GEMSTONES

By Gordon T. Austin

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Webster's defines a gem "as any jewel, whether stone, pearl or the like, having value and beauty that are intrinsic and not derived from its setting; a precious or, sometimes, a semiprecious stone cut and polished for ornament. A stone of value because it is carved or engraved, as a cameo or intaglio." Additionally, the dictionary states that gemstone or gem material is a stone or material from which a gem may be cut. In less formal or common terms a gem, gemstone, or gem material may be described as specimens of minerals or organic materials used for personal adornment, display, or to manufacture objects of art because they possess beauty, rarity, and durability.

In 1991, the value of natural gemstones from deposit in the United States was $84.4 million, an increase of 60% compared with that of 1990. Production of gemstones included faceting rough, lapidary rough, carving material, specimen material, natural and cultured freshwater pearls, mother of pearl, fossil ivory, amber, agatized coral, and coral.

Synthetic gemstones are grown in the laboratory but have essentially the same appearance, and optical, physical, and chemical properties as the natural material that they represent. Synthetic gemstones 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 gemstone 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 gemstones, would be classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced. In 1991, the reported combined production value of U.S. synthetic and simulant materials was $17.9 million, about a 17% decrease from that of 1990.

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

DOMESTIC DATA COVERAGE

The U.S. Bureau of Mines estimates U.S. production 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 number of operations surveyed in 1991 was essentially the same as the number surveyed in 1990. The response rate was essentially the same also. 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 gemstones 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 gemstones. The voyages of Columbus brought increased interest in gemstone 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 resulted in the development of the largest known diamond deposit in the world.

Commercial mining of gemstones has never been extensive in the United States. Although more than 60 different gem 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, as are many other gemstone deposits throughout the United States. Many gem-quality stones are found at these locations 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 gemstones data. Customarily, diamond, ruby, sapphire, and emerald are considered the major gems.

The most important qualities of gemstones 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. In cut gems, the perfection of the polish enhances the luster. 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 gemstones. In some cases these inclusions may be used to identify the country and even the mine from which the stone was recovered. 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 approximate 2,700 mineral species, only about 100 possess all of the attributes required of a gem. It must be noted that collectors of gems may not require that a gem be durable because the stone is destined for display and is not to be worn. Therefore, the number of species of gemstones may be greater than the 100 that meet all of the requirements. 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, is an isometric crystalline form of the element carbon.

In general, gemstones 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 gems from gemstones 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. Gemstones are cut into gems 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 gemstone. 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, electroplated diamond, silicon carbide, or aluminum oxide wheels or coated abrasive disks. In grinding, the hardness of the gemstone 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, or rouge.

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

Facet cutting usually is employed on transparent gemstones to increase brilliancy and appearance. It generally is 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. Often the softer gems are used only for display and not for making 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

The world market for rough diamonds is controlled to a degree by De Beers Centenary AG's marketing arm, the Central Sales Organization (CSO). It is by far the most controlled of the world's commodity markets. An estimated 80% to 85% of gem and natural industrial diamond is marketed by the CSO. The marketing is done through the 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, and Lucerne, Switzerland. There are 10 such sights each year.

Diamonds reach the CSO sights through three channels. De Beers owned and operated mines, contracts sales by mine owner and operators, and open-market competitive sales. The distribution of rough diamonds in the Republic of South Africa is determined by the South Africa Diamond Board. All categories of rough diamonds that can be processed economically in South Africa must first be offered to local manufacturers. Rough can be exported duty free only if it has first been offered to the local market, otherwise a 15% duty is charged. Different systems of offering rough on the local market apply to the different mine producers, but they must offer the rough to local manufacturers in a manner determined by the board.

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 1 illustrates the timing and the amounts of the average CSO price increases for rough gem diamonds from 1949 until the present, while table 2 indicates the value of CSO's annual sales for the past 10 years. The compounded effect over 43 years of these increases is a price increase of about 1,800%. Thus, a piece of rough that sold for $100 in August 1949 would sell for about $1,800 in April 1991. *(See tables 1 and 2.)*

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 500,000 cutters—made a major impact on world diamond trade. India consumes most of the world's small-gem, cheap-gem, and near-gem rough material in the manufacture of small stones, which resulted in annual cut-stone exports worth billions of dollars. 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 gemstones is centered in Thailand, India, Hong Kong, Korea, China, and Brazil, where cheap labor and favorable export laws ensure the lowest total costs for finished gems. 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, Yerevan, 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 that is paid to each 20-worker team that 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 consumption of rough and yield of finished goods 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.

During 1991, Leo and Schachter & Co. opened the United States' newest, largest, and most modern diamond polishing factory in New York. The factory is fully computerized to track every diamond from rough to finished stone. The computer predicts the cash return from each piece of rough based on estimates of the rough's color, clarity, yield, and make, estimates are reported to be within 2% of actuals. The factory employs 40 polishers.

Geology-Resources

Gemstones are found 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 deposits. Gemstones form primarily by precipitation from watery solutions, by crystallization from molten rock, and by metamorphic processes. Approximately one-third of gemstones is composed of silicate minerals, about one-fifth of alumina-silicates, and almost 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 in table 3. *(See table 3.)*

There are no large resources of major gem materials defined in the United States. Emerald deposits are known in North Carolina, as are ruby and sapphire. Historically, sapphires have been mined in Montana, and significant commercial mining once again is underway. Numerous other domestic deposits of gemstones 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 their reserve or the size of the resource.

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 gemstones 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 gemstones are even less available than for diamond.

Technology

Synthetic Gems.—Synthetic gemstone production uses many different methods, but they can be grouped into one of three types of processes: melt growth, solution growth, or extremely high-temperature, high-pressure growth.

The year 1902 saw the first production of synthetic ruby using the Verneuil flame-fusion process. Later, sapphire, spinel, rutile, and strontium titanate were grown with this technique. In this process, a single crystal, called a boule, forms in the flame of a simple, downward-impinging oxygen-hydrogen blowtorch. Pure oxides of aluminum (in the cases of ruby, sapphire, and spinel) or titanium (rutile and strontium titanate) are poured into the top of a small furnace and melted. Other oxides are added as needed for process control and to obtain the specific color desired. The melted material solidifies as a boule on a rotating fire-clay peg as the peg is slowly withdrawn.

A boule has a very characteristic shape, with a rounded end; a long, cylindrical body; and a tapering end. It is usually about 13 to 25 millimeters in diameter, 50 to 100 millimeters long, and weighs 75 to 250 carats (a carat is 200 milligrams). Under controlled conditions, boule about 5 millimeters in diameter and more than 890 millimeters long can be produced for the manufacturing of jewel bearings.

Another melt technique is the Bridgman-Stockbarge solidification method, named for an American, P. W. Bridgman, and a German, D. C. Stockbarge, who, aided by three Russians, J. Obreimov, G. Tammann, and L. Shubnikov, discovered and perfected the process between 1924 and 1936. Currently, the method is used primarily for growing nongem halide, sulfide, and various metallic oxide crystals, one of the metallic oxides being aluminum oxide or sapphire.

The Bridgman-Stockbarge process uses a specially shaped crucible, which is a cylindrical tube open at one end and capped at the other by a small, pointed cone. The crucible is filled with the powdered chemicals necessary to grow a specific crystal and is lowered slowly through a furnace. The small, pointed end of the cone cools first because it is the first part of the crucible that moves from the hottest part of the furnace into cooler regions and it is the first part to emerge from the furnace. As the crucible cools, the molten materials solidify, hopefully in the structure of a single crystal, in the point of the crucible. The crystal then acts as a seed around which the remainder of the molten material solidifies until the entire melt has frozen, filling the container with a single crystal.

