GEMSTONES

By Gordon T. Austin

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Webster's dictionary 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. So a gem, gemstone, or gem material may be described as inorganic or organic minerals used for personal adornment, display, or to manufacture objects of art because they possess beauty, rarity, and durability.

In 1993, the value of natural gemstones from deposits in the United States was $57.7 million, a decrease of 13% compared with that of 1992. Production of gemstones included faceting rough, lapidary rough, carving material, specimen material, natural and cultured freshwater pearls, mother of pearl, shell, fossil ivory, amber, and coral.

Laboratory grown synthetic gemstones 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. Laboratory grown simulants 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 1993, the reported value of production of U.S. synthetic and simulant materials was $17.9 million, about a 5% decrease from that of 1992.

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

DOMESTIC DATA COVERAGE

The U.S. Bureau of Mines (USBM) estimates U.S. production from the "Natural and Synthetic Gem Material Survey," a voluntary survey of U.S. operations, and from USBM estimates of unreported production. Of the 387 operations surveyed, 84% responded, 84% of the natural gemstone producers and 95% of the synthetic and simulant producers.

The number of operations surveyed in 1993 was 3% less than the number surveyed in 1992. The response rate was about the same. The USBM estimated the production by nonresponding operations, by professional collectors, and by amateur or hobbyist collectors. The basis for these estimates was 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.

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 25000 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 is extensive in the United States but not as large-scale operations. More than 60 different gemstones have been produced commercially from small domestic sources. Often, production rests in the hands of hobbyists and members of mineralogical and lapidary clubs. The Crater of Diamonds State Park near Murfreesboro, AR, is open to the public on a fee-per-day basis, as are many gemstone deposits throughout the United States. Each year many gem-quality stones are found at these locations.

Definitions, Grades, and Specifications

The gemstones data include information on select rocks, certain varieties of mineral specimens, and some organic materials, such as pearl, amber, jet, and coral. Customarily, diamond, ruby, sapphire, and emerald are the major gems.

The most important qualities of gemstones are beauty, durability, uniqueness, and rarity. Beauty, indicated as splendor, purity, or attractiveness, is 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. Yet, defects, described as "jardens" or "inclusions," may enhance the beauty and value of natural rubies, emeralds, and other gemstones. Sometimes these inclusions may be used to identify the country and even the mine from which the stone came. Durability is the resistance of a stone to abrasion, pitting, chipping, or splitting. Resistance to abrasion is correlated with relative hardness, but intrinsic brittleness and toughness suggest 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 2,900 mineral species, only about 100 possess all the attributes required of a gem. Collectors of gems may not require that a gem be durable because the stone is for display and is not to be worn. Therefore, the number of species of gemstones may be greater than the 100 that meet all 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 primarily turquoise and variscite. An exception is pearl, essentially calcium carbonate, which ranks high as a gem. Diamond, the best known gem, is an isometric crystalline form of the element carbon.

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 member of the group is 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 grossular species of the garnet group.

Products for Trade and Industry

Cutting of gems from gemstones is to obtain the most effective display of the material. No significant change is made in the fundamental properties, and the preparation is to enhance the desirable characteristics that are present initially. Gemstones are cut into gems in three main styles: faceted, cabochons, and baroque.

Facet cutting usually is on transparent gemstones to increase brilliancy and appearance. Often it 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 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 other common cuts are illustrated in figure 1. *(See figure 1.)*

Cabochons are cut in four operations: sawing, grinding, sanding, and polishing. Sawing, the first step in cutting, customarily is 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, 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 used. The scratches left by grinding are removed by progressively finer grinding and sanding. Disk or belt sanders use abrasives bonded to cloth, waterproof reinforced paper abrasives, or cloth charged with abrasive pastes. The final polish is on 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 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.

Industry Structure

The Central Sales Organization (CSO), the marketing arm of De Beers Centenary AG, highly controls the world market for rough diamonds. It is by far the most controlled of the world's commodity markets. The CSO markets about 80% of the world's gem and natural industrial diamond. The marketing through the CSO is by the Diamond Trading Co. Ltd. and Industrial Distributors Ltd. The CSO sells uncut gem diamonds for 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 by the South Africa Diamond Board. A new agreement was reached between De Beers Consolidated Mines Ltd., its customers, and the Government of South Africa on the method of domestic rough diamond distribution. In the past, all categories of rough diamonds that could be processed economically in South Africa must first be offered to local manufacturers. Rough could be exported duty free only if it had first been offered to the local market, otherwise a 15% duty was charged. Now, all rough will be shipped to London and mixed with diamonds from the other producers. Rough for South African cutters is then drawn from the world rough supply.

The CSO has been extremely successful at maintaining the rough diamond market for more than 50 years. In modern times there has never been a decrease in CSO's price of rough diamonds. *(See tables 1 and 2.)* The compounded effect over 44 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 $1,830 in February 1993.

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. In the early 1980's, the development of a large cottage industry in India—today there are 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.

Estimates are that Russia'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 Krystall factories have an incentive program for workers producing stones of 0.3 carat and larger. The incentive is a bonus of 5% of the added value that is paid to each 20-worker team and is shared by the team.

The diamond cutting and polishing factory at Nur Adjen, Armenia, produced about $60 million of income per year. The factory works at full capacity even in the winter because of its priority for electricity and heat. The factory's 1,800 workers are not allowed to drink at lunch (unlike Russian and Ukrainian diamond factory workers), have high morale, and comparatively high salaries; these factors resulted in high-quality production.

Annual cut diamond production depends on 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 Russian 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 newest, largest, and most modern U.S. diamond polishing factory in New York. The factory is 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.

Cutting and polishing of colored, synthetic, and simulant gemstones are centered in, listed according to importance, Thailand, India, Hong Kong, Republic of Korea, China, and Brazil, where cheap labor and favorable export laws ensure the lowest total costs for finished gems.

Geology-Resources

Gemstones form in a large variety of igneous, metamorphic, and sedimentary 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 silicate minerals, about one-fifth alumina-silicates, and almost one-seventh 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 one line item in table 3. *(See table 3.)*

There are no large resources of major gem materials defined in the United States. North Carolina has emerald, ruby, and sapphire deposits. Historically, sapphires have been mined in Montana, and commercial mining is underway again. Many other domestic deposits of gemstones are known and have been mined for many years. Still, there are no systematic evaluations of the magnitude of these deposits, and no 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. Diamond exploration is underway by several companies in the Colorado-Wyoming State line area, and in Michigan, Minnesota, Wisconsin, and Arkansas. Diamond-bearing kimberlites have been located and bulk samples have been processed for diamond recovery.

World resources of gemstones are nearly all unevaluated. However, world gem diamond reserves are estimated to be about 300 million carats, including near-gem and cheap-gem qualities. Nearly all the reserves are in, listed in order of size, Australia, Africa and Russia. 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 producers use 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, a 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 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, the rod is lowered into the crucible until the seed just touches the melt, and 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.

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 when attempting 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 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 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, Czochralshi, and scull melting processes are the melt techniques most often used for gem materials. *(See table 4.)*

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

In recent years the bleaching and impregnating of jadeite jade have become much more common. Investigators at gem laboratories estimate that as much as 90% of the jadeite sold in Taiwan is bleached; this includes both high- and low-quality material. The treatment is a two-step process where the jadeite is first chemically bleached using hydrochloric acid, nitric acid, or sodium compounds. The bleaching can take several hours to several weeks. The jadeite is then impregnated with a polymer, wax, or resin.[3]

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 I_1 improved to SI_2. 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.[4]

An additional type of treatment for sapphire and ruby is 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 gems. 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 gems is permanent, it remains confined to a shallow surface layer." Therefore, recutting or repolishing is not recommended.[5]

Exploration.—Gemstone exploration should be undertaken in much the same manner as any other mineral exploration program. Historically, this has not been the case, except for diamond exploration. Exploration for diamonds starts with an area analysis to determine favorable geologic settings. The analysis is followed by on-the-ground regional reconnaissance and mapping. Airborne geophysical surveys may be completed before or after the regional reconnaissance work. Followup geologic work on the ground is used to determine the presence of kimberlite or lamproite host rock. If a host rock is present, then drilling and sampling determine if diamonds are present and in what quantity and quality.

