic jaspers, agates, thundereggs, petrified wood, and to a certain degree, gem labradorite. Oregon's State rock, the "thunderegg," may be the best known gem material from Oregon. Graveyard Point, Priday, and Polka Dot are names that are uniquely associated with beautiful Oregon agates. The same is true for the relationships between the names Biggs, Deschutes, and Sucker Creek and picture or scenic jasper. Yet, gem labradorite, which includes both sunstone and heliolite, is currently the largest single contributor to the value of annual gem material production in Oregon. At least seven firms or individuals currently are producing sunstone and/or heliolite from three different geographic areas.

The other gem material to contribute significantly to the value of Oregon gem material production is opal. During 1988, the first significant commercial mining and marketing of a variety of very fine quality opals from Opal Butte began. The varieties produced include hyalite, rainbow, contra luz, hydrophane, crystal, fire, blue, and dendritic. Exquisite stones as large as 315 carats have been cut from contra luz rough from this deposit.

Tennessee has the largest U.S. production of freshwater pearls and freshwater mussel shells of the 11 producing States. The fishing and marketing of freshwater pearls and mussel shells are not new in the United States or in Tennessee. There has been an established U.S. freshwater mussel fishing industry since the mid-1850's. The mussels are from the family Unioidae, of which about 20 different species are commercially harvested. During 1990, the value of U.S. mussel shell exports was more than $50 million.

To date, freshwater pearls from the United States have been a byproduct of the shell industry. Currently, the primary use of the shells is to make the bead nucleus used by the Japanese cultured pearl industry. Additionally, the shells are used in making cameos and as mother-of-pearl. With the coming of the freshwater cultured pearl farms in Tennessee and the increasing popularity of freshwater pearl jewelry with the U.S. consumer, this may change. In 1963, the first experimental U.S. freshwater cultured pearl farm was established. Since the technology for culturing freshwater pearls was proven in the late 1970's, six freshwater pearl farms have been established. These farms are the beginning of the U.S. freshwater cultured pearl industry, and the cultured pearl is the heart and future of the U.S. pearl industry.

The gem material that Utah is best known for, topaz, is not well suited for use as a gem stone, but it does make a fine mineral specimen. Topaz crystals have been collected from certain rhyolite flows in the Thomas Mountains for more than 100 years. Similar crystals also are found in select rhyolites in the Wah Wah Mountains. The crystals from the Thomas Mountains are predominately small, 10 to 20 millimeters long and 4 to 6 millimeters across, and crystals from the Wah Wah Mountains are even smaller. Occasionally, large gem-quality crystals are found. The color of the topaz varies from colorless to light yellow, sherry brown, rose or light pink. Unfortunately, the light yellow to sherry brown color fades to colorless if exposed to sunlight or heat and rose or light pink colored crystals are rare. Because of the size of the crystals and problem with color fading, the material yields only small to very small colorless stones.

Another Utah gem material with nearly a 100-year production history is gem variscite, first produced in about 1893 near Fairfield. The latest recorded commercial production was from near Lucin during the summer of 1990. Variscite occurs as fracture fillings or as nodules. The nodules may be solid, almost geode in nature, or fractured solid nodules that have undergone alteration. The color of the variscite varies from deposit to deposit and from location to location within the same deposit. It is a shade of light to dark yellow-green, but can occur as a dark, nearly jade green and so pale as to appear almost white. It also can have black and brown spiderwebbing.

Another gem material from Utah is snowflake obsidian. Snowflake obsidian (also known as flower obsidian) earns its name from the bluish-white or grayish-white patterns of cristobalite included into the normally black obsidian. During 1990, two different firms produced this material commercially.

Topaz, variscite, and obsidian from Utah are well known and are nice materials. But, in the author's opinion, the red beryl from the Wah Wah Mountains is the most remarkable and desirable of Utah's gem materials. Bixbite, the variety name for red beryl (called red emerald by some) occurs in rhyolites at several locations in the Thomas and Wah Wah Ranges. The beryl varies in color from a pink to bright red, with the bright red being what could be called strong raspberry-red. The material from most of the locations is not as spectacular, either in crystal size or color, as the crystals from the Violet claims in the Wah Wah's.

The Violet claims in the Wah Wah's are the only known location for commercial production of red beryl. In recent years, the claims have furnished a small but steady supply of materials for both mineral specimens and a few fine-quality cut stones. The crystals average about 10 millimeters in length, and most are flawed. Because of the size of the crystals and flaws, finished stones only average about 0.40 carats with few more than 1 carat. The largest finished stone to date is only 4.46 carats. The material is expensive, but justifiably so, because of its beauty and rarity.

Certain other States produce a single gem material of note; they are Alaska with its two jade mines; Florida's agatized coral; Hawaii's black coral; Minnesota's thomsonite; New York's herkimer quartz; Ohio's flint; and South Dakota's rose quartz.

The value of production by individual gem material can be reported for those materials that have three of more producers and if one of the three does not account for more than 75% of the total or two of the producers account for 95% or more of the production. Table 4 is a list by commodity in alphabetic order, with values in dollars rounded to the nearest thousand.

### Consumption and Uses

Consumption of domestic gem material production was in the commercial and amateur manufacture of jewelry, for exhibit in gem and mineral collections, and for decorative purposes in statuettes, vases, other art objects, and certain industrial applications.

Industrial uses of tourmaline include a simple laboratory instrument to show the polarization of light, as a material to measure the compressibility of fluids, and in gages for measuring high pressures. Mortar and pestle sets, knife edges for balances, textile rollers, and spatulas are some nongem uses of agate. The manufacturing of jewel bearings for timing devices, gages, meters, and many other types of instruments requiring precision elements used natural gem material. These uses are now mostly supplied by artificial and synthetic crystalline materials.

TABLE 4

**VALUE OF 1990 U.S. GEM STONE PRODUCTION, BY GEM MATERIALS**

| Gem materials | Value |
|---|---|
| Agate | $250,000 |
| Beryl | 105,000 |
| Coral (all types) | 60,000 |
| Garnet | 78,000 |
| Gem feldspar | 500,000 |
| Geode/nodules | 240,000 |
| Fire agate | 20,000 |
| Jasper | 148,000 |
| Obsidian | 27,000 |
| Opal | 146,000 |
| Peridot | 884,000 |
| Petrified wood | 633,000 |
| Quartz | 1,767,000 |
| Sapphire/ruby | 3,727,000 |
| Topaz | 26,000 |
| Tourmaline | 350,000 |
| Turquoise | 1,105,000 |
| Total | 10,066,000 |

Some industrial applications requiring clean homogeneous stones used low-quality gem diamond. The quantity of natural and synthetic industrial-grade diamonds used in the United States each year is 12 to 15 times greater than the amount of diamonds consumed by the jewelry industry.

The uses of synthetic and simulant gem crystals include applications in frequency controllers, polarizers, transducers, radiation detectors, infrared optics, bearings, strain gages, amplifiers, lasers, lenses, crucibles, and many more. A recently developed use is as connectors for optical fibers.

The 1990 estimated value of U.S. apparent consumption was $3,059 million, down about 18% from 1989's record high. The average annual estimated consumption for the past 10 years was $2,871 million, with a high of $3,711 in 1989 and a low of $1,642 in 1982. The trend for estimated consumption for the past 10 years was one of continued growth with about 68% total increase.