This process is simple, and crystals of various sizes can be grown. The crystals are typically about 51 millimeters in diameter and 15 millimeters in length, but large ones exceeding 890 millimeters in diameter and weighing more than 1 metric ton have been grown. The crystals have the same shape as the crucible.

The Czochralshi pulled-growth method is used for ruby, sapphire, spinel, yttrium-aluminum-garnet (YAG), gadolinium-gallium-garnet (GGG), and alexandrite. Czochralshi developed his method about 1917 while working with crystals of metallic nutrients.

In the Czochralshi method, ingredient powders—nutrients—are melted in a platinum, iridium, graphite, or ceramic crucible. A seed crystal is attached to one end of a rotating rod, then the rod is lowered into the crucible until the seed just touches the melt. Then the rod is slowly withdrawn. The crystal grows as the seed pulls materials from the melt, and the material cools and solidifies. Yet, because of surface tension of the melt, the growing crystal stays in contact with the molten material and continues to grow until the melt is depleted of the desired material.

Typically, the seed is pulled from the melt at a rate of 1 to 100 millimeters per hour. Crystals grown using this method can be very large, more than 51 millimeters in diameter and 1 meter in length, and of very high purity. Each year this method grows millions of carats of crystals for use as gems, laser rods, windows for special scientific or technical applications, and for other industrial applications.

Certain gemstones pose unique problems with regard to attempts to grow them. The problems arise because certain materials are either so reactive that they cannot be melted even in unreactive platinum and iridium crucibles or they melt at much higher temperatures than the crucible materials can endure. Therefore, another melting system must be used, called the skull melting system. Cubic zirconia, because of its high melting point (2,700° C), must be grown using the skull melting method.

The "skull" is a hollow-walled copper cup. Water is circulated through the hollow walls to cool the inside wall of the skull. The cup is filled with powdered ingredients and heated by radio frequency induction until the powders melt. Because the water cools the walls of the skull, the powdered materials next to the walls do not melt, and the molten material is contained within a shell of unmelted material. Therefore, the reactive or high-temperature melt is contained within itself. When the heat source is removed and the system is allowed to cool, crystals form by nucleation and grow until the entire melt solidifies. Crystals grown using this system vary in size, depending on the number of nucleations. In growing cubic zirconia, a single skull yields about 1 kilogram of material per cycle.

Solution techniques for making synthetic gems include flux methods for emerald, ruby, sapphire, spinel, YAG, GGG, and alexandrite. The other solution method is the hydrothermal method, often used for growing beryl (emerald, aquamarine, and morganite) and quartz.

Quartz crystals are grown in a hydrothermal solution in large pressure vessels known as autoclaves. Careful control of temperature and pressure in the different areas of the autoclave result in the feed material, known as lascas, dissolving in the hotter portion. The material redeposits on seed crystals, located in the cooler portion, forming synthetic quartz crystals. The process usually takes 30 to 60 days for the crystals to reach the desired size. The process can also produce rock crystal, amethyst, or citrine.

The same system is used to grow beryl crystals. Beryl seed crystals are suspended in the cooler upper portion of an autoclave. Nutrient materials dissolve in the hotter, lower portion of the autoclave and, because of the temperature and pressure gradients, migrate to the cooler seeds and are deposited. 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.

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 4. *(See table 4.)*

Enhancement of Gemstones.—Enhancement of all types of gemstones through chemical and physical means has become much more commonplace and in the past few years has included a wider variety of 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]

Many gemstones 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 material include surface coatings of various types, interference filters, foil backings, surface decoration, and inscribing. Chemical treatment is more widespread than just the common dying of quartz, treatment of turquoise, and oiling of emeralds. Chemical treatment and impregnations have been used to enhance amber, beryl, chalcedony, coral, diamonds, emerald, ivory, jade, lapis lazuli, opal, pearl, quartz, ruby, sapphire, tiger's eye, and turquoise.[2]

Since about 1987, fractures, cleavages, and other void-type imperfections that reach the surface in diamonds have been filled using a process developed by Mr. Zvi Yehuda, of Ramat Gan, Israel. This treatment can enhance that apparent clarity of treated faceted diamonds; examples are available that show SI stones enhanced to VS and I1 improved to SI2. Recently, it was announced that Yehuda also had developed a similar treatment for emeralds.

The oldest and most common method of gemstone 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 amber, beryl, diamond, quartz, ruby, sapphire, topaz, tourmaline, zircon, and zoisite.[3]

Recently, an additional type of treatment for sapphire has appeared—diffusion treatment, a chemical-heat treatment. In this process a thin layer of color is diffused into the surface of the gem. The color may be diffused as little as 0.1 millimeter or as much as 0.4 millimeter into the gem. The treatment is a long process of heat treatment in a bath of chemicals containing the proper proportions of titanium and iron. The American Gem Trade Association (AGTA) adopted a policy for the disclosure of diffusion treated sapphires. The policy is "If the color of a gemstone is confined to an area near the surface so that the color of the stone would be visibly affected by recutting or repolishing then the following statement must also appear: Although the color induced in the diffusion treated sapphire is permanent, it remains confined to a shallow surface layer." Therefore, recutting or repolishing is not recommended.[4]

Mining.—Gemstone 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 buckets or baskets for carrying material; often drilling and blasting is employed. A larger operation includes 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 (20 to 30 carats per 100 tons of ore) produced at as low a cost as possible.

Placer mining for gemstones 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, Namibia, the Republic of South Africa, and the U.S.S.R.

Processing.—Most gemstones are broken or crushed where necessary and concentrated by various combinations of hand picking, washing, screening, or jigging. In large-scale operations, mineral beneficiation methods are mechanized and employ the latest technology in each step 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.

ANNUAL REVIEW

Production

In 1991, all 50 States produced at least $1,000 worth of gem materials. Ten States accounted for 95% of the total value of production of natural gemstones. The States, in order of declining value of production, were Tennessee, California, Missouri, South Dakota, Arizona, Montana, Oregon, Texas, Arkansas, and Nevada. Certain States were known best for the production of a single gem material (i.e., Tennessee for freshwater pearls and Arkansas for quartz). Other States produced a variety of gemstones. Arizona produced the greatest variety. 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 gemstones. Historically, North Carolina is 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 $28.4 million per year, with a high of $84.4 million in 1991 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 averaged $7.4 million per year and was generally level. In the second trend, 1986 to the present, production averaged $424 million and was the result of an increase of 1,567% in the number of producers surveyed. The reported value of synthetic and simulant gemstone production was $17.7 million in 1990. The reported value of production decreased 17%. The average value of production of these gem materials for the past 6 years was $16.5 million, with a high of $20.5 million in 1990 and a low of $10.3 million in 1986. Fifteen firms, five in California; four in Arizona; and one each in Massachusetts, Michigan, New Jersey, North Carolina, Ohio, and Washington, produce synthetic and simulant gem material. The eight States, in order of declining value of production, were Massachusetts, California, New Jersey, Michigan, Washington, North Carolina, Arizona, and Ohio.

Arizona is well known for the widest variety of gemstones produced by any State. In 1991, they 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. Production from Arizona of these gemstones was the largest in terms of dollar value in the United States and the world's largest for the first two. Additionally, four manufacturers of synthetic or simulant gem materials were in Arizona and produced about $100,000 worth of material.

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.

Since 1972 hobbyists have found from 300 to 1,500 diamonds per year at the Crater of Diamonds State Park. From 1906 to the present, it is estimated that production from the deposit is 100,000 to 150,000 carats; 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 exploratory drill holes. Although a Federal appellate court has cleared the way for the program to continue, the program is currently on hold.