Historically, most gemstone deposits have been found by following float material to the source or by alluvial sample collected while searching for some other mineral, usually gold. One of the largest Maine tourmaline deposits was found when tourmaline crystal were found in the roots of an overturned tree. In the future, gemstone exploration will be conducted in a more businesslike and scientific manner. Successful exploration for gemstone deposits begins with the selection of target areas based on the presence of known favorable host rocks. Geologic studies and maps, topographic maps, and aerial photographs are used to identify favorable metamorphic, igneous, alluvial, or eolian geological formations.

The second step is field examination of the selected targets. This may include geologic mapping and limited sampling, but in many cases reconnaissance studies are sufficient. The next step, if warranted, is to sample the deposit in detail to measure the physical parameters of the deposit, specifically its grade and size.

The method of sampling used depends upon the type of deposit. Hard-rock deposits, igneous or metamorphic, are sampled differently than alluvial or eolian deposits.

Hard-rock deposits can be either diamond core drilled or trenched. Trenches should be oriented perpendicular to the strike of the formation and can be dug by hand, with a dozer, or with a backhoe.

Placer deposits can be sampled by drilling, trenching, or by excavating pits or shafts. The physical nature of the deposit; its thickness, hardness, and grain size; and whether it is above or below the water table influence the method of sampling chosen. For shallow deposits, hand augers or power augers can be used to drill sample holes. In deposits that are too hard to hand auger because of the presence of clay, iron oxide cement, or mild calcium carbonate cement, two-person motor-driven augers or vehicle-mounted augers (such as post hole diggers or telephone pole hole diggers) work well. However, augering does not always provide uncontaminated samples and is not effective below the water table.

Truck-mounted water-jet drills and rotary hammer drills are used to test thick deposits and deposits that are too hard to drill with other methods. A water-jet drill uses flush-jointed drill pipe with perforations near the bit to direct jets of water forward and downward from the bit. A hammer advances the drill bit and casing at the same time. Water from the jets flushes out the hole and returns cuttings to the surface in the annulus between the drill pipe and casing. Also, truck-mounted rotary drills equipped with double-pipe drill string and downhole hydraulic hammers can be used. Compressed air is forced down the inner pipe and returns samples to the surface in the annulus between the inner pipe and outer casing. Bits are selected depending on the type of material to be drilled.

Trenching can be carried out using either a dozer or a backhoe, depending on the size and depth of the deposit. In unconsolidated sediments it is difficult to maintain the stability of the walls of trenches, and samples can be contaminated by material sloughing from above. Bulk samples can be collected from 1-cubic-meter pits or shafts. However, again, wall stability can be a problem unless some form of shoring is used.

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; drilling and blasting may be 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 Russia and the lamproite pipes of Australia represent the ultimate in that huge quantities of ore must be mined to extract small quantities of diamond (as few as 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 Russia.

Processing.—Most gemstone ores 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 1993, all 50 States produced at least $1,000 worth of gem materials. Ten States accounted for 93% of the total value of production of natural gemstones. The States, in order of declining value of production, were Tennessee, Maine, Arizona, Arkansas, Alabama, Kentucky, Oregon, Utah, California, and Nevada. These States accounted for about 93% of the total value of U.S. production of natural gemstones. 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. Tennessee, Arkansas, Alabama, and Kentucky, in declining order of value of production, were the major producers of freshwater mussel shell and pearl. 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 reported value of synthetic and simulant gemstone production was $17.9 million in 1993, a decrease of 5% over that of 1992. Fourteen firms, four in California; four in Arizona; and one each in Massachusetts, Michigan, New Jersey, North Carolina, Ohio, and Washington, produced synthetic and simulant gem material. Production during 1993 included the manufacture of amethyst, azurite/malachite, cubic zirconia, emerald, lapis, ruby, sapphire, and turquoise. The materials were made by

10 plants operating in 8 States. The States, in descending order of value of production, were California, Massachusetts, New Jersey, Washington, Arizona, Michigan, New Mexico, and Ohio.

Arizona is known for its variety of gemstones that include agate, amethyst, antlerite, azurite, chrysocolla, fire agate, fluorite, garnet, jade, jasper, malachite, obsidian (Apache tears), onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. Yet, turquoise, peridot, petrified wood, and azurite-malachite accounted for more than 90% of the total value of gem material produced. Arizona was the largest domestic producer of azurite, fire agate, peridot, petrified wood, and turquoise. Also, it is estimated that Arizona was the world's largest producer of peridot, turquoise, and petrified wood and a significant producer of pyrope garnet. Many gem and mineral dealers believe that the value of mineral specimens produced from Arizona deposits is equal to, if not greater than, the value of gemstone produced. The USBM does not survey the production of mineral specimens, but its gemstones survey does capture data on that portion of the mineral specimens that are gemstones. The mineral specimen information collected is for gemstones that are used as specimen, because the value of the specimen is in the total value of production of the individual gemstone. This is particularly true for the production of Arizona's petrified wood. Additionally, four manufacturers of synthetic or simulant gem materials in Arizona produced about $0.3 million worth of material.

Arkansas continued to be the State with the greatest value of quartz production. At least four firms produced significant amounts of gem and specimen rock crystal from deposits in the areas around Hot Springs, Mt. Ida, and Jessieville. As stated earlier, the rivers, lakes, and reservoirs of Arkansas continued as the second largest source of U.S. freshwater mussel shell and pearl. Arkansas also produces several different mineral specimens other than rock crystals, but only the rock crystal specimen production is in the gemstone production numbers.

During 1993 at Crater of Diamonds State Park, Murfreesboro, AR, visitors reported finding 800 diamonds that totaled 144.44 carats. Crater of Diamonds State Park is the only location in the United States to have reported sustained production of diamonds for any appreciable length of time. Diamonds are found by visitors to the State park who pay a daily fee to hunt for diamonds using only handtools. It is possible that 1993 could be the last year that Arkansas has the only operating diamond mine. Mining tests were underway during late 1993 and early 1994 on two diamond properties in the Colorado-Wyoming Stateline Mining District. 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.

Gemstone production from California includes a variety of materials almost a large as Arizona's. Tourmaline production from the State is significant, and California has the only producer of benitoite. Additionally, deposits in the State produce agate, alabaster, beryl, dumortierite, fire agate, garnet, gem feldspar, jade, jasper, kunzite, lepidolite, obsidian, quartz, rhodonite, topaz, and turquoise. Yet, even with this long list of gemstones, most people think of California in terms of its State gem benitoite, its high-quality tourmalines, and its fine orange spessartine garnets.

The State also has a freshwater culture pearl farm at Marysville, but it did not harvest shell or pearls during 1993. The farm uses animals imported from Tennessee and other southeastern States. Production 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 largest of any State for synthetics and simulants.

Colorado is not known as a gemstone-producing State, but it does hold some gemstone honors. 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 produce turquoise commercially, and it still has commercial turquoise mines. It also produced the United States' finest gem-quality rhodochrosite and a quantity of high-quality rhodonite.