In 1990, the value of U.S. estimated apparent consumption of diamonds decreased 18% to $2.6 billion. The average annual value of apparent consumption of diamonds for the past 10 years was $2,293 million, with a high of $3,115 million in 1989 and a low of $1,642 million in 1982. The trend for the value of apparent consumption for the past 10 years was one of significant increase. The value of apparent consumption of diamonds increased 90% over the period.

The 1990 estimated apparent consumption of colored stones, led by emerald, ruby, and sapphire, was valued at $397.1 million, a decrease of 3%. The annual average value of consumption of colored stones for the past 9 years was $325.0 million, with a high of $406.9 million in 1989 and a low of $252.4 million in 1982. The trend for apparent consumption of colored stones for the past 9 years was one of fluctuating increases and decreases, but the general tread was one of increased consumption.

The estimated apparent consumption of pearls—natural, cultured, and imitations—was $16.5 million, a decrease of about 89% from that of 1989. This large decrease makes one wonder if there is not an error in the import data for pearls. The value was only 17% of the 9-year low reached in 1982.

Estimated apparent consumption of synthetic and imitation gem materials increased about 115% to $94.1 million. Average apparent consumption of synthetic and imitation gem materials for the past 9 years was $55.2 million per year, with a high of $109.1 million in 1987 and a low of $13.9 million in 1982. The trend for apparent consumption for the past 9 years was one of generally strong growth except for the significant decrease in 1989. Annual apparent consumption increased about 577% over the 9 years.

### Prices

Demand, beauty, durability, rarity, freedom from defects, and perfection of cutting determine the value of a gem stone. But the major factor in establishing the price of gem diamond is the control over output and prices as exercised by the CSO Diamond Trading Co. Ltd. The CSO is a subsidiary of De Beers Consolidated Mines Ltd.

The average U.S. wholesale asking price of the top 25 grades ( D through H color and IF through VS2 clarity) of a 1-carat diamond fluctuated between $6,200 and $7,000 and was $7,000 at yearend. The average value per carat of all grades, sizes, and types of gem-quality diamond imports was $525, a 29% increase compared with that of 1989. The average value of diamond imports for the past 10 years was $405 per carat, with a high of $525 in 1990 and a low of $353 in 1984. The trend for the average annual value of diamonds imported for the past 10 years was one of general decline, from the 10-year high in 1980 to stable prices in 1986, 1987, and 1988, followed by the 1989 and 1990 increases.

The average yearend wholesale purchase price of a fine-quality 1-carat ruby, paid by retail jewelers on a per stone or memo basis, was $4,200, an increase of 20% from that of 1989. The average value of ruby imports increased 49% to $48.71 per carat. The average annual value of ruby imports for the past 9 years was $37.93 per carat, with a high of $48.71 in 1990 and a low of $16.42 in 1984. The trend for the value of ruby imports for the past 9 years was one of rapid decline, 52% for the period from 1982 to 1984. This was followed by a steady, moderate increase.

The average yearend wholesale purchase price of a fine-quality 1-carat sapphire, paid by retail jewelers on a per stone or memo basis, was $1,600, a 14% increase from that of 1989. The average value of sapphire imports decreased 11% to $21.57 per carat. The average annual value of sapphire imports for the past 9 years was $23.22 per carat, with a high of $27.97 in 1987 and a low of $18.50 in 1984. The trend for the value of sapphire imports for the past 9 years was one of fluctuating increases and decreases. The 9-year period ended with the 1990 value 12% below the 1982 value.

The average yearend wholesale purchase price of a fine-quality 1-carat emerald, paid by retail jewelers on a per stone or memo basis, was $2,750, the same as for 1989. The average value of emerald imports decreased 28% to $43.65 per carat. The average annual value of emerald imports for the past 10 years was $57.18 per carat, with a high of $78.79 in 1988 and a low of $35.06 in 1984. The trend for the value of emerald imports for the past 10 years was one of fluctuating increases and decreases from 1981 through 1984. A steady moderate growth followed until the 2 years of decline in 1989 and 1990, the average value in 1990 being about 76% of the 1981 value.

**Foreign Trade**

The export value of gem materials increased 33% to $1,566 million, a record high. The quantity of diamonds exported increased 45% to 1,003,760 carats, and the value of diamond exports increased about 29% to $1,398.8 million. The average annual quantity of diamonds exported for the past 10 years was 496,477 carats, with a high of 1,003,760 in 1990 and a low of 184,871 in 1982. The trend for the quantity of diamonds exported for the past 10 years was one of moderate decline, 13%, during the first 2 years, followed by significant growth, 443%, from 1983 to 1990. The average annual value of diamond exports for the past 10 years was $643.6 million, with a high of $1,398.8 million in 1990 and a low of $292.8 million in 1982. The trend for the value of diamond exports for the past 10 years was one of decline, 16%, over 3 years, followed by 3 years of moderate growth, 32%, and then 3 years of significant growth, 112%. This resulting in record-high exports in 1990.

The export of other precious stones, cut but unset and other than diamonds and pearls, increased about 62% to $70.6 million. The average annual export value for the past 9 years for these natural gem stones was $42.9 million, with a high of $70.6 million in 1990 and a low of $27.7 million in 1984. The 9-year trend for exports value of these types of gem materials was one of fluctuating increases and decreases, but one resulting in a significant total increase, 139% for the period.

Exports of synthetic gem material decreased 8% to $42.5 million. The average annual value of exports for the past 9 years was $18.6 million, with a high of $46.0 million in 1989 and a low of $6.0 million in 1987 and 1988. The 9-year trend for the value of exports was one of extreme decline, 52%, for 1982–88, followed by steady significant growth, 608%, during the past 2 years.

Exports of natural, cultured, and imitation pearls, not set or strung, decreased about 74% to $0.9 million.

Reexports of gem material decreased 84% to $47.3 million.

The value of gem materials imported decreased 10% to $4,609.3 million from the 1989 record high of $5,115 million. The value of imported gem diamonds accounted for about 86% of the total. The average annual value of gem material imports for the past 10 years was $3,839 million, with a high of $5,115 million in 1989 and a low of $2,384 million in 1982.

The value of imported gem diamonds decreased about 9% to $3,955.2 million from the 1989 record high of $4,358 million. The 10-year trend for the value of diamond imports was one of generally steady continuous growth

TABLE 5

**PRICES OF U.S. CUT DIAMONDS, BY SIZE AND QUALITY**

| Carat weight | Description, color [1] | Clarity [2] (GIA terms) | Price range per carat [3] Jan. 1989–Jan. 1990 | Average [4] July 1989 |
|---|---|---|---|---|
| 0.25 | G | VS1 | $1,300–$1,400 | $1,400 |
| .25 | G | VS2 | 1,100– 1,200 | 1,200 |
| .25 | G | SI1 | 880– 970 | 970 |
| .25 | H | VS1 | 1,100– 1,200 | 1,200 |
| .25 | H | VS2 | 1,000– 1,100 | 1,100 |
| .25 | H | SI1 | 860– 950 | 950 |
| .50 | G | VS1 | 2,500– 2,700 | 2,900 |
| .50 | G | VS2 | 2,300– 2,500 | 2,600 |
| .50 | G | SI1 | 1,900– 2,300 | 2,200 |
| .50 | H | VS1 | 2,300– 2,600 | 2,600 |
| .50 | H | VS2 | 2,100– 2,400 | 2,400 |
| .50 | H | SI1 | 1,800– 2,100 | 2,100 |
| .75 | G | VS1 | 2,900– 3,500 | 3,300 |
| .75 | G | VS2 | 2,700– 3,200 | 3,000 |
| .75 | G | SI1 | 2,300– 2,800 | 2,600 |
| .75 | H | VS1 | 2,600– 3,000 | 2,900 |
| .75 | H | VS2 | 2,300– 2,700 | 2,600 |
| .75 | H | SI1 | 2,100– 2,500 | 2,400 |
| 1.00 | G | VS1 | 4,600– 4,600 | 4,600 |
| 1.00 | G | VS2 | 4,100– 4,100 | 4,100 |
| 1.00 | G | SI1 | 3,500– 3,500 | 3,500 |
| 1.00 | H | VS1 | 4,100– 4,100 | 4,100 |
| 1.00 | H | VS2 | 3,600– 3,600 | 3,600 |
| 1.00 | H | SI1 | 3,200– 3,200 | 3,200 |

