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. In less formal or common terms a gem, gemstone, or gem material may be described as specimens of minerals or organic materials used for personal adornment, display, or to manufacture objects of art because they possess beauty, rarity, and durability.

In 1992, the value of natural gemstones from deposits in the United States was $66.2 million, a decrease of 22% compared with that of 1991. Production of gemstones included faceting rough, lapidary rough, carving material, specimen material, natural and cultured freshwater pearls, mother of pearl, fossil ivory, amber, and coral.

Synthetic gemstones are grown in the laboratory but have essentially the same appearance and optical, physical, and chemical properties as the natural material that they represent. Synthetic gemstones produced in the United States include alexandrite, coral, diamond, emerald, garnet, lapis lazuli, quartz, ruby, sapphire, spinel, and turquoise. Simulants are laboratory grown gem materials that have an appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. The gemstone simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gem stones, would be classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced. In 1992, the reported combined production value of U.S. synthetic and simulant materials was $18.9 million, about a 6% increase from that of 1991.

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

DOMESTIC DATA COVERAGE

The U.S. Bureau of Mines estimates U.S. production from the "Natural and Synthetic Gem Material Survey," a voluntary survey of U.S. operations, and from Bureau estimates of unreported production. Of the 380 operations surveyed, 94% responded, accounting for about 96% of the total production, 93% of the natural production, and 99% of the synthetic and simulant production.

The number of operations surveyed in 1992 was essentially the same as the number surveyed in 1991. The response rate was slightly better. The Bureau estimated the production by nonresponding operations, by professional collectors, and by amateur or hobbyist collectors. The basis for these estimates were information from published data, conversations with gem and mineral dealers, analyses of gem and mineral shows and sales statistics, and from information informally supplied by collectors.

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 relatively small domestic sources. In many instances, production rests in the hands of the numerous hobbyists and members of mineralogical and lapidary clubs. The Crater of Diamonds State Park near Murfreesboro, AR, is open to the public on a daily-fee basis, as are many other gemstone deposits throughout the United States. Many gem-quality stones are found at these locations each year.

Definitions, Grades, and Specifications

Select rocks, certain varieties of mineral specimens, and some organic materials, such as pearl, amber, jet, and coral, are included in gemstones data.

Customarily, diamond, ruby, sapphire, and emerald are considered the major gems.

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

Of the approximate 2,700 mineral species, only about 100 possess all of the attributes required of a gem. Collectors of gems may not require that a gem be durable because the stone is destined for display and is not to be worn. Therefore, the number of species of gemstones may be greater than the 100 that meet all of the requirements. Silicates furnish the greatest number, including such minerals as beryl, topaz, tourmaline, and feldspar. Oxides such as corundum (ruby and sapphire) and quartz (amethyst, agate, etc.) comprise the second largest group. Sulfides, carbonates, and sulfates are of small importance; the phosphates yield primarily turquoise and variscite. An exception is pearl, essentially calcium carbonate, which is ranked high as a gem. Diamond, the best known gem, is an isometric crystalline form of the element carbon.

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

Products for Trade and Industry

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

Facet cutting usually is employed on transparent gemstones to increase brilliancy and appearance. It generally is confined to the harder materials. Softer materials may be faceted, but extreme care must be exercised in cutting and polishing the stones and in their use in jewelry. Often the softer gems are used only for display and not for making jewelry. The "round brilliant" cut, most commonly used in faceting, has 58 facets, 33 above the circle "girdle" and 25 below it, arranged in eightfold symmetry. The "round brilliant" and some other common cuts are illustrated in figure 1. *(See figure 1.)*

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

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

Industry Structure

The world market for rough diamonds is controlled to a high degree by De Beers Centenary AG's marketing arm, the Central Sales Organization (CSO). It is by far the most controlled of the world's commodity markets. An estimated 80% of gem and natural industrial diamond is marketed by the CSO. The marketing is done through the CSO by the Diamond Trading Co. Ltd. and Industrial Distributors Ltd. The CSO sells uncut gem diamonds on behalf of De Beers and most other major producers at sights (approved bidder viewings) in London, England, and Lucerne, Switzerland. There are 10 such sights each year.

Diamonds reach the CSO sights through three channels—De Beers owned and operated mines, contract sales by mine owner and operators, and open-market competitive sales.