During 1993, two diamond deposits in the Colorado-Wyoming State Line diamond district were tested by bulk sampling. Reports in the International California Mining Journal, February 1994, issue indicated that the Kelsey Lake project of Colorado Diamond Corp., project manager for Redaurum Red Lake Mines Ltd., collected several bulk samples from the alluvial deposits associated with the Kelsey Lake kimberlites. A 6.2-carat, gem-quality diamond was recovered from one sample and a 1.1-carat stone from another. To date, sampling of the Kelsey Lake projects has yielded 268 stones larger than 2 millimeters, of which 60% was gem quality and 25% was more than 1 carat. Plans have been completed and activities are underway for a 100,000-ton test mining program. On May 31, 1994, the Denver Post reported the underground mining test by Royal Star Resources Ltd., a Canadian company, of the Sloan Ranch kimberlite deposit 40 kilometers northwest of the town of Fort Collins. Samples totaling 1,200 tons were processed and yielded more than 3,500 diamonds, the largest a 5.51-carat stone. Additional kimberlite will be mined and processed before a decision can be made about the economic feasibility of mining diamonds from the Sloan Ranch kimberlite.

Many locations in the State produce small quantities of aquamarine, the Colorado State gemstone. The best 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, and other gem-quality garnet lead 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 are mined commercially 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.

Maine and tourmaline are almost synonymous in the gemstone industry. In 1822, Maine's Mount Mica was the site of the first gemstone production in the United States. In 1993, 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. At least two deposits in the State produced significant quantities of tourmaline during the year.

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.

A new discovery of amethyst in an old producing area resulted in the production of a significant amount of faceting- and specimen-grade amethyst in 1993.

Montana produces many different gemstones, some suited for faceting, while others are 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, deposits in the State also produced amethyst, amazonite, azurite, covellite, cuprite, garnet, onyx, opal, petrified wood, rhodochrosite, rhodonite, smokey quartz, sphalerite, and wonderstone (banded rhyolite) 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, Dry Cottonwood Creek, and Rock Creek.

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 show that over the years, 75 to 100 different mines or prospects produced sizable quantities of turquoise. The value of production varied from a few thousand dollars 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 forms primarily as replacement of wood, or sometimes, the replacement of cones of conifer trees. A severe crazing problem restricts the use of the opal. Currently, two mines in Virgin Valley are open on a fee-to-dig basis during the summer months. The operators of these mines also mine the deposits for their 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 from a gold placer mine, the rubies and sapphires were from the Cowee Valley, and the emeralds were from 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. During 1993, deposits in North Carolina also produced gem-quality garnets, kyanite, emerald, and aquamarine.

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 associated uniquely 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 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 and the fire opal is as fine as the best from Mexico.

Tennessee has the largest U.S. production of freshwater mussel shells and pearls of the 11 producing States. 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 harvested commercially. During 1993, the value of U.S. mussel shell exports was more than $32 million.

Historically, freshwater pearls from the United States were a byproduct of the shell industry. 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 has changed. 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 and heart of the U.S. pearl industry.

In Wisconsin and Michigan, 12 kimberlite pipes have been identified on exploration holdings, 7 have yielded microdiamonds, and 3 have not been tested. Ashton Mining of Canada, Inc. announced that its Great Lakes project found a small kimberlite body in the Crystal Falls area of Michigan. The company also reported the possibility of additional kimberlite bodies in the Upper Peninsula of Michigan.

Utah 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 and 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. 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 is variscite, first produced in about 1893 near Fairfield. The latest recorded commercial production was from near Lucin during the summer of 1992. Variscite forms 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 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 1992, two different firms produced this material commercially.

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, 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 about 10 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; New York reported significant quartz production (herkimer diamonds) from the Herkimer-Middleville area and a small amount of almandite garnet production from the North Creek area; New Mexico reported production of agate, turquoise, copper minerals, and gem feldspar; both Alaska and Hawaii reported the production of gem-quality coral; Minnesota reported production of thomsonite and agate; Ohio reported production of flint; and South Dakota produced rose quartz.

The value of 1993 production by individual gemstone can be reported for those materials that have three or more producers and if one producer does not account for more than 75% of the total or if two do not account for 95% or more of the production. *(See table 5.)*

Consumption and Uses

Consumption of domestic gemstones was in the manufacture of jewelry; for exhibit in gem and mineral collections; for decorative purposes in statuettes, vases, and other art objects; and for 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, showing a minimum value of cohesion in the direction of 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. Another use for one type of jewel bearing is 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 produced for lasers, including chromium-doped chrysoberyl (dope being an element added to the crystal growing nutrients to get a particular color), synthetic alexandrite, and varieties of doped 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 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. Although industrial diamond has replaced much of the corundum used in the lens-polishing industry, some 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 was 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 1993 estimated value of U.S. apparent consumption of gems and gemstones was $4,266 million, up about 24% from that of 1992. In 1993, the value of U.S. estimated apparent consumption of diamonds increased about 29% to $3.6 billion. The 1993 estimated apparent consumption of colored stones, led by emerald, ruby, and sapphire, was valued at $517 million, an increase of 30%. The estimated apparent consumption of pearls—natural, cultured, and imitations—was $18 million, a 6% decrease. Estimated apparent consumption of synthetic and imitation gemstones decreased about 13% to $102.3 million.

Prices

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

The average U.S. wholesale asking price of the top 25 grades (D through H color and IF through VS_2 clarity) of a 1-carat diamond fluctuated between $7,200 and $7,300, and was about $7,300 at yearend. The average value per carat of all grades, sizes, and types of gem-quality diamond imports was $444, essentially the same as that of 1992. 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 $3,900, the same as that of 1992. The average value of ruby imports decreased 15% to $25.14 per carat.

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 $1,400, the same as that of 1992. The average value of sapphire imports decreased 5% to $15.46 per carat.

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 1992. The average value of emerald imports decreased 38% to $44.83 per carat. *(See tables 6 and 7.)*

Foreign Trade

The value of all diamond exports plus reexports increased 10% to $1.50 billion. The quantity of cut diamonds exported and reexported decreased 10% to 911,419 carats, and the value of diamond exported and reexported increased 9% to $1.44 billion.

The value of other precious stones, cut but unset or rough other than diamonds, pearls, and synthetics, exported and reexported decreased from $241.2 million to $103.1 million. The value of synthetic gemstone exports plus reexports decreased from $21.2 million to $19.3 million.

The value of natural, cultured, and imitation pearls, not set or strung, exports and reexports of pearls increased from $6.7 million to more than $7.3 million.

The value of gems and gemstones imported increased 18% to a record high $5,850.9 million. The value of imported gem diamonds accounted for about 86% of the total.

The value of imported gem diamonds increased 23% to a record high $5,096.3 million. The imports of cut diamonds increased 26% in quantity and 23% in value to 9.7 million carats and $4,486.3 million, respectively.

The value of imports of other gem and gemstones, led by emerald, ruby, and sapphires, was $754.5 million. Emerald imports increased 14% to $244.4 million. The value of ruby imports increased 16% to $90.6 million, but was less than the record-high value for the past 10 years of $98.4 million in 1990. The value of sapphire imports was $79.3 milion, an increase of 6% compared to that of 1992.

The value of imported gem materials other than diamond, emerald, ruby, and sapphire increased 35% to $327.7 million. *(See tables 8, 9, 10, 11, and 12.)*

World Review

Diamond sales by De Beers Centenary AG was $4.4 billion in 1993, an increase of 28% compared with 1992 sales of $3.4 billion. Sales during the first half of 1993 were $2.5 billion, 42% more than the $1.8 billion for the first half of 1992. Sales during the second half of 1992 were only $1.8 billion, but still 12% more than the $1.6 billion sales for the second half of 1992. A De Beers official stated that there were sharp sales gains in the Indian-type cheaper rough, but larger rough, more than 3 carats, was sold sparingly. De Beers controls about 80% of the rough, uncut diamonds sold in the world. Sales of colored stones remained strong. In February, De Beers increased the price of rough diamonds by an average of 1.5%. Not all prices went up 1.5%—some were unchanged while others increased as much as 8%.