[1] Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; H-I—traces of color.
[2] Clarity: IF—no blemishes; VVS1—very, very slightly included; VS—very slightly included; VS2—very slightly included, but not visible; SI1—slightly included.
[3] Jeweler's Circular-Keystone. V. 161, No. 3, Feb. 1990.
[4] Jeweler's Circular-Keystone. V. 159, No. 2, Sept. 1989.

TABLE 6

## PRICES OF U.S. CUT COLORED GEM STONES, BY SIZE[1]

| Gem stones | Carat weight | Price range per carat in 1990[2] | Average price per carat[2] Jan. 1989 | Jan. 1990 |
|---|---|---|---|---|
| Amethyst | 1 | $6- $18 | $8.00 | $13.00 |
| Aquamarine | 1 | 100- 250 | 175.00 | 175.00 |
| Emerald | 1 | 1,900-3,500 | 2,400.00 | 2,750.00 |
| Garnet, tsavorite | 1 | 500- 800 | 950.00 | 650.00 |
| Ruby | 1 | 3,000-4,000 | 3,000.00 | 3,500.00 |
| Sapphire | 1 | 800-2,000 | 1,050.00 | 1,400.00 |
| Tanzanite | 1 | 250- 350 | 354.00 | 300.00 |
| Topaz | 1 | 6- 12 | 7.50 | 9.00 |
| Tourmaline, red | 1 | 60- 125 | 92.50 | 92.50 |

[1] Fine quality.
[2] Jewelers' Circular-Keystone. V. 161, No. 3, Mar. 1990, p. 190. These figures represent a sampling of net prices that wholesale colored stone dealers in various U.S. cities charged their cash customers during the month for fine-quality stones.

with an increase of 80% for the period. During the period, the value of imported uncut diamonds increased 42%, while the value of cut stones imported increased 89%.

The imports of cut diamonds decreased 29% in quantity and 11% in value to 6.3 million carats and $3,384.4 million, respectively. The average annual quantity of cut diamonds imported was 6.6 million carats, with a high of 8.9 million in 1989 and a low or 1.6 million carats in 1982. The trend for the quantity of cut diamond imports for the past 10 years was one of continued increases until the 1990 decline; the period still ended with imports 80% greater than at the beginning of the period. The average annual value of imported cut diamonds was $2,762.4 million, with a high of $3,805.5 in 1989 and a low of $1,641.0 million in 1982. The trend for the value of imported cut diamonds for the past 10 years was of strong growth and increases. The value at the end of the period was 88% greater than at the beginning.

The value of imports of other gem materials, led by emerald, ruby, and sapphire, was $558.9 million, an decrease of about 26% compared with that of 1989. Emerald imports decreased about 22% to $162.4 million. The average annual value of emerald imports for the past 10 years was $151.9 million, with a high of $207.5 million in 1989 and a low of $120.8 million in 1982. The 10-year trend for the value of emerald imports was one of fluctuating increases and decreases resulting in a 44% increase for the period.

The value of ruby imports increased 18% to $98.4 million, a record-high value for the past 10 years. The average annual value of imports for the past 10 years was $77.2 million, with a high of $98.4 in 1990 and a low of $58.7 in 1987. The 10-year trend for import values was one of extreme fluctuations. The period ended with values having increased 68% from the 10-year low and establishing a record high for the period.

The value of sapphire imports decreased 18% from the 1989 10-year high to $81.9 million. The average annual value of sapphire imports for the past 10 years was $81.8 million, with a high of $100.0 million in 1989 and a low of $63.3 million in 1982. The 10-year trend for the value of imports was one of extremely fluctuating increases and decreases. The period ended with the value slightly lower than at the beginning of the period.

The value of imported gem materials other than diamond, emerald, ruby, and sapphire decreased 41% to $216.2 million. The average annual value of imports was $325.3 million, with a high of $429.5 in 1988 and a low of $134.6 in 1981. The 10-year trend for the value of imports was one of fluctuating increases and decreases resulting in the period ending 61% higher than the period started.

### World Review

De Beers, Cententary AG's diamond marketing arm, the CSO, reported 1990 sales of rough, uncut diamonds increased 2% over that of 1989 to $4.17 billion. Sales for the year were up, but sales for the second half of 1990 were 32% less than the sales for the first half of the year. Also, if the sales were adjusted for inflation, which was about 6% in the United States and higher in other leading consumer countries, the value of diamond sales actually decreased. The CSO markets from 80% to 85% of the total world production of natural diamonds. Sales of colored stones remained strong.

Natural diamond production occurs in Africa, Asia, Australia, and South America. The principal producing localities are as follows: in Africa—Angola, Botswana, Namibia, the Republic of South Africa, and Zaire; in Asia—U.S.S.R. (northeastern Siberia and in the Yakut A.S.S.R.); in Australia; and in South America—Venezuela and Brazil.

Foreign countries in which major gem stone deposits (other than diamond) occur are Afghanistan (beryl, kunzite, ruby, tourmaline); Australia (beryl, opal, sapphire); Brazil (agate, amethyst, beryl, kunzite, ruby, sapphire, tourmaline, topaz); Burma (beryl, jade, ruby, sapphire, topaz); Colombia (beryl, sapphire); Kenya (beryl, garnet, sapphire); Madagascar (beryl, rose quartz, sapphire, tourmaline); Mexico (agate, opal, topaz); Sri Lanka (beryl, ruby, sapphire, topaz); Tanzania (tanzanite, garnet, ruby, sapphire, tourmaline); and Zambia (amethyst, beryl).

***Angola.***—Endiama, the state diamond company, signed a two-part agreement with De Beers' CSO that reestablished a trading relationship that was ended in 1985. The first part of the agreement calls for De Beers to provide a $50 million loan to Endiama to be used to increase the production from the Cuango area. De Beers will market all of the production from the Cuango area; the area accounts for about 80% of Angola's production.

The second part of the agreement calls for De Beers to spend $50 million over 5 years on the evaluation of the Camutue kimberlite in northeastern Angola and on the search for additional kimberlite sources of diamonds.

Any mines resulting from this agreement will be jointly developed by De Beers and Endiama.

Endiama also signed an agreement with Steinmetz Evens Diamonds for the sale of diamonds produced in the Andrada and Lucapa areas. The alluvial deposits of these areas are about depleted and are of little interest to De Beers.[4]

*Australia.*—Diamond production in Australia decreased slightly because of a decrease in the production from Argyle. Argyle produced 33.8 million carats compared with 1989 production of 34.4 million, a decrease of about 2%. Estimates of 1990 Bow River production are about 900,000 carats.