Gemstone production from California includes a variety of materials. Tourmaline production from the State is the largest in the Nation, and California has the only producer of benitoite. Additionally, agate, alabaster, beryl, dumortierite, fire agate, freshwater mussel shell and pearls, garnet, gem feldspar, jade, jasper, kunzite, lepidolite, obsidian, quartz, rhodonite, topaz, and turquoise are produced from deposits in the State. Yet, even with this long list of gemstones, most people think of California in terms of its State gem benitoite, its 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 13 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. The Himalaya continues to produce substantial quantities of fine-quality tourmaline.

As unusual as it may sound, the State also has a freshwater culture pearl farm at Marysville. The farm uses animals imported from Tennessee and other southeastern States. Productions includes pearls, shell, and finished nucleus for cultured pearl implants.

California also has four manufacturers of synthetic or simulant gemstones. The value of production from the State is the second largest for synthetics and simulants.

Colorado is not known as a gemstone-producing State, but it does hold some gemstone 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 fee-for-dig 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 State's finest gem-quality rhodochrosite and a quantity of high-quality rhodonite.

Many different locations in the State produce aquamarine, the Colorado State gemstone. 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 4,349 meters, may be the highest gemstone location in the United States. White Mountain, separated from Antero by a small saddle, is only slightly lower at 4,237 meters.

Star garnet, the Idaho State gemstone, leads the list of gemstones 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 are found at several other locations in Idaho and are mined periodically by hobbyists or professional collectors for the gemstone market.

Opal is the second largest contributor to the total value of gemstone production 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) was 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 problem. The Forest Service prohibits 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.

In the U.S. gemstone industry, Maine and tourmaline are almost synonymous. In 1822, Maine's Mount Mica was the site of the first gemstone production in the United States. In 1991, Plumbago Mining Corp. was actively mining the Mount Mica pegmatite for gem material and mineral specimens. Over the years, production from Mount Mica has included hundreds of kilograms 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.

Production from Maine deposits also includes 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 2,300 kilograms 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. The mine did not produce during 1991.

Montana produces many different gemstones, some suited for faceting, while others are better suited for the cutting of cabochons, carvings, or objects-of-art. Montana is noted for the production of sapphires, Montana moss agate, and Dryhead agates. 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 from deposit in the State for use as gemstones.

Sapphires have been produced from Montana deposits since 1865. In recent years, 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 fee-for-dig sapphire operations on the Missouri River and Rock Creek.

Until 1989, the value of Nevada's gemstone 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 $1 million 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 is found primarily as replacement of wood, or sometimes, the replacement of cones of conifer trees. The use of the opal is greatly restricted because of a severe problem with crazing. Currently, two mines in Virgin Valley are open to individuals on a fee-for-dig 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, have been found. During 1988 was the last time all four major gemstones 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 deposits along 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 ruby, sapphire, and fee-for-dig 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 gemstones.

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 overstated. During the period when commercial mines operated in the area, gemstones were 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 1 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 were made in the 1920's, the 1950's, the 1970's, and the latest attempt 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 (sunstone) is currently the largest single contributor to the value of annual gemstone production in Oregon. At least seven firms or individuals currently are producing sunstone from three different geographic areas.

The other gemstone to contribute significantly to the value of production from Oregon 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 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 mussel shells and pearls of the 11 producing States. The fishing and marketing of freshwater mussel shells and pearls 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 1991 the value of U.S. mussel shell exports was more than $63 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 gemstone that Utah is best known for, topaz, is not well suited for use as a gem, 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 gemstone with nearly a 100-year production history is variscite, first produced in about 1893 near Fairfield. The latest recorded commercial production was from near Lucin during the summer of 1991. Variscite is found 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 be a dark, nearly jade green and so pale as to appear almost white. It also can have black and brown spiderwebbing.

Another 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 1991, 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 gemstones. Bixbite, the variety name for red beryl (called red emerald by some) is found 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 gems. 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 carat 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 1991 production by individual gemstone 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. *(See table 5.)*

Consumption and Uses

Consumption of domestic gemstones 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.

Frequently, tourmaline is used as a standard for calibrating piezoelectric manometers and testing devices. It is also a control substance in boron experiments because it is itself an inert boron-containing compound. Tourmaline is the standard used in tests to check possible effects of water-soluble boron in fertilizers.

Many scientific and industrial instruments use tourmaline. One such use is tourmaline tongs, a simple laboratory instrument that shows the polarization of light. Because tourmaline is both pyroeletric and piezoelectric, meaning it generates electricity when heated or compressed, it is a component of instruments for measuring high pressures and fluid compressibility. Thermal dosimeters, which were early instruments that measured the intensity of radium emanations, depended upon tourmaline's pyroelectric properties.

Once the mark of a top-rated watch or timepiece was that it was Swissmade and had 18 or 21 ruby or sapphire jewel bearings. Originally, these jewel bearings were made from natural ruby and sapphire. Later, the availability of inexpensive synthetic gemstones allowed the natural materials to be replaced in the manufacture of jewel bearings.

Why are ruby and sapphire used as bearings? Because ruby and sapphire, color variations of the mineral corundum, are second only to diamond in hardness; they have no cleavage (cleavage being the tendency for a crystallized mineral to break in certain definite directions, indicates a minimum value of cohesion in the direction easy fracture) and thus they are very durable; they have a very low coefficient of friction when highly polished; they are chemically inert; and they can be cut and polished without great difficulty.

Watches were not the only instruments in which sapphire and ruby bearings were used. Most precision gauges in aircraft and boats depend upon jewel bearings, as do many gauges, meters, and other instruments in manufacturing and chemical plants. The military is still highly dependent on jewel bearings for many of its high-tech weapons systems. Recently, another use for one type of jewel bearing appeared—as connectors for optical fibers.

In recent years, technological advances allowed the growth of large, high-quality synthetic ruby crystals, called laser ruby, for the manufacture of laser rods. Several other synthetic gemstones also are being produced for lasers, including chromium-doped chrysoberyl (dope being a element added to the crystal growing nutrients to achieve a particular color), synthetic alexandrite, and varieties of doped yttrium-aluminum-garnet (YAG).

Lasers require high-purity, optically perfect crystals. The crystal must be large enough so that a laser rod can be cut from the raw crystal, and the mineral or material must have the correct physical properties to allow light amplification without the necessity of excessive energy. Synthetic ruby, sapphire, and YAG have all these characteristics.

Over the years, both natural and synthetic corundum have been ground and graded as an abrasive. Corundum was the major compound used in the polishing of eyeglass lenses. While industrial diamond has replaced much of the corundum used in the lens-polishing industry, some polishers still use corundum for specialized lenses.

Other gem materials have enjoyed limited uses in nongem applications. The abrasive and ceramic industries use topaz as a raw material because of its hardness and chemical features. Once, lenses for eyeglasses were made from gem-quality beryl—if the morganite variety of beryl were used, one would truly be looking at the world through rose-colored glasses. Mortar and pestle sets, knife edges for balances, textile rollers, and spatulas are some nongem uses of agate.

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 1991 estimated value of U.S. apparent consumption was $3,059 million, down about 18% for 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 1991, the value of U.S. estimated apparent consumption of diamonds was essentially unchanged from that of 1990 at $2.6 billion. The average annual value of apparent consumption of diamonds for the past 10 years was $2,419 million, with a high of $3,115 million in 1989 and a low of $1,279 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 100% 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 $19.5 million, an increase of about 18% from the 10-year low in 1990. The average annual consumption for the past 10 years was $163.0 million, with a high of $244.7 million in 1984 and a low of $16.5 million in 1990.

Estimated apparent consumption of synthetic and imitation gemstones decreased about 78% to $20.9 million. Average apparent consumption of these materials for the past 10 years was $51.8 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 10 years was one of generally strong growth except for the significant decrease in 1989 and 1991. Annual apparent consumption at the end of the period was 50% greater than at the beginning of the period. The U.S. Department of Commerce reported that jewelry store retail sales were $13.8 billion, a 3.6% decrease compared with those of 1990.