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—Russia (northeastern Siberia and in the Yakutia); 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.—Odebrecht, a Brazilian company, purchased modular diamond recovery plants from Van Eck & Lurie for use on its diamond projects in Angola. Odebrecht is undertaking projects in Quango Province for Endiama, the Angolan state mining corporation.

Australia.—Argyle's diamond production of 42 million carats was another record year for the mine. Since the start of mining in 1983, more than 304 million carats of diamonds has been recovered from the AK-1 pipe and alluvial operations. Argyle's annual pink diamond sale saw a single buyer, a Geneva-based jeweler, buy the entire 46-stone, 41.48-carat offering for $2.25 million.

The Philips Range Joint Venture, a venture between Triad Minerals NL and Black Hill Minerals Ltd., both Australian companies, and the Canadian firm Cliff Resources Corp., has completed a drilling project on the Aries kimberlite pipe and has started a 100,000-ton bulk sampling of the overburden. The venture has processed 1,700 tons of overburden through its 100-tons-per-hour plant and recovered 69 diamonds that weighed 26.7 carats with five stones greater than 1 carat.[6] Ashton Mining Ltd. continued to explore the Merlin and adjacent Excalibur prospects in the Northern Territory. A 70-ton sample from Merlin produced 20 commercial-size stones; 20% were gem quality, 20% were near-gem, and the largest stone was 2.44 carats. On the Excalibur, a 60-kilogram sample produced 7 macrodiamonds and 92 microdiamonds. Many drill holes on the prospect have intercepted kimberlite down to 111 meters.

Botswana.—The largest diamond ever found in Botswana, 446 carats, was recovered at the Jwaneng Mine. The stone is currently being evaluated and no value has been set.

Preliminary exploration work is underway on the Gemsbok project to evaluate five diamond prospecting licenses. The licenses cover about 4,800 square kilometers. The project is a 50-50 joint venture between Scintilore Explorations and Fancamp Resources.

The $3 million diamond cutting and polishing factory jointly owned by Lazare Kaplan Botswana, a subsidiary of the U.S. firm Lazare Kaplan International, and the Government of Botswana is the newest cutting factory in Botswana. The factory was subsidized to train local cutters under Botswana's financial assistance policy for foreign investors. The factory will purchase rough from De Beers' CSO.

Brazil.—Southwestern Gold Corp. and Hillsborough Resources have had encouraging results from their joint-venture exploration on the 592,000-hectare Canabrava project in Minas Gerais. Sampling discovered kimberlite indicator minerals and stream samples contained diamonds. Diamonds from the stream samples contained one pink diamond.[7]

The KWG Resources and Diamond Co. Ltda. Charneca diamond property joint venture in Minas Gerais began production with a 750-cubic-meter-per-day washing plan and plans to add a second 300-cubic-meter-per-day plant. KWG, the operating partner, reported the recovery of 31 gem-quality diamonds weighing 79 carats during the first 19-days of operation. The joint venture controls two additional concessions in Minas Gerais—the Santo Antonio and Grupiaria.[8]

Burma (Myanmar).—The Burmese 30th Annual Gems, Jade, and Pearl Emporium attracted 654 buyers from 16 countries and accounted for a near record $14.7 million. Jade sales were $11.5 million; pearls, $0.6 million; and gems, $1 million. The gem sales were mostly cut rubies and sapphires. Some rough was offered as well as cut peridot, spinel, green tourmaline, danburite, almandine garnet, aquamarine, diopside, enstatite, zircon, colorless topaz, and scapolite. For the first time heat-treated rubies were offered for sale. The heat-treated material was all from the new Monghsu Mine.[9]

Canada.—Broken Hill Proprietary Co., an Australian company, and its Canadian partner Dia Met Minerals, Ltd. announced the start of work on the first diamond mine in Canada with their presentation of their mining plan to environmental authorities. The mine and other facilities would cost about $375 million and would be in full operation by 1997.

During 1993, diamond exploration activities were too extensive to be summarized in this limited space. It is recommended that interested individuals obtain copies of "Diamond in Canada: An Over View of Current Developments" by R. Irvine and M. Boucher, Industrial Minerals Division, Mineral Metal Commodities Branch Mineral Policy Sector, Energy, Mines and Resources Canada, Ottawa, Ontario; or "Mineral Exploration in Canada: Recent Developments and the Diamond Story" by J. M. Duke and B. A. Kjarsgaard, Geological Survey of Canada, Ottawa, Ontario.

China.—The New China News Agency announced a De Beers Chinese joint venture that includes equipment and technology for exploration and processing of diamond ore, assistance in training personnel, and the opening of a diamond cutting factory. The new factory will be in Shanghai, one of two major cities targeted by De Beers' recently announced $1.2 million marketing campaign to increase China's consumption of cut diamonds.

Ghana.—The Government of Ghana has agreed to sell 80% of the Government-owned Ghana Consolidated Diamond Mines, Ltd., 40% each to De Beers and Lazare Kaplan International. A new company, Birim River Diamonds Ltd., will operate the diamond mines with De Beers as the managing partner. Plans are for production to be increased to 0.4 million carats per year in 3 years; eventually production will increase to 1 million carats per year.

Greece.—In February, a new synthetic ruby, grown by a flux process, was announced to the industry at the Athens Jewelry Fair by J. and A. Douras, its producers. The material is grown in a plant in Piraeus. The Douros method grows crystals that are 20 to 50 grams and smaller that are almost identical in appearance to Ramaura material. The refractive indices, density, absorption spectrum, fluorescence, and dichroism of the new synthetic are the same as for natural ruby.

India.—India processed about 65% of the carats of the world's rough diamonds, accounting for a 45% share of the world trade in finished goods. While most of the finished goods were less than 20 points in size, the industry is increasing the amount of larger goods cut. The 11 million carats of cut diamonds exported accounted for 17% of the value of total exports from India.

Mali.—Mink Minerals Resources Inc., a Canadian firm, agreed to acquire 65% of Syndicat Diamat—the Mali diamond exploration and development company owned by the Governments of Mali and France—by spending more than $6 million over 3 years and additional amounts over 3 additional years. The Syndicat Kenieba district concession has 21 identified kimberlite pipes, 8 of which contain diamonds. Sampling of paleo placer deposits within the concession yielded more than 70 gem-quality diamond, many larger than 1 carat.

Namibia.—Namibian Minerals Corp. (Namco), a firm just listed on the Vancouver Stock Exchange, is undertaking a program to evaluate and develop two Namibian marine concessions covering 920 square kilometers. Detailed geophysical surveys and sampling are planned with the start of mining scheduled for early 1995. The concessions are off the coast for the port of Luderirz and Hottentots Bay in water 200 meters or more in depth. According to Namco, the concessions may contain as many as 27 million carats, and projections of production are 150,000 to 250,000 carats per year.

Russia.—The Russian diamond mining industry, with about 95% of production coming from five mines in Sakha—Udachny, Aikhal, Mir, International, and Sytykanskaya—is undergoing much change. Construction is underway on the Jubilee Mine that will begin production in 1994. Two deep vertical shafts have been completed at the International Mine, and plans are underway to convert the Mir from an open pit to underground mine. Additionally, efforts are underway to bring the five kimberlite pipes north of Archangel into production.

Current diamond exploration includes Ashton Mining's work in the Karelia area, work near Krasnovishersk in the Pern district, Kondor and Imperial, Inc. are exploring known pipes in Archangel, Gorizont Co. is exploring additional areas in Archangel, and geologists have discovered diamonds in the Khanka depression close to the city of Lesozavadsk near the Sino-Russian border.