The distribution of rough diamonds in the Republic of South Africa is determined by the South Africa Diamond Board. A new agreement was reached between De Beers Consolidated Mines

Ltd., its customer, 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 is 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. Table 1 illustrates the timing and the amounts of the average CSO price increases for rough gem diamonds from 1949 until the present, while table 2 indicates the value of CSO's annual sales for the past 10 years. The compounded effect over 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 $1,800 in April 1991. *(See tables 1 and 2.)*

For more than 30 years, the major diamond cutting and polishing centers of the world were in Belgium and Israel, with a certain amount of the larger stones being cut in the United States. In the early 1980's, the development of a large cottage industry in India—today there is estimated to be more than 500,000 cutters—made a major impact on world diamond trade. India consumes most of the world's small-gem, cheap-gem, and near-gem rough material in the manufacture of small stones, which resulted in annual cut-stone exports worth billions of dollars. These small stones averaged less than one-fifth of a carat (0.20 carat). The availability of small inexpensive stones resulted in substantial changes in the design of jewelry. The utilization of small cut diamond stones (usually 0.07 to 0.14 carats each, called melee) to create a pavè effect (set close together to conceal the metal base) is but one example.

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

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

Annual cut diamond production is a function of the number of workers in the industry and their productivity. If it is assumed that the industry has a production rate of 20 carats of finished goods per month per worker and that polished yields are less than 40%, then the industry's 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 United States' newest, largest, and most modern diamond polishing factory in New York. The factory is fully computerized to track every diamond from rough to finished stone. The computer predicts the cash return from each piece of rough based on estimates of the rough's color, clarity, yield, and make; estimates are reported to be within 2% of actuals. The factory employs 40 polishers.

Cutting and polishing of colored, synthetic, and simulant gemstones is 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 are found 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 composed of silicate minerals, about one-fifth of alumina-silicates, and almost one-seventh of oxides. The remaining compositional groups include the sulfides, phosphates, borosilicates, carbonates, and, in the single case of diamond, an element. The composition of selected gem materials is included as one of the items in table 3. *(See table 3.)*

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

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

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

Technology

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

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

A boule has a very characteristic shape, with a rounded end, a long, cylindrical body, and a tapering end. It is usually about 13 to 25 millimeters in diameter, 50 to 100 millimeters long, and weighs 75 to 250 carats (a carat is 200 milligrams). Under controlled conditions, 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 the structure of a single crystal, in the point of the crucible. The crystal then acts as a seed around which the remainder of the molten material solidifies until the entire melt has frozen, filling the container with a single crystal.

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

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

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

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

Certain gemstones pose unique problems with regard to attempts to grow them. The problems arise because certain materials are either so reactive that they cannot be melted even in unreactive platinum and iridium crucibles or they melt at much higher temperatures than the crucible materials can endure. Therefore, another melting system must be used, called the skull melting system. Cubic zirconia, because of its high melting point (2,700^{0} C) must be grown using the skull melting method.

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

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

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

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

Other techniques involve solid- or liquid-state reactions and phase transformations for jade and lapis lazuli; vapor phase deposition for ruby and sapphire; ceramics for turquoise, lapis lazuli, and coral; and others for opal, glass, and plastics.

The Verneuil, Czochralshi, and skull melting processes are the melt techniques most often used for gem materials. The various synthetics and the method of production are shown in table 4. *(See table 4.)*

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

Many gemstones can be enhanced by chemical treatment or impregnations. The treatments may alter the bulk of the gem material or only penetrate the surface. This includes bleaching, oiling, waxing, plastic impregnations, color impregnations, and 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]

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 has developed a similar treatment for emeralds.

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

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

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

Diamond mining in the kimberlite pipes of Africa and 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 (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 1992, all 50 States produced at least $1,000 worth of gem materials. Ten States accounted for 83% of the total value of production of natural gemstones. The States, in order of declining value of production, were Tennessee, California, Arizona, Louisiana, Texas, Oregon, Oklahoma, Iowa, Arkansas, and North Carolina. Certain States were known best for the production of a single gem material (i.e., Tennessee for freshwater pearls and Arkansas for quartz). Other States produced a variety of gemstones. Arizona produced the greatest variety. Production included agate, amethyst, antlerite, azurite, chrysocolla, fire agate, garnets, jade, malachite, obsidian, onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. California, Idaho, Montana, and North Carolina also produced a variety of gemstones. Historically, North Carolina is the only State to have produced all four of the major gems: diamond, emerald, ruby, and sapphire.

The average production value of natural gem materials for the past 10 years was $34.9 million per year, with a high of $84.4 million in 1991 and a low of $7.4 million in 1983. The value of production for the past 10 years must be separated into two trends. The first trend was the period between 1981 through 1985, during which time approximately 24 operations reported production. Production averaged $7.4 million per year and was generally level. In the second trend, 1986 to the present, production averaged $45.7 million and was the result of an increase of 1,567% in the number of producers surveyed.

The reported value of synthetic and simulant gemstone production was $18.9 million in 1992, an increase of 6% over that of 1991. The average value of production of these gem materials for the past 7 years was $16.9 million, with a high of $20.5 million in 1990 and a low of $10.3 million in 1986. 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. The eight States, in order of declining value of production, were California, Massachusetts, Arizona, New Jersey, Washington, North Carolina, Michigan, and Ohio.