Prices

Demand, beauty, durability, rarity, freedom from defects, and perfection of cutting determine the value of a gem. In establishing the price of gem diamond, the CSO's control over output and prices also is a major factor.

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 $7,200 and $7,300, and was $7,300 at yearend. The average value per carat of all grades, sizes, and types of gem-quality diamond imports was $517, a slight decrease compared with that of 1990. 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 stabile 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 decreased 39% to $29.80 per carat. The average annual value of ruby imports for the past 10 years was $37.12 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 10 years was one of rapid decline, 52% for the period from 1982 to 1984. This was followed by a steady, moderate increase until the 1991 decrease.

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 increased 8% to $23.31 per carat. The average annual value of sapphire imports for the past 10 years was $23.23 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 10 years was one of fluctuating increases and decreases. The 10-year period ended with the 1991 value 5% 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 4% to $42.01 per carat. The average annual value of emerald imports for the past 10 years was $55.65 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 1982 through 1984. A steady moderate growth followed until the 3 years of decline in 1989, 1990, and 1991. The average value in 1990 being about 76% of the 1981 value. *(See tables 6 and 7.)*

Foreign Trade

The value of exported exports plus reexports increased 9% to $1,712 million, a record high. The quantity of cut diamonds exported and reexported increased slightly to 1,008,154 carats, and the value of diamond exported and reexported decreased slightly to $1,351.2 million. The average annual quantity of cut diamonds exported and reexported for the past 10 years was 577,581 carats, with a high of 1,008,154 in 1991 and a low of 184,871 in 1982. The trend for the quantity of cut diamonds exported and reexported for the past 10 years was one of significant growth, 445%, from 1982 to 1991. The average annual value of cut diamonds exported and reexported for the past 10 years was $734.6 million, with a high of $1,398.8 in 1990 and a low of $292.8 million in 1982. The trend for the value for the past 10 years was one of fluctuating increase and decline over 3 years, followed by 6 years of growth, 32%, and then 1 year of slight decline. The period ended with value of exports and reexports 361% greater than at the start of the period.

The value of other precious stones, cut but unset and other than diamonds and pearls, exported and reexported increased to $71.9 million. The 10-year trend for value of exports plus reexports of these types of gemstones was one of fluctuating increases and decreases, but one resulting in a significant overall total increase for the period. The value of exports and reexports of other precious stones not cut or set was $113.6 million. An additional $22.1 million worth of other gemstones was exported or reexported during 1991.

The value of synthetic gemstone exports plus reexports was $21.9 million. The 10-year trend for the value of exports plus reexports was one of extreme decline during the period between 1982 to 1988, followed by significant growth, 608%, during 1989-90, and then a significant decline in 1991.

The value of natural, cultured, and imitation pearls, not set or strung, exports and reexports of pearls increased significantly to more than $4.2 million.

The value of gems and gemstones imported increased slightly to $4,640.6 million compared with those of 1990, but still below 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 gems and gemstones imports for the past 10 years was $4,027 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 increased slightly to $3992.0 million compared with that of 1990, but below 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 until the decline in 1990 and the small growth in 1991 that resulted in current value still being less than that of 1988. Even with the downward adjustment, total increase for the period was 108%. During the period the value of imported uncut diamonds increased 91%, while the value of cut stones imported increased 111%.

The imports of cut diamonds increased 6% in quantity and 2% in value to 6.7 million carats and $3,464.6 million, respectively. The average annual quantity of cut diamonds imported was 6.9 million carats, with a high of 8.9 million in 1989 and a low of 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 79% greater than at the beginning of the period. The average annual value of cut diamond imports was $2,929.2 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 cut diamond imports for the past 10 years was of strong growth and increases. The value at the end of the period was 111% greater than at the beginning.

The value of imports of other gem and gemstones, led by emerald, ruby, and sapphire, was $531.1 million, a decrease of about 5% compared with that of 1990. Emerald imports increased slightly to $165.5 million. The average annual value of emerald imports for the past 10 years was $155.3 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 37% increase for the period.

The value of ruby imports decreased 28% to $70.9 million from 1990's record-high value for the past 10 years of $98.4 million. The average annual value of imports for the past 10 years was $74.9 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 21% from the 10-year low for the period.

The value of sapphire imports was $81.6, essentially unchanged from that of 1990. The average annual value of sapphire imports for the past 10 years was $81.7 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 29% greater than that at the beginning of the period.

The value of imported gem materials other than diamond, emerald, ruby, and sapphire increased slightly to $213.1 million. The average annual value of imports was $332.5 million, with a high of $429.5 in 1988 and a low of $210.3 in 1990. The 10-year trend for the value of imports was one of fluctuating increases and decreases resulting in the period ending essentially at the same level that the period started. *(See tables 8, 9, 10, 11, and 12.)*

World Review

Diamond sales by De Beers Centenary AG was $3.93 billion in 1991, a decrease of 6% compared with 1990 sales of $4.17 billion. Sales during the second half of 1991 were only $1.84 billion, 11% less than the $2.08 billion sales for the second half of 1990. A De Beers official stated that the reduction in sales was the result of the Persian Gulf war and the economic turndown in the United States. De Beers controls about 80% of the rough, uncut diamonds sold in the world. Sales of colored stones remained strong.

In May, De Beers unveiled the 273-carat Centenary diamond, reportedly the largest top-colored, flawless diamond outside of the British Crown Jewels. The Centenary was cut from a 599-carat piece of rough recovered at the Premier Mine in the Republic of South Africa in 1986. Three years were spent in preparing, cutting, and polishing the modified heart-shaped stone. The Centenary is insured for more than $100 million.

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. *(See table 13.)*

Foreign countries in which major gemstone 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.—The Government of Angola's diamonds company, Endiama, entered into a prospecting agreement with a Portuguese-Zairian consortium. The consortium is Sociedade Portuguesa de Envestimentos and SAICAN; both firms are privately held. It is reported that the Zairian firm may have links with President Mobutu Sese Seko of Zaire. The prospecting rights are along the Cuango River near the Angola-Zaire border, the same area included in the April diamond sales agreement between Angola and De Beers Centenary.[5]

Australia.—Stirling Resources NL has entered into a joint venture with Sabminco NL on Stirling's Boab Creek exploration license in West Kimberleys of Western Australia. Stirling has identified what is interpreted to be a potential kimberlite pipe and buried alluvial channel. The license is adjacent to Sabminco's Diamond Mountain project area where Sabminco has recovered gem-quality diamonds from drill holes in a buried alluvial channel.

Brazil.—The Director of the Brazilian Gem and Precious Metal Institute announced that he expected that exports of cut gems and uncut gemstones would be about $200 million for 1991. This would be an increase of 18% compared with 1990's $170 million worth of exports. He is hopeful that exports will increase to as much as $500 million within 2 years. One reason for the increase in exports is that the domestic market is weak; in 1980 domestic purchases of gemstones was $800 million, in 1990 they were $360 million, and only $300 million in 1991.

Canada.—Uranerz Exploration, operator of its joint venture with Cameco, announced the recovery of additional diamonds from drill samples from the Fort a la Corne property. The latest stones recovered averaged 0.04 carat with the largest at 0.6 carat. Some on the stones recovered were of gem quality.

Uranerz's exploration program has identified 70 potential kimberlite pipes in a corridor that is 50 kilometers by 20 kilometers from Price Albert to Nipawin in Saskatchewan. The first 15 sites tested proved to be kimberlites, and to date a total of 160 diamonds have been recovered from drill cores. Uranerz is playing down the exploration results, but experts are speculating on the possibility of a diamond mine in Saskatchewan by the end of the decade. Normally, geologists search for indicator minerals, minerals that form under the same conditions as diamonds, but at the Fort a la Corne property they found the actual diamonds in the drill samples.