Mr. Thomas Chatham, president of U.S.-based Chatham Created Gems, Inc., announced the formation of Chatham-Siberian Gem Co., based in Moscow. The company will grow and market synthetic white, yellow, and blue diamonds. The diamonds will be made using the high-temperature, high-pressure process. The new company plans to begin marketing about 100 carats of finished goods per month at a price that is 10% of that of equivalent natural diamonds.

In Moscow, J.V. Intertrade, a joint venture between the Moscow Municipality, the Russian Committee for Precious Stones and Metals, and Kaszirer Diamond and Oltusky—both Belgian firms—opened a diamond cutting factory. The Municipality provided land and construction. The committee is expected to insure a supply of rough, and the Belgians invested $6 to $7 million in funds. Ruisdiamond, an Israeli-Russian joint venture, also opened a new cutting factory in Moscow. It will use laser technology on types of rough that are difficult to cut. The newest cutting factory in Yakutia is in the city of Namtsy: It is the sixth factory to open in Yakutia during 1993, and an additional seven cutting factories have been announced.

Mr. Valerie Rudakov, president of Almazy Rossi-Sakha, the firm responsible for mining, sorting, pricing, and selling Russia's rough diamonds, announced the opening of an internal Russian Diamond Selling Center. Operating much like the CSO, the Selling Center will allocate diamonds to Russian cutting factories as if they were CSO sightholders. Almazy Rossi-Sakha is a joint stock company in which 32% is controlled by the governments of Russia and Sakha each, 8% by the eight regions of Sakha, 5% by the Guarantee Fund, and 23% by employees. The company's goals are to supply adequate rough diamonds at "world prices" to Russian cutting factories and to ensure the continued well being and growth of the Russian cutting industry.

South Africa, Republic of.—Diamond Field Resources (DFR), a Canadian company, purchased the Loxton Dan and Frank Smith diamond mines in the Kimberley area. The company reports that the mines have reserves sufficient for an additional 20 years of operation even at the increased rate plan. DFR plans to increase production from the mines to 100,000 carats per year. DFR also has a marine diamond concession off the coast of Luderitz in Namibia.

Tanzania.—During 1993, the Government of Tanzania lifted the restrictions on diamond sales and exploration to foreign investors. Because of these changes Dual Resources and Pue Gold Resources, both Canadian firms, each purchased 20% of Tanzania Diamond Mines' (TDM) diamondiferous kimberite project, two contiguous diamond lining leases, and three exploration licenses. East Africa Diamond Exploration, a wholly owned subsidiary of TDM, will manage the joint-venture project.[10]

European Ventures acquired a 50% interest in Tan Range Exploration Corp.'s 60-square-kilometer diamond concession; both firms are Canadian. European agreed to spend $300,000 on exploration over the next 2 years, and issued Tan Range 100,000 shares of European's common stock.[11]

Uruguay.—It is estimated that annual exports of amethyst are about 80 tons valued at more than $500,000. The amethyst is for mineral specimens, decorator pieces, and as gemstones.

Zaire.—Sediza, De Beers' Zairian diamond purchasing company, purchased a +770-carat top-colored, gem-quality rough diamond. It is reported that the firm paid an artisanal miner $7 million for the stone and paid the Government of Zaire a 10% fee to export it. Because of its shape, the rough will be sawed or cleaved into two pieces for cutting.

Zimbabwe.—The River Ranch Mine, operated by Auridiam Zimbabwe Ltd., a joint venture between the Canadian firm Cornerstone Investments Ltd. and Auridiam Consolidated NL of Australia, is expanding production from its current 50,000 carats per year to 130,000 carats per year and plan to produce 330,000 carats per year by 1995. Gem-quality stones account for about 60% of the production, and many of the stones are larger than 8 carats. During 1993, the mine produced two large fine stones—one was 29.6 carats and the other was 17 carats. Recovered fragments totaling 356.2 carats from one broken stone and 33.4 carats from another single stone suggest the presence of very large stones.

The joint venture between Reunion Mining and Argosy Mining Corp. has confirmed the discovery of a second kimberlite pipe on its Hwange project in western Zimbabwe. The pipe is about 10 kilometers from an earlier discovered pipe. The joint venture announced that additional exploration permits have been added to the venture to increase the Hwange project area.

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]Pages 61-78 of work cited in footnote 7.
[3]Bleached and Impregnated Jadeite, Jewelry News Asia, Issue 103, March 1993, pp. 118,120.
[4]Pages 25-44 of work cited in footnote 7.
[5]Rapaport Diamond Report. Colored Stones Section. V. 15, No 9. Mar. 6, 1992, p. 26.
[6]Industrial Minerals (London). No. 312, 1993, p. 13.
[7]Mining Journal (London). V. 321, No. 8247, 1993, p. 277.
[8]———. V. 321, No. 8243, 1993, p. 209.
[9]Gemological Institute of America. Gems & Gemology. V. 29, No. 1. 1993, p. 64.
[10]Mining Journal (London). V. 320, No. 8227, 1993, p. 404.
[11]———. V. 320, No. 8220, 1993, p. 276.

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Gemstones. Ch. in Mineral Commodity Summaries, 1994.
Mineral Facts and Problems, 1985.
Mineral Industry Surveys, Annual Advance Summary Supplement: Directory of Principal Gemstone Producers in the United States, 1993.
Mineral Industry Surveys, Annual Advance Summary Supplement: An Overview of Gemstone Production in the United States.

TABLE 1
DE BEER'S 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	Feb. 1993	1.5

TABLE 2
DE BEER'S CSO ROUGH DIAMOND SALES AND STOCKS

(Billions of dollars)

Year	Sales	Stocks
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
1992	3.42	3.36
1993	4.40	4.10

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 aluminum 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.
Bixbite	do.	do.	Small	Very high	7.5-8.0	2.63-2.80	do.	1.58	Pressed plastics, tourmaline	Refractive index.
Emerald	do.	Green	Medium	do.	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 ultra-violent light.
Golden (heliodor)	do.	Yellow to golden	Any	Low to medium	7.5-8.0	2.63-2.80	do.	1.58	Citrine, topaz, glass, doublets	
Goshenite	do.	do.	Any	Low	7.5-8.0	2.63-2.80	do.	1.58	Quartz, glass, white sapphire, white topaz	Refractive index.
Morganite	do.	Pink to rose	Any	Low	7.5-8.0	2.63-2.80	Low	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	Russia (small), Sri Lanka (medium)	High	8.5	3.50-3.84	Double	1.75	Synthetic	Dichroism, inclusions in synthetic sapphire.
Catseye	do.	Greenish to brownish	Small to large	do.	8.5	3.50-3.84	do.	1.75	Synthetic, shell	Gravity and translucence.
Chrysolte	do.	Yellow, green, and/or brown	Medium	Medium	8.5	3.50-3.84	do.	1.75	Tourmaline, peridot	Refractive index, silky.
Coral	Calcium carbonate	Orange, red, white, black, or green	Branching, medium	Low	3.5-4.0	2.6-2.7	do.	1.49-1.66	False coral	Dull translucent.

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
Corundum:										
Ruby	Aluminum oxide	Rose to deep purplish red	Small	Very high	9.0	3.95-4.10	Double	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 strae, bubble inclusions.
Diamond	Carbon	White, blue-white, yellow, brown, green, pink, blue	Any	Very high	10.0	3.516-3.525	Single	2.42	Zircon, titania, cubic zirconia	High index, dispersion, single refraction, hardness, cut, luster.
Feldspar:										
Amazonite	Alkali aluminum-silicate	Green	Large	Low	6.0-6.5	2.56	—	1.52	Jade	Cleavage, sheen, vitreous to pearly opaque, grid.
Labradorite	do.	Gray with blue and bronze sheen color play	do.	Low	6.0-6.5	2.56	—	1.56	do.	Cleavage, sheen, vitreous to pearly opaque, grid.
Moonstone	do.	White	do.	Low	6.0-6.5	2.77	—	1.52-1.54	Glass or white onyx	Blue sheen, opalescent.
Garnet	Complex silicate	Brown, black, yellow, green, ruby red, or orange	Small to medium	Low to high	6.5-7.5	3.15-4.30	Single 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	Crypto-crystal-line	1.65-1.68	Onyx, bowenite, vesu-vianite, 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.
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.
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 refracation, low dichroism.