Arizona is well known for the widest variety of gemstones produced by any State. In 1992, these included agate, amethyst, antlerite, azurite, chrysocolla, fire agate, fluorite, garnet, jade, jasper, malachite, obsidian (Apache tears), onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. Yet, turquoise, peridot, petrified wood, and azurite-malachite accounted for more than 90% of the total value of gem material produced. Production from Arizona of these gemstones was the largest in terms of dollar value in the United States and the world's largest for the first two. Additionally, four manufacturers of synthetic or simulant gem materials were in Arizona and produced about $1.8 million worth of material.

Arkansas is famous for the production of quartz crystals, but it appears that the fads that have supported the production of quartz crystals for the past few years has ended. It is second in value of production of freshwater pearls and shells and the only State in the United States that has had any sustained diamond production.

Since 1972, hobbyists have found from 300 to 1,500 diamonds per year at the Crater of Diamonds State Park. From 1906 to the present, it is estimated that production from the deposit is 100,000 to 150,000 carats; this amount of diamond production is insufficient to classify the United States as a diamond-producing country. Still, the potential to become a diamond producer may be there, and efforts were underway to evaluate this potential more fully. A four phased program to evaluate the diamond deposit was halted by legal actions after completing three exploratory drill holes in 1990. After a Federal appellate court cleared the way for the program to continue, phase 1, the drilling of 26 core holes totaling 2,600 meters, was completed during 1992.

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

The State also has a freshwater culture pearl farm at Marysville. 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 commercially produce turquoise and still has commercially operated turquoise mines. It also produced the United States' finest gem-quality rhodochrosite and a quantity of high-quality rhodonite.

Many different locations in the State produce aquamarine, the Colorado State gemstone. The best known locations and the locations with the longest history of continued production (since about 1884) are Mount Antero and White Mountain in Chaffee County. Mount Antero, at 4,349 meters, may be the highest gemstone location in the United States. White Mountain, separated from Antero by a small saddle, is only slightly lower at 4,237 meters.

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

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

In the U.S. gemstone industry, Maine and tourmaline are almost synonymous. In 1822, Maine's Mount Mica was the site of the first gemstone production in the United States. In 1992, Plumbago Mining Corp. was actively mining the Mount Mica pegmatite for gem material and mineral specimens. Over the years, production from Mount Mica has included hundreds of kilograms of fine-quality gem and mineral specimen tourmaline.

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

Production from Maine deposits also includes fine-quality beryls—aquamarine, heliodor, and morganite. Pegmatites in Oxford, Androscoggin, and Sagadahoc Counties regularly produce fine-quality blue and blue-green aquamarine, rich yellow- and gold-colored heliodor, and rose- and peach-colored morganite.

Montana produces many different gemstones, some suited for faceting, while others are better suited for the cutting of cabochons, carvings, or objects-of-art. Montana is noted for the production of sapphires, Montana moss agate, and Dryhead agates. Yet, amethyst, amazonite, azurite, covellite, cuprite, garnet, onyx, opal, petrified wood, rhodochrosite, rhodonite, smokey quartz, sphalerite, and wonderstone (banded rhyolite) also are produced or have been produced from deposit in the State for use as gemstones.

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

Nevada has been a major producer of turquoise since the 1930's, and until the early 1980's, the State was the largest turquoise producer in the United States. Estimates indicate that over the years, 75 to 100 different mines and/or prospects have produced sizable quantities of turquoise. Production varied from a few thousand dollars worth of material at some properties to more than $1 million at others. Estimates of total production to date are between $40 to $50 million.

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

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

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

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

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

Tennessee has the largest U.S. production of freshwater mussel shells and pearls of the 11 producing States. There has been an established U.S. freshwater mussel fishing industry since the mid-1850's. The mussels are from the family Unioidae, of which about 20 different species are commercially harvested. During 1992 the value of U.S. mussel shell exports was more than $43 million.

To date, freshwater pearls from the United States have been 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 may change. 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.

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 is found as fracture fillings or as nodules. The nodules may be solid, almost geode in nature, or fractured solid nodules that have undergone alteration. The color of the variscite varies from 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 in 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 carats with few more than 1 carat. The largest finished stone to date is only 4.46 carats. The material is expensive, but justifiably so, because of its beauty and rarity.

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

The value of 1992 production by individual gemstone can be reported for those materials that have three or more producers and if one of the three does not account for more than 75% of the total or two of the producers account for 95% or more of the production. *(See table 5).*

Consumption and Uses

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

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

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

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

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

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

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

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

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

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

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

The 1992, estimated value of U.S. apparent consumption was $3,226 million, down about 13% from 1989's record high. The average annual estimated consumption for the past 10 years was $3,148 million, with a high of $3,705 in 1988 and a low of $2,132 in 1983. The trend for estimated consumption for the past 10 years was one of continued growth with some downward adjustments related to economic conditions.