In a move to increase the market for diamonds from the Argyle mine, Argyle Diamonds of Australia announced a multimillion dollar advertisement program to promote champagne colored diamonds. The multipart program will be directed primarily at the U.S. market.

More than 90 companies are involved in diamond projects in Australia, with another 23 companies exploring for diamonds on offshore projects. The success of the Argyle mine and reassessment of old information has led to the latest rush concentrated in New South Wales, with some companies in northern New South Wales claiming to have discovered pipes larger than that at Argyle.

Miners in Coober Pedy claimed to have found the world's biggest opal; the uncut opal weighed 5.27 kilograms and has an estimated worth of $3 million. The stone is 233.37 centimeters long and 12.19 centimeters wide. The opal is milky white in color.

*Botswana.*—Corona Corp. agreed to acquire control of Repadre Capital Corp. and the new firm will be named Corona Diamonds International Corp. Repadre had agreed to a joint venture with Ampal (Pty.) Ltd. to develop Ampal's diamond licenses in Botswana. Ampal holds multiple prospecting licenses covering about 20,700 square kilometers upon which a number of kimberlites have been identified. Exploration drilling is schedule to start on 30 to 50 of these targets. Corona Diamonds could earn a 40% interest in the properties by spending about $1.75 million before December 31, 1991. Additional interests can be earned by further expenditures.

The Government of Botswana and Lazare Kaplan International Inc. (LKI) signed a long-term agreement for a diamond cutting and polishing factory in Botswana. The agreement represent a major investment by a U.S. company in Botswana. The factory will be a state-of-the-art plant using automated and manual equipment. LKI will manage the plant and train Botswana workers as operators. It is anticipated that the plant will ultimately employ at least 500 skilled workers.

The Government of Botswana and Mabrodiamn, 85% owner of Diamond Manufacturing Botswana (DMB), signed a contract to expand DMB's 12-year-old cutting factory at Garabone. The agreement was to expand the plant from its current 55 workers to 200 workers. The factory manufactures low-quality 2 grainer sawn rough, but some 10-carat sawn is manufactured also. Cutting factory labor costs in Botswana are lower than in Belgium, but higher than in the Far East.

*Canada.*—Uranerz Exploration and Mining of Canada reported finding two diamonds, one two millimeters and the other four millimeters, near Melfort in the area of Fort a la Corne. These diamonds are significantly larger than the microdiamonds found in the past. Microdiamonds have been found in the area by other companies, including Claud Resources and Monopros Ltd., a subsidiary of De Beers. None of the companies exploring in the area has yet to discover a commercial deposit of diamonds, but these larger stones do increase the interest of the companies exploring the area. Uranerz plans to spend $2 million on exploration in the area in the next 2 years.

*China.*—The Mineral Resources Bureau reports that geologists discovered 13 diamond deposits along the Tanlu Fault Zone that stretches across several Provinces in the eastern part of the country. The Bureau claims to have found more than 100 kimberlites and 4 diamond placers in Shandong Province, while in Liaoning Province it found 3 large primary deposits and 3 smaller placer deposits.

*Cook Islands.*—The Cook Islands received $25 million in aid from the U.S. Agency for International Development for the development of a black pearl industry. The pearl industry would be started on the island of Suwarrow and possibly extended to the islands of Pen-

TABLE 7

**U.S. EXPORTS AND REEXPORTS OF DIAMOND (EXCLUSIVE OF INDUSTRIAL DIAMOND), BY COUNTRY**

| Country | 1989 | | 1990 | |
|---|---|---|---|---|
| | Quantity (carats) | Value[1] (millions) | Quantity (carats) | Value[1] (millions) |
| Exports and reexports: | | | | |
| Belgium | 279,682 | $216.8 | 267,010 | $269.4 |
| Canada | 25,722 | 31.1 | 35,837 | 23.7 |
| France | 5,577 | 11.4 | 8,388 | 13.2 |
| Hong Kong | 140,686 | 253.5 | 163,845 | 316.4 |
| Israel | 250,888 | 214.2 | 248,766 | 221.0 |
| Japan | 114,634 | 206.8 | 98,777 | 282.9 |
| Singapore | 3,274 | 10.1 | 4,766 | 20.2 |
| Switzerland | 42,201 | 180.7 | 82,800 | 131.3 |
| Thailand | 39,575 | 16.4 | 51,211 | 35.1 |
| United Kingdom | 10,451 | 60.6 | 14,180 | 45.8 |
| Other | 137,798 | 42.1 | 28,180 | 39.7 |
| Total | 1,050,488 | 1,243.7 | 1,003,760 | 1,398.7 |

[1] Customs value.

Source: Bureau of the Census.

TABLE 8

## U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY

| Kind, range, and country of origin | 1989 | | 1990 | |
|---|---|---|---|---|
| | Quantity (carat) | Value[1] (millions) | Quantity (carat) | Value[1] (millions) |
| Rough or uncut, natural:[2] | | | | |
| Belgium | 57,962 | $18.0 | 104,544 | $26.1 |
| Brazil | 33,709 | 5.7 | 10,547 | 1.2 |
| Israel | 12,979 | 7.1 | 11,769 | 5.4 |
| Netherlands | 24,424 | 11.7 | 5,552 | 12.1 |
| South Africa, Republic of | 9,130 | 13.8 | 458 | .4 |
| Switzerland | 12,268 | 11.9 | 1,653 | 3.6 |
| United Kingdom | 747,397 | 254.0 | 300,579 | 287.1 |
| Venezuela | 7,275 | .9 | 8,923 | .5 |
| Other | 284,292 | 229.5 | 779,030 | 234.4 |
| Total | 1,189,436 | 552.6 | 1,223,055 | 570.8 |
| Cut but unset, not more than 0.5 carat: | | | | |
| Belgium | 1,531,997 | 962.7 | 769,047 | 326.9 |
| Brazil | 39,200 | 16.2 | 17,168 | 6.1 |
| Canada | 7,754 | 5.5 | 7,232 | 1.0 |
| Hong Kong | 101,828 | 48.1 | 176,077 | 45.4 |
| India | 3,136,459 | 792.4 | 2,946,261 | 768.8 |
| Israel | 1,784,444 | 1,104.3 | 471,820 | 224.0 |
| Netherlands | 19,227 | 24.1 | 4,363 | 2.4 |
| South Africa, Republic of | 10,707 | 15.7 | 8,326 | 7.5 |
| Switzerland | 41,986 | 75.6 | 12,894 | 4.7 |
| United Kingdom | 37,581 | 37.3 | 5,593 | 1.9 |
| Other | 138,808 | 57.0 | 80,997 | 39.8 |
| Total | 6,849,991 | 3,138.9 | 4,499,778 | 1,428.5 |
| Cut but unset, more than 0.5 carat: | | | | |
| Belgium | 266,164 | 99.0 | 516,109 | 651.1 |
| Hong Kong | 68,930 | 19.5 | 15,811 | 32.8 |
| India | 1,176,503 | 312.0 | 181,619 | 113.0 |
| Israel | 318,288 | 178.5 | 983,684 | 942.0 |
| Netherlands | 4,809 | 10.5 | 10,844 | 24.9 |
| South Africa, Republic of | 1,245 | .4 | 5,792 | 11.5 |
| Switzerland | 21,420 | 13.4 | 14,484 | 70.3 |
| United Kingdom | 11,116 | 8.2 | 28,288 | 52.6 |
| Other | 151,614 | 25.1 | 48,550 | 57.7 |
| Total | 2,020,089 | 666.6 | 1,805,181 | 1,955.9 |

[1] Customs value.
[2] Includes some natural advanced diamond.