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	do.	1.55	do.	Refractive index, double refration, translucent.
Spinel	Magnesium aluminum oxide	Any	Small to medium	Medium	8.0	3.5-3.7	Single	1.72	Synthetic, garnet	Refractive index, single refraction, inclusions.
Spinel, synthetic	do.	Any	Up to 40 carats	Low	8.0	3.5-3.7	Double	1.73	Spinel, corundum, beryl, topaz, alexandrite	Weak double refraction, curved striae, bubles.
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.
Hiddenite	do.	Yellow to green	do.	do.	6.5-7.0	3.13-3.20	do.	1.66	Synthetic spinel	Do.
Tanzanite	Complex silicate	Blue	Small	High	6.0-7.0	3.30	do.	1.69	Sapphire, synthetics.	Strong trichroism.
Topaz	do.	White, blue, green	Medium	Low to medium	8.0	3.4-3.6	do.	1.62	Beryl, quartz	Refractive index.
Tourmaline	do.	All, including mixed	do.	do.	7.0-7.5	2.98-3.20	do.	1.63	Peridot, beryl, corundum, glass	Double refraction, refractive index.
Turquoise	Copper aluminum phosphate	Blue to green	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.	do.	Douras	1990'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	do.	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.	Russia	1980's
Do.	Hydrothermal	Lechleitner	1960's
Do.	do.	Regency	1980's
Do.	do.	Biron	1980's
Do.	do.	Russia	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 U.S. GEMSTONE PRODUCTION, BY GEMSTONE

(Thousand dollars)

Gem materials	1992	1993
Agate	548	843
Beryl	323	470
Coral (all types)	122	166
Garnet	108	233
Gem feldspar	1,042	701
Geode/nodules	260	207
Fire agate	45	40
Jasper	111	531
Obsidian	4	10
Opal	756	639
Peridot	1,306	1,520
Petrified wood	211	234
Quartz	638	1,036
Sapphire/ruby	895	313
Topaz	12	8
Tourmaline	82	9,534
Turquoise	1,994	3,035
Total	8,457	19,520

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. 1993-Jan. 1994	Average[4] July 1993
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	2,900- 3,050	3,050
.50	G	VS2	2,600- 2,700	2,700
.50	G	SI1	2,300- 2,400	2,400
.50	H	VS1	2,700- 2,800	2,800
.50	H	VS2	2,500- 2,600	2,600
.50	H	SI1	2,200- 2,300	2,300
.75	G	VS1	3,500- 3,650	3,650
.75	G	VS2	3,200- 3,350	3,350
.75	G	SI1	2,800- 2,950	2,950
.75	H	VS1	3,100- 3,250	3,250
.75	H	VS2	2,800- 2,950	2,950
.75	H	SI1	2,600- 2,750	2,750
1.00	G	VS1	4,600- 4,800	4,750
1.00	G	VS2	4,100- 4,250	4,200
1.00	G	SI1	3,700- 3,850	3,800
1.00	H	VS1	4,100- 4,250	4,200
1.00	H	VS2	3,900- 4,050	4,000
1.00	H	SI1	3,600- 3,750	3,700

[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. 165, No. 3, Mar. 1994, p. 146.
[4]Jeweler's Circular-Keystone. V. 164, No. 9, Sept. 1993, p. 114.

TABLE 7
PRICES OF U.S. CUT COLORED GEMSTONES, BY SIZE[1]

Gemstone	Carat weight	Price range per carat in 1993[2]	Average price per carat[2] Jan. 1993	Average price per carat[2] Jan. 1994
Amethyst	1	$8- $18	$13.00	$13.00
Aquamarine	1	75- 90	82.50	82.50
Emerald	1	2,000- 3,500	2,750.00	2,750.00
Garnet, tsavorite	1	600- 900	750.00	750.00
Ruby	1	3,000- 4,800	3,900.00	3,900.00
Sapphire	1	800- 2,000	1,400.00	1,400.00
Tanzanite	1	100- 185	130.00	150.00
Topaz	1	5- 9	7.00	7.00
Tourmaline, red	1	60- 125	92.50	92.50

[1]Fine quality.
[2]Jewelers' Circular-Keystone. V. 165, No. 3, Mar. 1994, p. 146. 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 or territory	1992		1993	
	Quantity (carats)	Value[1] (millions)	Quantity (carats)	Value[1] (millions)
Exports and reexports:				
Australia	552	$1.7	585	$1.3
Belgium	r792,646	r322.3	443,623	363.9
Canada	r412,161	30.7	242,593	33.6
Germany	11,878	10.1	3,408	3.3
Hong Kong	r157,109	r311.3	232,487	333.5
India	101,717	15.4	128,675	15.8
Israel	r245,690	r250.3	320,100	286.7
Japan	r75,992	r121.4	88,756	144.5
Mexico	3,016	1.7	7,638	1.6
Singapore	r19,114	r30.7	14,604	35.7
South Africa, Republic of	928	1.7	1,276	2.0
Switzerland	r44,211	r146.2	36,605	160.4
Thailand	r17,369	r16.5	58,490	24.4
United Kingdom	r12,292	r50.8	13,925	43.5
Other	r29,903	r50.6	37,682	48.9
Total	r1,924,578	r1,361.4	1,630,447	1,499.1

rRevised.

[1]Customs value.

Source: Bureau of the Census.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY

Kind, range, and country or territory of origin	1992 Quantity (carats)	1992 Value[1] (millions)	1993 Quantity (carats)	1993 Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium	402,763	$81.9	143,860	$111.7
Brazil	26,867	1.4	55,214	4.7
Isreal	26,699	10.7	13,535	5.7
Netherlands	79,564	17.6	1,607	2.6
South Africa, Republic of	13,405	17.6	26,058	43.7
Switzerland	1,156	9.4	8,549	12.6
United Kingdom	685,544	189.1	1,127,237	229.3
Venezuela	318	.1	161	.1
Other	392,059	167.1	394,271	199.6
Total[3]	1,628,375	495.0	1,770,492	610.1
Cut but unset, not more than 0.5 carat:				
Belgium	795,348	270.5	951,502	315.7
Brazil	15,414	6.6	5,928	2.0
Canada	[r]6,552	2.1	5,709	1.5
Hong Kong	247,289	44.1	147,006	40.8
India	4,249,843	935.2	5,577,187	1,178.7
Israel	670,327	313.0	800,084	347.8
Netherlands	3,338	1.1	1,778	.4
South Africa, Republic of	7,263	6.3	5,658	5.4
Switzerland	11,055	4.6	8,357	2.8
United Kingdom	4,779	1.4	3,146	.6
Other	80,899	19.2	109,748	25.7
Total[3]	[r]6,092,107	1,604.2	7,616,103	1,921.4
Cut but unset, more than 0.5 carat:				
Belgium	589,036	776.2	676,500	912.2
Hong Kong	[r]14,886	30.8	33,037	44.6
India	30,634	18.0	100,209	63.4
Israel	915,487	973.8	1,161,760	1,255.7
Netherlands	3,928	18.9	2,177	6.8
South Africa, Republic of	5,706	22.4	11,788	34.4
Switzerland	10,712	95.1	11,678	114.1
United Kingdom	20,061	35.1	14,041	35.9
Other	41,319	74.3	75,940	97.7
Total[3]	[r]1,631,769	2,044.5	2,087,130	2,564.8

[r]Revised.
[1]Customs value.
[2]Includes some natural advanced diamond.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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