Dia Met Minerals Ltd. announced the results of the analysis of one drill hole on the Dia Met and BHP-Utah Mines Point Lake prospect, a 800-square-kilometer joint venture in the Northwest Territories. Analysis of a 59-kilogram sample of core taken from between 140 and 180 meters yielded 81 diamonds each less than 2 millimeters in diameter. The drill hole was in a kimberlite pipe that is estimated to have a surface area of between 162,000 and 324,000 square meters and to have a depth of 1 kilometer. The Point Lake prospect is about 480 kilometers north of Yellowknife, the capital of Northwest Territories. The announcement has set off a rush to stake claims around the Point Lake prospect.

China.—A 60.5-carat diamond was unearthed from the Wafangdian Mine in

Dalian city in northeast Liaoning Province. Since the Wafangdian Mine went into production in 1990 many diamonds more than 10 carats have been found.[6]

Argyle Diamonds has opened a diamond cutting and polishing factory in China. The factory is a joint project between the Australian International Development Assistance Bureau and the China Pearl, Diamond, Gem, and Jewelry Import and Export Corp.

The factory, about 30 kilometers from the center of Beijing, is one of the most modern and best equipped training factories in the world. It is planned for the factory to train about 900 cutters by the end of 1992. The factory began training with five Australian trained Chinese cutters and nine skilled international trainers recruited by Argyle.[7]

Cook Islands.—In June, about two-thirds of the 39,000 black pearls offered in the first full auction by Cook Islands Pearls Ltd. was sold. A total of 54 lots, with a reserve price of $2.7 million, was expected to bring more than $4.5 million. The highest successful bid for a single lot was $114,000 by Kikuchi Pearl Co. Ltd. of Japan.[8]

Ghana.—The Government of Ghana, Lazare Kaplan of the United States, and Inco Ltd. of Canada have entered into an agreement to mine and market Ghanaian diamonds. This is the first privatization of the diamond industry under the current Government. The agreement was 2 years in the making.

The agreement calls for a two-phased mining plan, the first of which will take 7 to 11 years to complete. The mine will be brought to a production level of about 0.5 million carats per year. The second phase will bring the mine to a production level of about 1 million carats per year. Currently, the mine production is between 0.1 and 0.2 million carats per year.

Murtob Mining Co. Ltd. of Akwatia purchased a diamond concentrating plant from Somerville Engineering Associates of England. The plant is trommel and jig-grease tables style.

Guinea.—Bridge Oil Inc.'s Aredor Mine recovered another 100-plus carat stone. Since 1986 the Aredor Mine has produced more than five stones more than 100 carats. The latest stone was 192.9 carats and estimated to be worth more than $2.0 million. The other large stones were; 100 carats sold in 1986 for $1.56 million, 143 carats sold in 1987 for $3.65 million, 181.77 carats sold in 1988 for $8.62 million, and a 255.6 carat sold for more than $10 million in 1989. The largest stone on record for the Aredor Mine was a nongem-quality 460-carat stone.[9]

India.—Total rough diamond imports for 1991 increased 57% in volume to 59,990,000 carats compared with those of 1990, while the value decreased 0.5% to $1,990 million. The net polished diamond exports for 1991 totaled 8,817,000 carats valued at $2,564 million, an increase of 0.2% and a decrease of 5%, respectively, compared with those of the previous year. This reflected the demand for cheaper goods for most of the year.

Ashton Mining, an Australian company, negotiated an agreement with the Indian National Mineral Development Corp. to assist in the modernization of the Panna Mine. The mine produced about 20,000 carats of diamonds in 1991, and the modernization is intended to increase production by increasing the amount of ore processed.

Indonesia.—Indonesian Diamond Corp. was delayed in the construction of its diamond plant in South East Kalimantan. The plant was ready for production in December 1991. The pilot plant, capable of running about 30 cubic meters per hour, processed material from the mine until the commercial plant was completed. The delay and cost overruns resulted in the plant costing about $1.1 million more than the original estimate of $2 million. The first diamonds from the commercial operation, 2,200 carats, were sold for an average price of $191 per carat. It is planned to operate both plants in the coming year to process about 54,000 cubic meters of ore per month and recover about 5,400 carats of diamonds each month.

Israel.—Israel has established a joint venture involving the U.S.S.R. and Panama to polish and market emeralds from the Ural area of the U.S.S.R. The joint venture will operate under the name Emural and have exclusive right on the U.S.S.R. emeralds for the next 50 years.

Two Israeli companies, Hargem and Izumrud, will supply the company with training as well as the polishing equipment and technology. Two factories were opened in the U.S.S.R. with about 200 workers and 4 Israeli experts. The joint venture is expected to eventually supply about 20% of the world emeralds.

The 1991 exports of polished diamonds from Israel were valued at $2,472 million, an 11% decrease compared with those of 1990. During the year, 630 diamond cutting factories employed more than 9,500 workers.

Namibia.—Consolidated Diamond Mines (CDM) began production at the open pit Elizabeth Bay Mine in June. It is planned that the mine will produce about 4 million tons of ore per year that will result in the recovery of about 250,000 carats of diamonds. The production from the Elizabeth Bay Mine will increase CDM's annual production to about 1 million carats per year. During the expected 10-year life of the mine, the mine should produce about 2.5 million carats of diamonds.

Monarch Minerals and Mining, Inc., a U.S. firm, announced production began at its new diamond mine in southeastern Namibia in July. The mine is located on Monarch's 50-square-kilometer mining concession at the mouth of the Fish River.

Tahiti.—Sales of black pearls at the 14th International Pearls Sale in Papeete, Tahiti, were 48,771 pearls for $4.97 million. These sales represented an increase of 19% in the number of pearls sold, but the total value of sales decreased 17% and the average price per pearl decreased 30% compared with those of 1990. The pearls ranged in size from 8.5 to 18 millimeters in diameter and were of much better quality than in recent years. There were 40 overseas buyers at the auction representing companies from 6 different countries.

Tanzania.—Late in the year the Government of Tanzania urgently invited tenders from competent companies for mineral rights at the Merelani tanzanite area, Arusha region. The tender areas are nine 200-meter by 300-meter blocks. The applicants must be experienced gemstone miners, processors, and marketers. Additionally, they must indicate the prospecting methods they intend to use, the availability of equipment, the method of drilling, a detailed work program, security arrangement for the mine, and the financial commitment to the program. The successful applicants will be required to post a $25,000 bond.

U.S.S.R.—Reports on Radio Moscow indicate the discovery of a major diamond field in Buryatskaya on the Soviet side of the Mongolian border. It is reported that more than 10 diamond-bearing sites in the eastern part of the Sayany Mountains were found. The discovery comes after 50 years of small-scale prospecting in the region, during which small quantities of diamonds were found.

The world's biggest new source of diamonds in this century may be the five kimberlite diamond pipes near the village of Pomorie at Lamonsov in the North Russian oblast of Archangelsk. Development plans for the pipes are for two shafts to a depth of about 1,000 meters, one on each side of the pipe. The cost to develop the five pipes, including the infrastructure and power station, is estimated to be $4 billion. Funds of the project will have to come from foreign sources or joint ventures.

Tokyo Maruichi Shoji Co. (Maruichi) of Japan entered into a joint venture with the Yakut Autonomous Soviet Socialist Republic for Maruichi to produce an unspecified amount of diamonds from the Republic for export to Japan. According to the agreement, approximately 10% of the diamonds will be cut and polished prior to export. This appears to be one step in the Yakut authorities taking control of the Republic's diamond production from the central U.S.S.R. Government.