Source: Bureau of the Census.

rhyn and Pukapuka.

*Guinea.*—Currently, at least four companies are either exploring for or mining diamonds in Guinea. Aredor, the company with the longest history in diamond operations in the country, is experiencing a decline in production and in profits. The decline in production is because of decreasing ore grades. The decreasing profits is because of a combination of lower diamond production and a lower sales price for diamonds. The 1990 average sales price for Aredor's diamonds was down 19% to $245 per carat.

Star Diamonds has a prospection license area 30 kilometers to the south and east of the Aredor lease. The alluvial deposits that are of the most interest are those on the flats near Bouro and those at the headwaters of the Bouloumba.

Sidam-Minorex is exploring in an area for diamonds near Forecariah, east of Conakry, and Hydro Mineral Exploration is exploring for diamonds near Bounoudou.

Brigade Aurifere de Guinee has a concession to mine gold in an area north of the Aredor lease in which diamonds may be found also.

*Hong Kong.*—Less than 50% (42 of 98) of the jadeite jewelry lots were sold at Christie's Swire Ltd.'s auction in October. The 42 lots brought in $1.4 million. The sale was disappointing according to Christie's, but the jadeite market is and always has been extremely volatile. In November, buyers purchased about 75% (90 of 121 lots) of the jadeite jewelry sold at auction by Sotheby's Hong Kong Ltd. The total purchase price of the jewelry was $4.02 million. According to a Sotheby's representative, the market for top-quality jade is strong, but the market for decorative materials is very soft.

*India.*—Imports of rough diamonds fell in 1990 by 16% in value and 37% in volume to $1.97 billion and 38 million carats, respectively. Total exports of polished stones for the year also declined, caratage decreased 13% to 8.7 million carats, and value fell 9% to $2.7 billion. The decline in demand of cut goods resulted in the closing down of thousands of production units in the past 12 months and as many as 20,000 workers laid off by yearend. The decreases were blamed on the recession in the United States and the Persian Gulf war. Cut diamonds account for 90% by value of gem and jewelry exports, which in turn account for nearly 20% of the country's total exports.

*Indonesia.*—Development of the Danau Seran diamond project in South East Kalimantan began in late 1990. Dry mining and a conventional diamond recovery plant will be used in place of a dredge. This approach is cheaper and easier to finance. The Danau Seran contains about 2.9 million cubic meters of diamondiferous gravel with a grade of 0.1 carats per cubic meter. The deposit will be mined over the next 3 years at a production rate of 72,000 cubic meters per month. The group that put up the $2 million in financing will control a 25% equity interest. The interests of Indonesian Diamond Corp. (formerly Acorn Securities) and Keymead have been reduced to 44.7% and 10.3%, respectively, with PT Aneka Tambang (Indonesian Government) holding the remainder.[5]

*Malaysia.*—Boulders of nephrite jade were discovered in Sabah State in the northern part of Borneo. The boulders ranged in size from about 0.5 meters to 1.0 meters. The jade has a flawless area of good color that is suitable for jewelry. The source of the boulders and the commercial viability of the deposit are not known at this time.

*Sierra Leone.*—The Government of Sierra Leone granted a 20-year concession to Sunshine Mining Co. of the United States to mine and market diamonds from the Kono kimberlite deposit. Exploration and development work to date indicates the deposit contains about 2.4 million carats of recoverable gem-quality diamonds. Sunshine estimated the project capital costs at about $54 million.

The Government of Sierra Leone granted a lease to Intertarade Prospecting, a Swedish firm, to mine diamonds in an area north of Freetown. The firm announced plans to spend about $3 million dollars on deposits that are reported to be of marginal viability.

Wildcat Holdings PL, a wholly oned subsidiary of Pioneer Resources, entered into an agreement with Xerxes Ltd. to explore for diamonds in the Baoma district. The area is believed to contain both alluvial and kimberlite diamond deposits.

*South Africa, Republic of.*—The De Beers Mine, the smallest of the four mines De Beers Consolidated Mines Ltd. operates in Kimberley, is scheduled to close in October 1990. Treatment of surfaces stockpile ore at the mine will continue well into 1991. The mine was discovered in 1871 and operated as an open pit mine until 1885, at which time underground operations were started. The mine closed in 1908 and remained closed until opening once more in 1960 and operated until 1990.

TABLE 9

**U.S. IMPORTS FOR CONSUMPTION OF GEM STONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY**

| Kind and country | 1989 | | 1990 | |
|---|---|---|---|---|
| | Quantity (carats) | Value[1] (millions) | Quantity (carats) | Value[1] (millions) |
| Emerald: | | | | |
| Belgium | 10,605 | $1.2 | 21,217 | $1.1 |
| Brazil | 80,829 | 12.8 | 1,189,248 | 6.3 |
| Colombia | 429,390 | 73.1 | 382,051 | 58.2 |
| France | 5,345 | 4.0 | 10,202 | 2.5 |
| Germany, Federal Republic of | 23,902 | 3.2 | 44,811 | 2.1 |
| Hong Kong | 135,423 | 18.9 | 156,111 | 13.2 |
| India | 2,068,254 | 25.9 | 1,317,886 | 24.7 |
| Israel | 89,559 | 24.7 | 93,973 | 20.6 |
| Japan | 10,178 | 1.1 | 2,769 | .2 |
| South Africa, Republic of | 146 | (2) | 52 | (2) |
| Switzerland | 60,265 | 28.6 | 144,394 | 18.9 |
| Taiwan | 1,681 | .7 | 4,533 | .2 |
| Thailand | 366,925 | 5.0 | 291,458 | 7.4 |
| United Kingdom | 6,187 | 2.5 | 9,722 | 2.6 |
| Other | 112,866 | 5.8 | 51,962 | 4.4 |
| Total | 3,401,555 | 207.5 | 3,720,389 | 162.4 |
| Ruby: | | | | |
| Belgium | 7,760 | 1.1 | 4,250 | .4 |
| Brazil | 8,093 | (2) | 1,562 | .1 |
| Colombia | 337 | (2) | 346 | .1 |
| France | 21,483 | 3.5 | 3,340 | 2.2 |
| Germany, Federal Republic of | 20,822 | .8 | 11,580 | .8 |
| Hong Kong | 79,583 | 6.1 | 49,175 | 5.3 |
| India | 455,954 | 1.6 | 313,583 | 2.3 |
| Israel | 26,326 | 3.8 | 12,857 | 1.1 |
| Japan | 796 | 0.4 | 13 | (2) |
| Switzerland | 70,098 | 19.7 | 190,056 | 26.6 |
| Thailand | 1,778,218 | 38.9 | 1,323,506 | 46.6 |
| United Kingdom | 3,596 | 2.9 | 66,831 | 6.5 |
| Other | 73,345 | 4.6 | 42,991 | 6.4 |
| Total | 2,546,411 | 83.4 | 2,020,090 | 98.4 |
| Sapphire: | | | | |
| Australia | 30,439 | .4 | 3,013 | .2 |
| Austria | 377 | (2) | 202 | (2) |
| Belgium | 26,155 | 2.2 | 14,131 | .5 |
| Brazil | 8,705 | .2 | 2,827 | .1 |
| Canada | 5,622 | .6 | 2,126 | .2 |
| Colombia | 358 | .2 | 1,328 | (2) |
| France | 7,825 | 1.4 | 2,409 | 1.9 |
| Germany, Federal Republic of | 31,999 | 1.4 | 44,834 | .9 |
| Hong Kong | 102,671 | 8.4 | 83,519 | 3.9 |
| India | 112,937 | 1.0 | 101,510 | .8 |
| Israel | 29,535 | 4.7 | 26,140 | 1.5 |
| Japan | 2,532 | .6 | 7,666 | .1 |

See footnotes at end of table.