Kind and country or territory	1992 Quantity (carats)	1992 Value[1] (millions)	1993 Quantity (carats)	1993 Value[1] (millions)
Emerald:				
Belgium	4,381	$0.7	8,122	$2.1
Brazil	125,548	4.5	1,100,146	4.0
Colombia	403,988	92.4	581,333	118.9
France	3,753	4.1	490	1.0
Germany	149,870	4.3	66,929	2.3
Hong Kong	232,025	19.2	271,592	21.5
India	1,208,678	16.5	2,090,983	26.8
Israel	116,586	21.4	447,491	27.9
Switzerland	164,283	39.6	105,266	24.1
Taiwan	3,452	.3	581	2.5
Thailand	299,313	6.6	706,280	6.8
Other	[r]244,029	[r]4.0	72,928	6.5
Total	2,955,906	213.5	5,452,141	244.4
Jade:				
Brazil		9.0		7.3
Germany		15.7		13.8
Hong Kong		12.7		15.4
India	NA	6.1	NA	7.0
Israel		5.4		6.0
Taiwan		2.8		3.1
Thailand		47.5		17.5
Other		10.3		10.6
Total	NA	109.2	NA	80.7
Ruby:				
Belgium	9,065	1.1	4,932	.7
Brazil	6,793	.3	7,219	.1
France	790	.6	629	.7
Germany	17,677	1.1	101,945	1.2
Hong Kong	[r]99,823	[r]3.9	218,116	6.2
India	375,745	1.7	1,012,472	2.8
Israel	12,094	1.5	14,938	1.8
Switzerland	36,221	23.3	19,664	15.7
Thailand	2,008,030	39.1	2,181,489	47.9
United Kingdom	2,401	3.3	3,784	2.5
Other	[r]66,306	[r]2.0	39,175	10.3
Total	[r]2,634,945	[r]77.9	3,604,363	90.6
Sapphire:				
Australia	4,682	.1	12,377	.1
Beglium	6,744	.7	18,710	.8
Brazil	23,326	.2	2,585	.1
Canada	187,196	.5	48,593	.8
Germany	49,194	1.3	122,609	1.0
Hong Kong	[r]113,716	[r]3.9	202,914	3.7
Israel	28,987	1.2	30,554	1.0
Sri Lanka	85,218	3.5	196,128	4.5
Switzerland	27,608	13.6	32,786	7.8
Thailand	3,991,362	45.5	4,255,519	54.1

See footnotes at end of table.

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

Kind and country or territory	1992 Quantity (carats)	1992 Value[1] (millions)	1993 Quantity (carats)	1993 Value[1] (millions)
Sapphire—Continued:				
United Kingdom	4,210	$1.2	5,404	$0.8
Other	[r]88,663	[r]3.4	201,604	4.6
Total	[r]4,610,906	75.1	5,129,783	79.3
Other:				
Rough, uncut:				
Australia	NA	2.1	NA	2.6
Brazil	NA	30.2	NA	21.4
Colombia	NA	4.4	NA	6.1
Hong Kong	NA	1.0	NA	7.1
South Africa, Republic of	NA	.3	NA	2.4
Switzerland	NA	.7	NA	.3
Zambia	NA	1.0	NA	.8
Other	11,702,472	13.8	21,772,815	9.0
Total	41,130,452	53.5	56,187,445	49.7
Cut, set and unset:				
Australia		3.8		4.2
Brazil		9.0		7.2
China		.9		1.8
Germany		15.7		13.8
Hong Kong	NA	[r]17.3	NA	20.3
India		6.9		8.0
Japan		9.3		10.1
Switzerland		.8		1.2
Taiwan		3.1		3.5
Thailand		47.5		17.5
Other		17.1		16.6
Total	NA	131.5	NA	104.2

[r]Revised. NA Not available.
[1]Customs value.

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 or territory	1992	1993
Synthetic, cut but unset:		
Australia	1.9	3.4
Austria	6.3	3.7
Germany	[r]10.1	10.7
Hong Kong	2.9	2.0
Korea, Republic of	4.2	2.1
Switzerland	4.6	3.8
Thailand	23.2	12.5
Other	[r]4.8	5.9
Total	[r]58.0	44.1
Imitation:		
Austria	[r]69.9	45.9
Czechoslovakia	7.0	—
Germany	2.8	2.0
Japan	2.3	.7
Other	2.7	11.4
Total	[r]84.7	60.0

[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	1992 Quantity	1992 Value[1]	1993 Quantity	1993 Value[1]
Diamonds:				
Rough or uncut	1,628	495,003	1,770	610,113
Cut but unset	7,724	[r]3,648,640	9,703	4,486,270
Emeralds: Cut but unset	2,956	213,497	5,452	244,356
Coral and similar materials, unworked	2,787	6,115	2,800	5,442
Jade: Cut and rough	NA	109,233	NA	80,679
Rubies and sapphires: Cut but unset	7,246	[r]153,059	8,734	169,934
Pearls:				
Natural	NA	3,896	NA	2,887
Cultured	NA	[r]18,195	NA	20,483
Imitation	NA	[r]3,698	NA	1,957
Other precious and semiprecious stones:				
Rough, uncut	408,236	41,446	558,900	38,378
Cut, set and unset	NA	[r]109,376	NA	80,825
Other	281	5,957	175	5,869
Synthetic:				
Cut but unset	[r]217,010	[r]57,950	163,423	44,107
Other	NA	[r]1,628	NA	1,523
Imitation gemstone	NA	[r]81,029	NA	58,071
Total	XX	[r]4,948,722	XX	5,850,894

[r]Revised. NA Not available. XX Not applicable.
[1]Customs value.

Source: Bureau of the Census.

TABLE 13

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

(Thousand carats)