Zimbabwe.—Auridium Consolidated NL of Australia has acquired the exploration license for the Ranch River diamond project that was forfeited by De Beers early in 1991. Kimberlitic Searches Ltd., a De Beers subsidiary, evaluated the project in the early 1980's and found the diamond project was uneconomical at that time. Auridium and its partner, Cornerstone Investments, Ltd., believe that given the current diamond market the project may be economical during the 1990's. Evaluations will be undertaken to determine if the deposit is economical at this time.

Delta Gold NL of Australia has applied for exploration rights in eight diamond-bearing areas totaling about 4,600 square kilometers. The company already has completed a great deal of fieldwork in the selected areas.

Current Research

An oval jade cabochon in a ring offered to Sotheby's Hong Kong Ltd. from 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.[10]

OUTLOOK

World demand for gem diamond can be expected to rise because of increasing effective personal incomes and the populations 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 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 gemstones increase. Demand for synthetic and simulant gemstones for both personal and industrial consumption is expected to increase. The diversity of sizes, types, uses, and values of gems and gemstones precludes any meaningful forecasting of future demand.

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[1]Nassau, K. Gemstone Enhancement. Buttersworth, 1984, pp. 46-60.
[2]CRA Gazette. July 1991, pp. 61-78.
[3]Pages 25-44 of work cited in footnote 2.
[4]Rapaport Diamond Report. Colored Stones Section. V. 15, No 9, Mar. 6, 1992, p. 26.
[5]Diamond Registry Bulletin. V. 23, No. 7, July 21, 1991, p. 3.
[6]Mining Journal. V. 316, No. 8128, June 28, 1991, p. 491.
[7]Page 6 of work cited in footnote 2.
[8]Business. Pacific Islands Monthly, v. 61, No. 7, July 1991, p. 48.
[9]Mining Journal. V. 317, No. 8132, July 26, 1991, p. 67.
[10]Jewellery News Asia. No. 75, Nov. 1990, p. 90.

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Gem Stones. Ch. in Mineral Commodity Summaries, 1992.
Mineral Facts and Problems, 1985.
Mineral Industry Surveys, Annual Advance Summary Supplement: Directory of Principal Gem Stone Producers in the United, 1990.
Mineral Industry Surveys, Annual Advance Summary Supplement: Gem Stone Production In Arizona, Arkansas, California, Colorado, Idaho, Montana, North Carolina, Oregon, Maine, New Hampshire, South Dakota, Utah, Nevada, and Tennessee.

TABLE 1

DE BEERS' 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

DE BEERS' CSO ROUGH DIAMOND SALES AND STOCKS

(Billions of dollars)

Year	Sales	Stocks
1982	1.30	1.71
1983	1.50	1.85
1984	1.61	1.95
1985	1.80	1.90
1986	2.56	1.85
1987	3.07	2.30
1988	4.17	2.00
1989	4.09	2.47
1990	4.17	2.68
1991	3.93	3.03

TABLE 3

GUIDE TO SELECTED GEMSTONES 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.

See footnotes at end of table.

TABLE 3—Continued
GUIDE TO SELECTED GEMSTONES 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
Chrysoberyl—Continued:										
Catseye	Beryllium aluminate	Greenish to brownish	Small to large	High	8.5	3.50-3.84	Double	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.
Sapphire, fancy	do.	Yellow, pink, white, orange, green, or violet	Medium to large	Medium	9.0	3.95-4.10	do.	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 striae, 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.

See footnotes at end of table.

TABLE 3—Continued

GUIDE TO SELECTED GEMSTONES 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
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	Large	Low	6.0-6.5	2.56	—	1.56	Jade	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 strained	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	Cryptocrystalline	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 3—Continued
GUIDE TO SELECTED GEMSTONES 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	2.58-2.66	—	—	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	Magnesuim 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	Double	1.66	Amethyst, morganite	Refractive index.

See footnotes at end of table.

TABLE 3—Continued

GUIDE TO SELECTED GEMSTONES 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
Spudumene—Continued:										
Hiddenite	Lithium aluminum silicate	Yellow to green	Medium	Medium	6.5-7.0	3.13-3.20	Double.	—	Synthetic spinel	Refractive index.
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	Glass, plastics	Difficult if matrix not present, matrix usually limonitic.
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.

TABLE 4
SYNTHETIC GEMSTONE PRODUCTION METHODS

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

TABLE 5
VALUE OF 1991 U.S. GEMSTONE PRODUCTION, BY GEM MATERIALS

Gem materials	Value
Agate	$535,000
Beryl	450,000
Coral (all types)	63,000
Garnet	251,000
Gem feldspar	1,485,750
Geode/nodules	769,640
Fire agate	194,100
Jasper	236,300
Obsidian	18,000
Opal	579,300
Peridot	1,757,000
Petrified wood	462,500
Quartz	5,197,300
Sapphire/ruby	3,282,000
Topaz	126,600
Tourmaline	629,000
Turquoise	610,800
Total	16,647,290

TABLE 6

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. 1990-Jan. 1991	Average[4] July 1991
0.25	G	VS1	$1,400 -$1,400	$1,400
.25	G	VS2	1,200 -1,200	1,200
.25	G	SI1	970 -970	970
.25	H	VS1	1,200 -1,200	1,200
.25	H	VS2	1,100 -1,100	1,100
.25	H	SI1	950 -950	950
.50	G	VS1	2,700 -2,700	2,700
.50	G	VS2	2,500 -2,500	2,500
.50	G	SI1	2,300 -2,300	2,300
.50	H	VS1	2,600 -2,600	2,600
.50	H	VS2	2,400 -2,400	2,400
.50	H	SI1	2,100 -2,100	2,100
.75	G	VS1	3,500 -3,500	3,500
.75	G	VS2	3,200 -3,200	3,200
.75	G	SI1	2,800 -2,800	2,800
.75	H	VS1	3,000 -3,000	3,000
.75	H	VS2	2,700 -2,700	2,700
.75	H	SI1	2,500 -2,500	2,500
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; G-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. 163, No. 3, Feb. 1991.
[4]Jeweler's Circular-Keystone, V. 162, No. 9, Sept. 1991.

TABLE 7

PRICES OF U.S. CUT COLORED GEMSTONES, BY SIZE[1]

Gemstone	Carat weight	Price range per carat in 1991[2]	Average price per carat[2]	
			Oct. 1990	Oct. 1991
Amethyst	1	$6 -$18	$13.00	$13.00
Aquamarine	1	100 -250	175.00	175.00
Emerald	1	1,900 -3,500	2,750.00	2,750.00
Garnet, tsavorite	1	500 -800	750.00	750.00
Ruby	1	3,000 -4,000	3,500.00	3,900.00
Sapphire	1	800 -2,000	1,400.00	1,400.00
Tanzanite	1	250 -350	262.50	210.00
Topaz	1	6 -12	9.00	9.00
Tourmaline, red	1	60 -125	92.50	92.50

[1]Fine quality.
[2]Jewelers' Circular-Keystone. V. 162, No. 12, Oct. 1991, p. 119. 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.