TABLE 9—Continued

## U.S. IMPORTS FOR CONSUMPTION OF GEM STONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY

| Kind and country | 1989 Quantity (carats) | 1989 Value[1] (millions) | 1990 Quantity (carats) | 1990 Value[1] (millions) |
|---|---|---|---|---|
| Sapphire—Continued | | | | |
| Korea, Republic of | 9,024 | (2) | 204 | (2) |
| Singapore | 481 | (2) | 4,931 | .6 |
| Sri Lanka | 63,184 | 4.1 | 106,211 | 5.4 |
| Switzerland | 67,086 | 15.6 | 91,574 | 11.3 |
| Thailand | 3,576,666 | 55.1 | 3,248,891 | 51.2 |
| United Kingdom | 9,435 | 2.5 | 11,135 | 1.8 |
| Other | 34,348 | 1.6 | 44,113 | 1.5 |
| Total | 4,119,379 | 100.0 | 3,796,764 | 81.9 |
| Other: | | | | |
| Rough, uncut: | | | | |
| Australia | | 1.4 | | 1.7 |
| Brazil | | 36.0 | | 37.4 |
| Colombia | | 10.5 | | 2.4 |
| Hong Kong | | 2.2 | | (2) |
| Nigeria | NA | .7 | NA | .1 |
| Pakistan | | 1.4 | | .4 |
| South Africa, Republic of | | .2 | | .4 |
| Switzerland | | 1.3 | | 3.5 |
| United Kingdom | | (2) | | .4 |
| Zambia | | .5 | | 1.2 |
| Other | | 11.1 | | 16.3 |
| Total | NA | 65.3 | NA | 63.3 |
| Cut, set and unset: | | | | |
| Australia | | 10.7 | | 6.1 |
| Brazil | | 5.0 | | 12.7 |
| Canada | | .2 | | .5 |
| China | | 1.1 | | 1.9 |
| Germany, Federal Republic of | | 12.2 | | 19.6 |
| Hong Kong | NA | 21.2 | NA | 18.5 |
| India | | 3.7 | | 5.8 |
| Japan | | 118.3 | | 11.7 |
| Switzerland | | 1.3 | | 1.7 |
| Taiwan | | 1.8 | | 3.4 |
| Thailand | | 10.0 | | 41.1 |
| United Kingdom | | 2.4 | | 2.1 |
| Other | | 15.7 | | 21.4 |
| Total | NA | 203.6 | NA | 146.5 |

NA Not available.
[1] Customs value.
[2] Less than 1/10 unit.
Source: Bureau of the Census.

The Kim Diamond Cutting Works, a diamond cutting factory, was constructed in Kimberley. The factory will employ at least 1,280 workers and will process 30,000 carats of local rough per week. The plant will produce from 0.01- to 0.30-carats stones for the export market.

*Sri Lanka.*—The Government of Sri Lanka changed the regulations on the export of geuda three times during 1990. The first change was made at the end of July when the agreement to sell geuda only to Thailand was ended and the sale of geuda was opened to buyers from all countries. In August, the exports of geuda was restricted to milky corundum; therefore, only firms specializing in the heat treatment of this type of geuda could export materials. In October, the regulations were amended to include silky, yellow silky, ottu, ooral, diesel, and dalan geuda. The Government descriptions used for geuda based on appearance under reflected light include milky (white, blue or yellow with a milky or soapy appearance), silky (white or blue with a shiny effect over the entire stone caused by rutile inclusions), yellow silky (yellow with shiny effect), ottu (blue patches or bi-colored), coral (color concentrated in patches without a definite outline and difficult to locate color source), diesel (brownish with oily appearance similar to diesel), and dalan (loosely sued for two or more of the above varieties in small sizes, also for large stones with many cracks and bubbles). Under the new system the number of carats of geuda exported in-

TABLE 10

## VALUE OF U.S. IMPORTS OF SYNTHETIC AND IMITATION GEM STONES, INCLUDING PEARLS, BY COUNTRY

(Million dollars[1])

| Country | 1989 | 1990 |
|---|---|---|
| Synthetic, cut but unset: | | |
| Austria | 3.7 | 3.6 |
| France | .4 | .8 |
| Germany, Federal Republic of | 9.4 | 9.6 |
| Japan | .4 | .6 |
| Korea, Republic of | 4.3 | 5.5 |
| Switzerland | 3.8 | 3.1 |
| Other | 7.4 | 9.4 |
| Total | 29.4 | 32.6 |
| Imitation: | | |
| Austria | 40.0 | 53.6 |
| Czechoslovakia | 3.1 | 1.9 |
| Germany, Federal Republic of | 1.6 | 1.6 |
| Japan | .4 | .3 |
| Other | 12.2 | 3.2 |
| Total | 57.3 | 60.6 |

[1] Customs value.
Source: Bureau of the Census.

TABLE 11

## U.S. IMPORTS FOR CONSUMPTION OF GEM STONES

(Thousand carats and thousand dollars)

| Stones | 1989 | | 1990 | |
|---|---|---|---|---|
| | Quantity | Value [1] | Quantity | Value [1] |
| Diamonds: | | | | |
| Rough or uncut | 1,189 | 552,557 | 1,223 | 570,750 |
| Cut but unset | 8,870 | 3,805,590 | 6,305 | 3,384,472 |
| Emeralds: Cut but unset | 3,402 | 207,546 | 3,720 | 162,375 |
| Rubies and sapphires: Cut but unset | 6,666 | 183,344 | 5,817 | 180,375 |
| Pearls: | | | | |
| Natural | NA | 4,382 | NA | 3,734 |
| Cultured | NA | 144,335 | NA | 19,097 |
| Imitation | NA | 5,456 | NA | 3,814 |
| Other precious and semiprecious stones: | | | | |
| Rough, uncut | NA | 65,298 | NA | 63,751 |
| Cut, set and unset | NA | 55,909 | NA | 119,866 |
| Other | NA | NA | NA | 5,917 |
| Synthetic: | | | | |
| Cut but unset | 99,292 | 29,368 | 113,367 | 32,649 |
| Other | NA | 3,441 | NA | 1,911 |
| Imitation gem stone | NA | 57,323 | NA | 60,594 |
| Total | XX | 5,114,549 | XX | 4,609,305 |

NA Not available. XX Not applicable.

[1] Customs value.

Source: Bureau of the Census.

creased, but the value of geuda exports decreased.[6]

***Tanzania.***—The Government of Tanzania and Tanex Ltd., a company associated with De Beers Centerary AG, concluded an agreement to explore for diamonds over a large area south of Lake Victoria and to the south and west of the Williamson Mine. Exploration in the past has discovered several kimberlites that contained diamonds, but none were economical to mine.