Country	1989				1990				1991			
	Natural			Syn-thetic[4]	Natural			Syn-thetic[4]	Natural			Syn-thetic[4]
	Gem[2]	Indus-trial	Total[3]		Gem[2]	Indus-trial	Total[3]		Gem[2]	Indus-trial	Total[3]	
Angola[5]	1,165	80	1,245	—	1,060	73	1,133	—	899	62	961	—
Australia	17,540	17,540	35,080	—	17,331	17,331	34,662	—	17,978	17,978	35,956	—
Belarus	—	—	—	—	—	—	—	—	—	—	—	—
Botswana	10,680	4,570	15,252	—	12,150	5,200	17,352	—	11,550	4,950	16,506	—
Brazil	350	150	500	—	600	900	1,500	—	600	900	[e]1,500	—
Central African Republic	334	81	415	—	303	78	381	—	296	82	379	—
China[e]	200	800	1,000	15,000	200	800	1,000	15,000	200	800	1,000	15,000
Côte d'Ivoire[e 6]	9	3	[7]12	—	9	3	12	—	11	4	15	—
Czech Republic[8]	—	—	—	—	—	—	—	—	—	—	—	—
Czechoslovakia[e 9]	—	—	—	[r]10,000	—	—	—	[r]10,000	—	—	—	[r]10,000
France[e]	—	—	—	4,000	—	—	—	[r]5,000	—	—	—	4,000
Gabon[e]	400	100	500	—	400	100	500	—	400	100	500	—
Ghana[10]	[r]395	[r]99	494	—	[r]520	[r]130	650	—	[r]560	[r]140	700	—
Greece[e]	—	—	—	1,000	—	—	—	1,000	—	—	—	1,000
Guinea[e 6]	137	10	147	—	119	8	127	—	91	6	97	—
Guyana	3	5	8	—	5	13	18	—	6	16	[r]22	—
India	[r]12	[r]3	15	—	[r]15	[r]3	18	—	[r]15	[r]3	18	—
Indonesia[e]	7	25	32	—	7	23	30	—	8	24	32	—
Ireland[e]	—	—	—	60,000	—	—	—	60,000	—	—	—	60,000
Japan[e]	—	—	—	25,000	—	—	—	25,000	—	—	—	30,000
Liberia[e 11]	[7]62	[7]93	[7]155	—	40	60	100	—	40	60	100	—
Namibia	910	20	927	—	750	15	763	—	1,170	20	1,187	—
Romania[e]	—	—	—	[r]5,000	—	—	—	[r]3,000	—	—	—	[r]3,000
Russia[e]	—	—	—	—	—	—	—	—	—	—	—	—
Serbia and Montenegro[12]	—	—	—	—	—	—	—	—	—	—	—	—
Sierra Leone[6]	90	39	129	—	66	12	78	—	160	83	243	—
Slovakia[9]	—	—	—	—	—	—	—	—	—	—	—	—
South Africa, Republic of:												
Finsch Mine	1,600	3,000	4,610	—	1,480	2,700	4,178	—	1,200	2,280	3,483	—
Premier Mine	700	1,520	2,215	—	720	1,600	2,328	—	700	1,550	2,250	—
Venetia Mine	—	—	—	—	20	40	62	—	100	200	303	—
Other De Beers' properties[13]	1,350	530	1,880	—	1,200	460	1,652	—	1,500	400	1,897	—
Other	350	50	411	—	380	100	488	—	400	100	498	—
Total	4,000	5,100	9,116	[e]60,000	[r]3,800	4,900	8,708	[e]60,000	3,900	4,530	8,431	[e]60,000
Swaziland	33	22	55	—	25	17	42	—	34	23	57	—
Sweden[e]	—	—	—	25,000	—	—	—	25,000	—	—	—	25,000
Tanzania	105	45	[e]150	—	60	25	85	—	70	30	100	—
U.S.S.R.[e 14]	11,500	11,500	23,000	[r]120,000	12,000	12,000	24,000	[r]120,000	10,000	10,000	20,000	[r]120,000
Ukraine	—	—	—	—	—	—	—	—	—	—	—	—
United States	—	—	—	W	—	—	—	W	—	—	—	90,000
Venezuela	70	185	255	—	[r]85	[r]248	333	—	102	112	214	—
Yugoslavia[e 15]	—	—	—	5,000	—	—	—	5,000	—	—	—	5,000
Zaire	[7]2,663	[7]15,092	17,755	—	[7]2,914	[7]16,513	19,427	—	3,000	14,814	17,814	—
Total	[r]50,665	[r]55,562	106,242	[r]325,000	[r]52,459	[r]58,452	110,919	[r]269,000	[r]51,090	[r]54,737	[r]105,832	[r]423,000

See footnotes at end of table.

TABLE 13—Continued

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

(Thousand carats)

Country	1992				1993[e]			
	Natural			Synthetic[4]	Natural			Synthetic[4]
	Gem[2]	Industrial	Total[3]		Gem[2]	Industrial	Total[3]	
Angola[5]	[r]1,100	[r]80	[r]1,180	—	470	30	500	—
Australia	[r]17,750	[r]22,250	[r, e]40,000	—	19,000	23,200	42,200	—
Belarus	—	—	—	[e]30,000	—	—	—	30,000
Botswana	[r]11,160	[r]4,790	[r]15,946	—	12,000	5,000	17,000	—
Brazil[e]	[r]653	[r]665	[r]1,318	—	600	900	1,500	—
Central African Republic	[r]307	[r]107	[r]414	—	307	106	413	—
China[e]	200	800	1,000	15,000	230	850	1,080	15,500
Côte d'Ivoire[e, 6]	11	4	15	—	11	4	15	—
Czech Republic[8]	—	—	—	—	—	—	—	5,000
Czechoslovakia[e, 9]	—	—	—	[r]10,000	—	—	—	—
France[e]	—	—	—	[r]3,500	—	—	—	3,500
Gabon[e]	400	100	500	—	400	100	500	—
Ghana[10]	[r]570	[r]140	[r]710	—	600	150	750	—
Greece[e]	—	—	—	750	—	—	—	1,000
Guinea[6]	90	5	95	—	90	5	95	—
Guyana	[r]13	[r]32	[r, e]45	—	14	36	50	—
India	[r]15	[r]3	18	—	16	3	19	—
Indonesia[e]	6	21	27	—	7	20	27	—
Ireland[e]	—	—	—	60,000	—	—	—	66,000
Japan[e]	—	—	—	30,000	—	—	—	32,000
Liberia[e, 11]	[r, 7]62	[r, 7]93	[r, 7]155	—	60	90	150	—
Namibia	[r]1,500	50	[r]1,548	—	1,100	40	[7]1,139	—
Romania[e]	—	—	—	[r, 7]—	—	—	—	—
Russia[e]	9,000	9,000	18,000	80,000	8,000	8,000	16,000	80,000
Serbia and Montenegro[12]	—	—	—	5,000	—	—	—	5,000
Sierra Leone[6]	[r]200	[r]96	[r]296	—	90	68	[7]158	—
Slovakia[9]	—	—	—	—	—	—	—	5,000
South Africa, Republic of:								
Finsch Mine	1,200	2,250	3,446	—	700	1,300	[7]2,012	—
Premier Mine	740	1,700	2,444	—	500	1,100	[7]1,596	—
Venetia Mine	660	1,200	1,868	—	1,750	3,200	[7]4,969	—
Other De Beers' properties[13]	1,350	500	1,849	—	900	350	[7]1,249	—
Other	450	100	549	—	450	100	550	—
Total	[r]4,400	[r]5,750	[r]10,166	[e]60,000	4,300	6,050	10,324	75,000
Swaziland	36	24	[r]51	—	27	18	45	—
Sweden[e]	—	—	—	25,000	—	—	—	25,000
Tanzania	[r]48	[r]20	[r]68	—	48	20	68	—
U.S.S.R.[e, 14]	—	—	—	—	—	—	—	—
Ukraine	—	—	—	[e]10,000	—	—	—	10,000
United States	—	—	—	90,000	—	—	—	103,000
Venezuela	[r]302	[r]176	[r]478	—	335	200	535	—
Yugoslavia[e, 15]	—	—	—	—	—	—	—	—

See footnotes at end of table.

TABLE 13—Continued

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

(Thousand carats)

Country	1992				1993[e]			
	Natural			Syn-thetic[4]	Natural			Syn-thetic[4]
	Gem[2]	Indus-trial	Total[3]		Gem[2]	Indus-trial	Total[3]	
Zaire	[r 7]8,934	[r 7]4,567	[r]13,501	—	9,500	5,500	15,000	—
Total	[r]56,757	[r]48,773	[r]105,521	[r]419,250	57,205	50,390	107,620	456,000

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

[1]Table includes data available through June 8, 1994. Total natural 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 Brazil (1989-90), and the Central African Republic (1989-90), 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]Natural gem and industrial data may not add to totals shown because of independent rounding.

[4]Includes all synthetic diamond production.

[5]Figures do not include smuggled artisanal production.

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

[7]Reported figure.

[8]Formerly part of Czechoslovakia.

[9]Dissolved on Dec. 31, 1992.

[10]"Gem" vs. "Industrial" diamond breakdown has been revised to reflect the value of near-gem material, classified as industrial prior to 1991, but which was ultimately being sold for well above industrial prices.

[11]Data for 1989 do not include smuggled production. Data for 1990-92 are estimates of artisanal production, likely smuggled out of Liberia, but which are comparable to that hitherto reported to the Government.

[12]Formerly part of Yugoslavia.

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

[14]Dissolved in Dec. 1991.

[15]Dissolved in Apr. 1992.

FIGURE 1

PRINCIPAL FORMS OF CRYPTOCRYSTALLINE AND CRYSTALLINE GEM STONE CUTS