TABLE 8

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

Country	1990[r] Quantity (carats)	1990[r] Value[1] (millions)	1991 Quantity (carats)	1991 Value[1] (millions)
Exports and reexports:				
Belgium	305,621	$274.0	787,290	$341.7
Canada	81,072	40.8	303,492	32.0
France	9,280	14.7	8,746	23.7
Hong Kong	163,591	316.5	118,966	267.6
Israel	254,240	222.3	260,924	238.3
Japan	110,024	283.6	107,285	195.5
Singapore	4,766	20.2	19,550	27.5
Switzerland	82,937	131.6	43,456	143.3
Thailand	53,327	45.5	35,019	39.3
United Kingdom	83,358	47.2	12,682	37.6
Other	67,204	36.2	142,173	36.1
Total	1,215,420	1,432.6	1,839,583	[2]1,382.7

[r]Revised.
[1]Customs value.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 9

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

Kind, range, and country of origin	1990		1991	
	Quantity (carat)	Value[1] (millions)	Quantity (carat)	Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium	104,544	$26.1	455,621	$40.7
Brazil	10,547	1.2	106,396	9.8
Israel	11,769	5.4	17,097	10.3
Netherlands	5,552	12.1	18,334	9.2
South Africa, Republic of	458	r.3	13,787	7.6
Switzerland	1,653	3.6	64,717	18.9
United Kingdom	300,579	287.1	625,965	249.5
Venezuela	r8,423	.5	20,580	.3
Other	r779,530	234.4	460,339	181.1
Total	1,223,055	r570.7	1,782,836	527.4
Cut but unset, not more than 0.5 carat:				
Belgium	769,047	326.9	789,422	280.1
Brazil	17,168	6.1	41,626	17.6
Canada	7,232	1.0	4,419	1.2
Hong Kong	176,077	45.4	132,735	29.0
India	2,946,261	768.8	3,373,905	825.4
Israel	471,820	224.0	727,175	357.9
Netherlands	4,363	2.4	5,612	1.7
South Africa, Republic of	8,326	7.5	16,517	10.0
Switzerland	12,894	4.7	21,237	6.2
United Kingdom	5,593	1.9	1,424	.7
Other	80,997	39.8	86,601	20.9
Total	4,499,778	1,428.5	5,200,673	1,550.7
Cut but unset, more than 0.5 carat:				
Belgium	516,109	651.1	592,530	793.9
Hong Kong	15,811	32.8	14,196	34.5
India	181,619	113.0	41,316	33.8
Israel	983,684	942.0	783,799	834.4
Netherlands	10,844	24.9	4,491	13.8
South Africa, Republic of	5,792	11.5	5,291	12.2
Switzerland	14,484	70.3	23,766	115.2
United Kingdom	28,288	52.6	9,018	34.8
Other	48,550	57.7	23,553	41.3
Total	1,805,181	1,955.9	1,497,960	1,913.9

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

Source: Bureau of the Census.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY

Kind and country	1990 Quantity (carats)	1990 Value[1] (millions)	1991 Quantity (carats)	1991 Value[1] (millions)
Emerald:				
Belgium	21,217	$1.1	10,782	$1.6
Brazil	1,189,248	6.3	1,554,717	6.7
Colombia	382,051	58.2	212,818	51.5
France	10,202	2.5	7,456	3.0
Germany, Federal Republic of	44,811	2.1	19,828	2.2
Hong Kong	156,111	13.2	114,521	13.4
India	1,317,886	24.7	1,298,384	22.7
Israel	93,973	20.6	134,178	21.3
Japan	2,769	.2	2,946	.7
South Africa, Republic of	52	([4])	206	0.3
Switzerland	144,394	18.9	66,283	23.3
Taiwan	4,533	.2	414	.1
Thailand	291,458	7.4	483,037	12.6
United Kingdom	9,722	2.6	8,755	.9
Other	51,962	[r]4.3	24,980	5.1
Total[3]	3,720,389	162.4	3,939,305	165.5
Ruby:				
Belgium	4,250	.4	8,127	1.3
Brazil	1,562	.1	11,517	.5
Colombia	346	.1	145	([4])
France	3,340	2.2	4,686	.9
Germany, Federal Republic of	11,580	.8	15,438	1.6
Hong Kong	49,175	5.3	38,030	4.4
India	313,583	2.3	455,938	1.9
Israel	12,857	1.1	10,736	.8
Japan	13	([4])	647	.1
Switzerland	190,056	26.6	72,979	16.5
Thailand	1,323,506	46.6	1,715,511	37.3
United Kingdom	66,831	6.5	12,089	3.2
Other	42,991	[r]6.3	32,128	2.4
Total[3]	2,020,090	98.4	2,377,971	70.9
Sapphire:				
Australia	3,013	.2	3,963	.3
Austria	202	([4])	603	([4])
Belgium	14,131	.5	5,044	1.3
Brazil	2,827	.1	7,932	.4
Canada	2,126	.2	8,109	.4
Colombia	1,328	([4])	111	([4])
France	2,409	1.9	4,695	1.3
Germany, Federal Republic of	44,834	.9	21,882	.8
Hong Kong	83,519	3.9	141,486	6.2
India	101,510	.8	59,588	.6
Israel	26,140	1.5	10,723	.8
Japan	7,666	.1	6,536	.5
Korea, Republic of	204	([4])	1,980	([4])

See footnotes at end of table.

TABLE 10—Continued

U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY

Kind and country	1990 Quantity (carats)	1990 Value[1] (millions)	1991 Quantity (carats)	1991 Value[1] (millions)
Sapphire—Continued:				
Singapore	4,931	$0.6	833	$0.4
Thailand	3,248,891	51.2	3,122,987	46.1
United Kingdom	11,135	1.8	15,895	1.4
Other	44,113	[r]1.6	14,062	.9
Total[3]	3,796,764	81.9	3,501,548	81.5
Other:				
Rough, uncut:				
Australia		1.7		1.1
Brazil		[r]41.5		35.2
Colombia		2.4		1.4
Hong Kong		[r]2.0		2.0
Nigeria		.1		.2
Pakistan	NA	.4	NA	.7
South Africa, Republic of		.4		.6
Switzerland		3.5		1.0
United Kingdom		.4		1.2
Zambia		[r]1.3		.8
Other		[r]15.9		11.8
Total	NA	[r]67.9	NA	56.0
Cut, set and unset:				
Australia		6.1		3.2
Brazil		[r]8.6		9.3
Canada		[r].4		.2
China		[r]1.4		.8
Germany, Federal Republic of		[r]19.5		15.2
Hong Kong		[r]17.6		16.4
India	NA	[r]5.6	NA	7.4
Japan		[r]10.0		9.3
Switzerland		1.7		1.1
Taiwan		[r]3.1		2.8
Thailand		[r]40.9		72.3
United Kingdom		2.1		2.1
Other		[r]19.8		14.4
Total[3]	NA	[r]136.8	NA	154.7

[r] Revised. NA Not available.
[1] Customs value.
[2] Less than 1/10 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 11

VALUE OF U.S. IMPORTS OF SYNTHETIC AND IMITATION GEMSTONES, INCLUDING PEARLS, BY COUNTRY

(Million dollars[1])

Country	1990	1991
Synthetic, cut but unset:		
Austria	3.6	3.4
France	.8	1.9
Germany, Federal Republic of	9.6	8.7
Japan	.6	.7
Korea, Republic of	5.5	4.9
Switzerland	3.1	2.8
Thailand	7.0	16.0
Other	2.4	4.4
Total	32.6	42.8
Imitation:		
Austria	[r]53.9	58.7
Czechoslovakia	1.9	4.1
Germany, Federal Republic of	1.6	1.8
Japan	[r]2.0	1.5
Other	[r]5.0	3.0
Total	[r]64.4	69.1

[r]Revised.
[1]Customs value.