***U.S.S.R.***—The Soviet Government entered into an agreement with De Beers giving De Beers exclusive marketing right to the U.S.S.R. diamond production for the next 5 years. The agreement was with Glavalmazzoloto, the organization that administers the sale and export of rough diamonds. Under the terms of the contract, a De Beers' subsidiary will provide a $1 billion advance against future production, but secured by the Soviet stockpile. It is estimated that the contract calls for a purchase of $1 billion worth of diamonds per year.

It is estimated that the U.S.S.R.'s diamond cutting industry employs about 16,000 workers. The eight Krystall factories at Moscow, Smolensk, Kiev, Barnaul, Vinnitsa, Yerecvan, Kusa, and Gomel employ fewer than 8,000, with the Moscow plant having about 900 workers. The workers at the various factories may be paid by different methods.

The workers at the Moscow plant are paid by the piece according to its size and difficulty of the cut. At Kiev, those workers whose work is not subject to inspection receive a 50% higher salary. Some of the Krystall factories have an incentive program for workers producing stones of 0.3 carats and larger. The incentive is a bonus of 5% of the added value, which is paid to each 20-worker team and is shared by the team.

Annual cut diamond production is a function of the number of workers in the industry and their productivity. If it is assumed that the industry has a production rate of 20 carats of finished goods per month per worker and that polished yields are less than 40%, then the industry's consumptions of rough and yield of finished can be estimated.

It is estimated that during a year the U.S.S.R.'s diamond cutting industry processes about 3.8 million carats of rough that yields about 1.6 million carats of polished goods. The polished goods would be worth between $500 million and $550 million on the world market.

Reportedly, the U.S.S.R. is considering a joint venture with unnamed Western concerns to open a new diamond mine and cutting factory. The mine would be on a deposit about 100 kilometers north of Archngel. Reports indicate that the deposit contains 50% gem-quality diamonds.

***Vietnam.***—A new ruby mine in Hoang Lien Son district of Luc Yen, 270 kilometers west of Hanoi, produced about 1.12 million carats of ruby during 1990. It is estimated by company officials that about 30% of the rough or 336,000 carats is top quality faceting rough; 40%, or 448,000 carats, is medium quality for faceting and cabochons; and 30% is low quality for beads and cabochons. The mine is operated by a Thai-Vietnamese joint venture between B.H. Mining Co. Ltd. and the Vietnamese state gem enterprise, Vinagemco. It is planned for the production to be sold at auction in Hanoi.

***Zaire.***—It was reported that a 345.7-carat diamond was found in the Sediza Mine. The stone is said to be internally flawless with only a few minor surface blemishes. Early estimates of the stone's value are as high as $3.8 million.

***Zambia.***—The Government of Zambia reduced restrictions on the mining and marketing of gem stones. Miners can now retain 50% of foreign exchange earnings instead of 20%. Additionally, a gem stone board, run by miners, and an auction system will be established. The Government estimates that Zambia exported $200 million worth of gem stones in 1989, although only $10 million were officially reported.

***Zimbabwe.***—De Beers was unable to reach agreement with the Government of Zimbabwe on the development of the River Ranch Kimberlite deposit near the southern border at Beitbridge. The deposit was originally discovered in 1975. The Government of Zimbabwe was unwilling to grant De Beers' CSO an exclusive marketing agreement. The Government wanted to market the production through its Minerals Marketing Corp., which would also retain a portion of the production for domestic processing. The Government has initiated procedures for the forfeiture of the River Ranch claims held by De Beers.

### Current Research

An oval jade cabochon in a ring offered to Sotheby's Hong Kong Ltd. for its 1990 jadeite jewelry auction was found to have been treated with a new procedure to improve its appearance. Testing by the Hong Kong Gems Laboratory discovered a coating that is a highly adhesive, colorless organic resin mixed with a chemical compound that makes it resistant to high temperatures. The Gemological Association of All Japan found an oval jade cabochon that had exceptionally good color, luster, and transparency that was poor quality white jadeite treated with a green resinous coating. The coatings can be identified by immersing the piece in methylene iodide and shining a bright light on the stone to display the thin transparent layer of the coating.[7]

## OUTLOOK

World demand for gem diamond can be expected to rise because of increasing effective personal income of the population of the United States and other industrialized countries. Also demand will increase because of highly effective promotional efforts. These promotions are changing social customs in many eastern countries, particularly with the use of diamond engagement rings. The changes are resulting in significant growth in the diamond market. Demand for other precious gems will continue to grow as diamonds become more expensive and the popularity and acceptance of colored stone increases. Demand for synthetic and simulant gem materials for both personal and industrial consumption is expected to increase. The diversity of sizes, types, uses, and values of gem materials precludes any meaningful forecasting of future demand.

[1] Nassau, K. Gemstone Enhancement. Buttersworth, 1984, pp. 46-60

[2] Jewelry News Asia, No. 75, Nov. 1990, pp. 61-78.

[3] Pages 25-44 of work cited in footnote 2.

[4] Mining Journal. V. 316, No. 8103, Jan. 4, 1991, p. 1.

[5] Industry in Action Mining Journal. V. 315, No. 8096 Nov. 9, 1990, p. 357.

[6] Jewelry News Asia, No. 76, Dec. 1990, p. 28.

[7] Jewelry News Asia, No. 75, Nov. 1990, p. 90.

## OTHER SOURCES OF INFORMATION


**Bureau of Mines Publications**

Gem Stone Producers in the United States, 1990.

Gem Stones. Ch. in Mineral Commodity Summaries, 1991.

Mineral Facts and Problems, 1985.

Mineral Industry Surveys, Annual Advance Summary Supplement: Directory of Principal.

Mineral Industry Surveys, Annual Advance Summary Supplement: Gem Stone Production In Arizona, Oregon, Maine, Utah, Nevada, and Tennessee.

TABLE 12

## DIAMOND: WORLD PRODUCTION, BY TYPE AND COUNTRY[1]

(Thousand carats)