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES

(Thousand carats and thousand dollars)

Stones	1990		1991	
	Quantity	Value[1]	Quantity	Value[1]
Diamonds:				
Rough or uncut	1,223	570,750	1,783	527,424
Cut but unset	6,305	3,384,472	6,699	3,464,599
Emeralds: Cut but unset	3,720	162,375	3,939	165,508
Coral and similar materials, unworked	2,792	7,504	2,556	6,746
Rubies and sapphires: Cut but unset	5,817	180,375	5,880	152,475
Pearls:				
Natural	NA	3,734	NA	4,525
Cultured	NA	19,097	NA	16,753
Imitation	NA	3,814	NA	2,459
Other precious and semiprecious stones:				
Rough, uncut	NA	[r]55,436	NA	43,825
Cut, set and unset	NA	[r]113,949	NA	133,376
Other	NA	[r]6,727	NA	5,404
Synthetic:				
Cut but unset	113,367	32,649	148,173	42,820
Other	NA	1,911	NA	2,094
Imitation gemstone	NA	60,594	NA	66,649
Total[2]	XX	[r]4,603,388	XX	4,634,656

[r]Revised. NA Not available. XX Not applicable.
[1]Customs value.
[2]Data may not add to totals shown because of independent rounding

Source: Bureau of the Census.

TABLE 13

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

(Thousand carats)

Country	1987			1988				1989			
	Gem[2]	Natural industrial	Total	Gem[2]	Natural industrial	Total	Synthetic	Gem[2]	Natural industrial	Total	Synthetic
Angola[e]	180	10	190	950	50	1,000	—	1,165	80	1,245	—
Australia	13,650	16,683	30,333	17,413	17,413	34,826	—	17,540	17,540	35,080	—
Botswana	9,368	3,840	13,208	10,660	4,569	15,229	—	10,676	4,576	15,252	—
Brazil	300	200	500	353	180	533	—	350	150	500	—
Central African Republic	304	108	412	284	59	343	—	334	81	415	—
China[e]	200	800	1,000	200	800	1,000	15,000	200	800	1,000	15,000
Côte d'Ivoire[e] [5]	15	6	21	8	3	11	—	9	3	12	—
Czechoslovakia[e]	—	—	—	—	—	—	5,000	—	—	—	5,000
France[e]	—	—	—	—	—	—	4,000	—	—	—	4,000
Ghana[6]	65	400	465	[r]78	[r]181	[r]259	—	[r]86	[r]201	[r]287	—
Greece[e]	—	—	—	—	—	—	1,000	—	—	—	1,000
Guinea[6]	163	12	175	136	10	146	—	138	10	148	—
Guyana	2	5	[e]7	1	3	4	—	3	5	8	—
India	16	3	19	11	3	4	—	3	12	15	—
Indonesia[e]	7	22	29	7	22	29	—	7	25	32	—
Ireland[e]	—	—	—	—	—	—	60,000	—	—	—	[e]60,000
Japan[e]	—	—	—	—	—	—	25,000	—	—	—	25,000
Liberia	112	183	[e]295	67	100	167	—	62	93	155	—
Namibia	971	50	1,021	[r]890	[r]48	938	—	910	17	927	—
Romania[e]	—	—	—	—	—	—	5,000	—	—	—	4,500
Sierra Leone[5]	150	75	225	12	6	18	—	90	39	129	—
South Africa, Republic of:											
Finsch Mine	1,455	2,701	4,156	1,372	2,548	3,920	—	1,613	2,997	4,610	—
Premier Mine	772	1,713	2,485	696	1,543	2,239	—	689	1,526	2,215	—
Other De Beers' properties[7]	1,427	546	1,973	1,388	531	1,919	—	1,360	520	1,880	—
Other	409	30	439	361	65	426	—	348	63	411	—
Total	4,063	4,990	9,053	3,817	4,687	8,504	[e]55,000	4,010	5,106	9,116	60,000
Swaziland	48	32	[e]80	44	29	73	—	33	22	55	—
Sweden[e]	—	—	—	—	—	—	25,000	—	—	—	25,000
Tanzania	[r]87	[r]37	[r]124	[r]60	[r]26	[r]86	—	[r]53	[r]23	[r]76	—
U.S.S.R.[e]	7,400	7,400	14,800	7,500	7,500	15,000	41,500	7,500	7,500	15,000	41,500
United States	—	—	—	—	—	—	W	—	—	—	W
Venezuela	38	68	106	54	74	128	—	70	185	255	—
Yugoslavia[e]	—	—	—	—	—	—	5,000	—	—	—	5,000
Zaire	3,885	15,540	19,425	2,724	15,439	18,163	—	2,663	15,092	17,755	—
Total	[r]41,024	[r]50,464	[r]91,488	[r]45,269	[r]51,202	[r]96,471	241,500	[r]45,902	[r]51,560	[r]97,462	246,000

See footnotes at the end of table

TABLE 13—Continued

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

(Thousand carats)

Country	1990 Gem[2]	1990 Natural industrial	1990 Total	1990 Synthetic	1991[e] Gem[2]	1991[e] Natural industrial	1991[e] Total	1991[e] Synthetic
Angola[e]	[r]1,215	[r]85	[r]1,300	—	1,215	85	1,300	—
Australia	17,331	17,331	34,662	—	17,978	17,978	[4]35,956	—
Botswana	12,146	5,206	17,352	—	12,000	6,000	18,000	—
Brazil	[r]600	[r]900	[r]1,500	—	600	900	1,500	—
Central African Republic	[r]303	[r]78	[r]381	—	300	70	370	—
China[e]	200	800	1,000	15,000	200	800	1,000	15,000
Côte d'Ivoire[e] [5]	9	3	12	—	11	4	15	—
Czechoslovakia[e]	—	—	—	5,000	—	—	—	5,000
France[e]	—	—	—	4,000	—	—	—	4,000
Ghana[6]	[r]191	[r]446	[r]637	—	210	490	700	—
Greece[e]	—	—	—	1,000	—	—	—	1,000
Guinea[6]	130	5	[e]135	—	85	6	[4]91	—
Guyana	3	5	8	—	3	5	8	—
India	3	12	[e]15	—	3	12	15	—
Indonesia[e]	7	23	[r]30	—	8	24	32	—
Ireland[e]	—	—	—	60,000	—	—	—	60,000
Japan[e]	—	—	—	25,000	—	—	—	30,000
Liberia	40	60	[e]100	—	40	60	100	—
Namibia	[r]745	[r]16	[r]761	—	1,170	24	[4]1,194	—
Romania[e]	—	—	—	4,500	—	—	—	4,500
Sierra Leone[5]	[r]66	[r]12	[r]78	—	175	68	[4]243	—
South Africa, Republic of:								
Finsch Mine	1,462	2,716	4,178	—	1,500	2,500	4,000	—
Premier Mine	724	1,604	2,328	—	700	1,500	2,200	—
Other De Beers' properties[7]	1,240	474	1,714	—	1,200	500	1,700	—
Other	400	[r]88	[r]488	—	400	112	512	—
Total	3,826	[r]4,882	[r]8,708	[e]60,000	3,800	[r]4,612	[r]8,412	60,000
Swaziland	[r]25	[r]17	[r]42	—	18	12	30	—
Sweden[e]	—	—	—	25,000	—	—	—	25,000
Tanzania	[r]59	[r]26	[r]85	—	56	24	80	—
U.S.S.R.[e]	7,500	7,500	15,000	41,000	7,500	7,500	15,000	60,000
United States	—	—	—	W	—	—	—	90,000
Venezuela	88	245	333	—	90	250	340	—
Yugoslavia[e]	—	—	—	5,000	—	—	—	5,000
Zaire	[r]2,914	[r]16,513	[r]19,427	—	3,000	17,000	20,000	—
Total	[r]47,401	[r]54,165	[r]101,566	245,500	48,462	55,924	104,386	359,500

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

[1]Table includes data available through May 19, 1992. 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 except for Australia (1987), Brazil (1987-90), and Central African Republic (1987-90), 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.

[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 mines.

FIGURE 1
PRINCIPAL FORMS OF CRYPTOCRYSTALLINE AND CRYSTALLINE GEMSTONE CUTS