| Country | 1986 | | | 1987 | | | 1988 | | | | 1989 | | | | 1990[e] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Natural | | | Natural | | | Natural | | | | Natural | | | | Natural | | | |
| | Gem[2] | Industrial | Total | Gem[2] | Industrial | Total | Gem[2] | Industrial | Total | Synthetic[3] | Gem[2] | Industrial | Total | Synthetic[3] | Gem[2] | Industrial | Total | Synthetic[3] |
| Angola | 240 | 10 | [e]250 | 180 | 10 | [e]190 | 950 | 50 | [e]1,000 | — | [r]1,165 | [r]80 | [r]1,245 | — | 1,200 | 80 | 1,280 | — |
| Australia | 13,145 | 16,066 | 29,211 | 13,650 | 16,683 | 30,333 | [r]17,413 | [r]17,413 | [r]34,826 | — | 17,540 | 17,540 | 35,080 | — | 17,331 | 17,331 | [4]34,662 | — |
| Botswana | 9,590 | 3,500 | 13,090 | 9,368 | 3,840 | 13,208 | 10,660 | 4,569 | 15,229 | — | 10,676 | 4,576 | 15,252 | — | 12,146 | 5,206 | [4]17,352 | — |
| Brazil | 310 | 315 | 625 | [r]300 | [r]200 | [r]500 | 353 | 180 | 533 | — | 350 | [r]150 | 500 | — | 350 | 150 | 500 | — |
| Central African Republic | 259 | 99 | 358 | 304 | 108 | 412 | 284 | 59 | 343 | — | [r]334 | [r]81 | [r]415 | — | 300 | 80 | 380 | — |
| China[e] | 200 | 800 | 1,000 | 200 | 800 | 1,000 | 200 | 800 | 1,000 | 15,000 | 200 | 800 | 1,000 | 15,000 | 200 | 800 | 1,000 | 15,000 |
| Côte d'Ivoire[e 5] | 10 | 4 | 14 | 15 | 6 | 21 | 8 | 3 | 11 | — | [r]9 | [r]3 | [r]12 | — | 9 | 3 | 12 | — |
| Czechoslovakia[e] | — | — | — | — | — | — | — | — | — | 5,000 | — | — | — | 5,000 | — | — | — | 5,000 |
| France[e] | — | — | — | — | — | — | — | — | — | 4,000 | — | — | — | 4,000 | — | — | — | 4,000 |
| Ghana[6] | 88 | 498 | 586 | 65 | 400 | 465 | [r]155 | [r]465 | [r e]620 | — | [r]124 | [r]370 | [r e]494 | — | 129 | 386 | 515 | — |
| Greece[e] | — | — | — | — | — | — | — | — | — | 1,000 | — | — | — | 1,000 | — | — | — | 1,000 |
| Guinea[6] | 190 | 14 | 204 | 163 | 12 | 175 | 136 | 10 | 146 | — | 138 | 10 | 148 | — | 130 | 5 | 135 | — |
| Guyana | 3 | 6 | 9 | 2 | 5 | [e]7 | 1 | 3 | 4 | — | [r]3 | [r]5 | [r]8 | — | 3 | 5 | 8 | — |
| India | 13 | 3 | 16 | [r]16 | 3 | [r]19 | [r]11 | 3 | 14 | — | 3 | [r]12 | [r]15 | — | 3 | 12 | 15 | — |
| Indonesia[e] | 6 | 22 | 28 | 7 | 22 | 29 | 7 | 22 | 29 | — | 7 | 25 | 32 | — | 7 | 23 | 30 | — |
| Ireland[e] | — | — | — | — | — | — | — | — | — | 60,000 | — | — | — | 60,000 | — | — | — | 60,000 |
| Japan[e] | — | — | — | — | — | — | — | — | — | 25,000 | — | — | — | 25,000 | — | — | — | 25,000 |
| Liberia | 63 | 189 | 252 | [r]112 | [r]183 | [r e]295 | 67 | 100 | 167 | — | [r]62 | [r]93 | [r]155 | — | 40 | 60 | 100 | — |
| Namibia | 970 | 40 | 1,010 | 971 | 50 | 1,021 | 901 | 37 | 938 | — | [r]910 | [r]17 | [r]927 | — | 735 | 13 | [4]748 | — |
| Romania[e] | — | — | — | — | — | — | — | — | — | 5,000 | — | — | — | 4,500 | — | — | — | 4,500 |
| Sierra Leone[5] | 215 | 100 | 315 | 150 | 75 | 225 | [r]12 | [r]6 | [r]18 | — | [r]90 | [r]39 | [r]129 | — | 100 | 50 | 150 | — |
| South Africa, Republic of: | | | | | | | | | | | | | | | | | | |
| Finsch Mine | 1,821 | 3,208 | 5,029 | 1,455 | 2,701 | 4,156 | 1,372 | 2,548 | 3,920 | — | 1,613 | 2,997 | 4,610 | — | 1,462 | 2,716 | [4]4,178 | — |
| Premier Mine | 882 | 1,977 | 2,859 | 772 | 1,713 | 2,485 | 696 | 1,543 | 2,239 | — | 689 | 1,526 | 2,215 | — | 724 | 1,604 | [4]2,328 | — |
| Other De Beers' properties[7] | 1,428 | 529 | 1,957 | 1,427 | 546 | 1,973 | 1,388 | 531 | 1,919 | — | 1,360 | 520 | 1,880 | — | 1,240 | 474 | [4]1,714 | — |
| Other | 342 | 41 | 383 | 409 | 30 | 439 | 361 | 65 | 426 | — | 348 | 63 | 411 | — | 400 | 74 | [4]474 | — |
| Total | 4,473 | 5,755 | 10,228 | 4,063 | 4,990 | 9,053 | 3,817 | 4,687 | 8,504 | [e]55,000 | 4,010 | 5,106 | 9,116 | [e]60,000 | 3,826 | 4,868 | [4]8,694 | 60,000 |
| Swaziland | 23 | 16 | 39 | 48 | 32 | [e]80 | 44 | 29 | 73 | — | 33 | 22 | 55 | — | 19 | 13 | 32 | — |
| Sweden[e] | — | — | — | — | — | — | — | — | — | 25,000 | — | — | — | 25,000 | — | — | — | 25,000 |
| Tanzania[e] | 133 | 57 | 190 | 105 | 45 | 150 | 105 | 45 | 150 | — | 105 | 45 | 150 | — | 105 | 45 | 150 | — |
| U.S.S.R.[e] | [r]7,400 | [r]7,400 | [r]14,800 | [r]7,400 | [r]7,400 | [r]14,800 | [r]7,500 | [r]7,500 | [r]15,000 | 41,500 | [r]7,500 | [r]7,500 | [r]15,000 | 41,500 | 7,500 | 7,500 | 15,000 | 41,000 |
| United States | — | — | — | — | — | — | — | — | — | W | — | — | — | W | — | — | — | W |
| Venezuela[8] | [r]46 | [r]165 | [r]212 | [r]38 | [r]68 | [r]106 | [r]54 | [r]74 | [r]128 | — | [r]70 | [r]185 | [r]255 | — | 88 | 245 | [4]333 | — |
| Yugoslavia[e] | — | — | — | — | — | — | — | — | — | 5,000 | — | — | — | 5,000 | — | — | — | 5,000 |
| Zaire | 4,661 | 18,643 | 23,304 | 3,885 | 15,540 | 19,425 | [r]2,724 | [r]15,439 | [r]18,163 | — | [r]2,663 | [r]15,092 | [r]17,755 | — | 2,700 | 15,300 | 18,000 | — |
| Total[8] | [r]42,038 | [r]53,702 | [r]95,741 | [r]41,042 | [r]50,472 | [r]91,514 | [r]45,402 | [r]51,494 | [r]96,896 | 241,500 | [r]45,992 | [r]51,751 | [r]97,743 | 246,000 | 46,921 | 52,175 | 99,096 | 245,500 |

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through May 17, 1991. Total diamond output (gem plus industrial) for each country actually is reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are U.S. Bureau of Mines estimates in the case of every country except Australia (1986-87), Botswana (1987), Brazil (1987), Central African Republic (1986-89), Guinea (1986-89), and Liberia (1986), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural, and for most countries, is based on the best available data at time of publication. Estimated distribution figures have been revised as necessary to correspond to reported total production figures.

[2] Includes near-gem and cheap-gem qualities.

[3] Includes all synthetic diamond production.

[4] Reported figure.

[5] Figures are estimates based on reported exports and do not include smuggled diamonds.

[6] Figures do not include smuggled artisanal production.

[7] Other De Beers' Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, Namaqualand Mines, and Venetia Mine.

[8] Data may not add to totals shown because of independent rounding.