In 1992, the value of U.S. estimated apparent consumption of diamonds increased about 8% to $2.8 billion. The average annual value of apparent consumption of diamonds for the past 10 years was $2.6 billion, with a high of $3.1 billion in 1989 and a low of $2.1 billion in 1983.

The 1992 estimated apparent consumption of colored stones, led by emerald, ruby, and sapphire, was valued at $392.0 million, a decrease of 3%. The estimated apparent consumption of pearls—natural, cultured, and imitations—was $19.1 million, a slight decrease. The average annual consumption for the past 10 years was $155.3 million, with a high of $244.7 million in 1984 and a low of $16.5 million in 1990. Estimated apparent consumption of synthetic and imitation gemstones increased about 464% to $117.9 million. Average apparent consumption of these materials for the past 10 years was $62.6 million per year, with a high of $117.9 million in 1992 and a low of $17.2 million in 1983. During 1992, sales in retail jewelry stores increased about 4% to $14.4 billion, according to the U.S. Department of Commerce.

Prices

Demand, beauty, durability, rarity, freedom from defects, and perfection of cutting determine the value of a gem. In establishing the price of gem diamond, the CSO's control over output and prices 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 VS2 clarity) of a 1-carat diamond fluctuated between $7,208 and $7,256, and was $7,208 at yearend. The average value per carat of all grades, sizes, and types of gem-quality diamond imports was $443, a 14% decrease compared to that of 1991. The average value of diamond imports for the past 10 years was $408 per carat, with a high of $525 in 1990 and a low of $353 in 1984.

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 1991. The average value of ruby imports decreased slightly to $29.53 per carat. The average annual value of ruby imports for the past 10 years was $36.67 per carat, with a high of $48.71 in 1990 and a low of $16.42 in 1984.

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 1991. The average value of sapphire imports decreased 30% to $16.29 per carat. The average annual value of sapphire imports for the past 10 years was $22.40 per carat, with a high of $27.97 in 1987 and a low of $16.29 in 1992.

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 1991. The average value of emerald imports increased 72% to $72.23 per carat. The average annual value of emerald imports for the past 10 years was $57.30 per carat, with a high of $78.79 in 1988 and a low of $35.06 in 1984. *(See tables 6 and 7).*

Foreign Trade

The value of diamond exports plus reexports decreased 5% to $1.45 billion. The quantity of cut diamonds exported and reexported decreased 10% to 911,419 carats, and the value of diamond exported and reexported decreased slightly to $1.32 billion.

The value of other precious stones, cut but unset or rough other than diamonds, pearls, and synthetics, exported and reexported increased from $105.5 million to $241.2 million. The value of synthetic gemstone exports plus reexports decreased slightly to $21.2 million.

The value of natural, cultured, and imitation pearls, not set or strung, exports and reexports of pearls increased 62% to more than $6.7 million.

The value of gems and gemstones imported increased 4% to $4,839.4 million compared to those of 1991, but was still below the 1989 record high of $5,115 million. The value of imported gem diamonds accounted for about 86% of the total. The average annual value of gems and gemstones imports for the past 10 years was $4,272 million, with a high of $5,115 million in 1989 and a low of $2,856 million in 1983.

The value of imported gem diamonds increased 4% to $4,143.6 million, but was below the 1989 record high of $4,358 million. The imports of cut diamonds increased 15% in quantity and 5% in value to 7.7 million carats and $3,648.6 million, respectively. The average annual quantity of cut diamonds imported for the past 10 years was 7.3 million carats, with a high of 8.9 million in 1989 and a low of 5.2 million carats in 1983. The average annual value of cut diamond imports was $3,130.0 million, with a high of $3,805.5 in 1989 and a low of $1,982.7 million in 1983.

The value of imports of other gem and gemstones, led by emerald, ruby, and sapphire, was $668.2 million, a decrease of about 26% compared to that of 1991. Emerald imports increased 29% to $213.5 million. The average annual value of emerald imports for the past 10 years was $164.6 million, with a high of $213.5 million in 1992 and a low of $134.1 million in 1983.

The value of ruby imports increased 10% to $77.8 million, but was less than the record-high value for the past 10 years of $98.4 million in 1990. The average annual value of imports for the past 10 years was $76.1 million, with a high of $98.4 in 1990 and a low of $58.7 in 1987. The value of sapphire imports was $75.1, a decrease of 8% compared to those of 1991. The average annual value of sapphire imports for the past 10 years was $82.9 million, with a high of $100.0 million in 1989 and a low of $70.8 million in 1985.

The value of imported gem materials other than diamond, emerald, ruby, and sapphire increased 35% to $327.7 million. The average annual value of imports was $338.9 million, with a high of $429.5 in 1988 and a low of $210.3 in 1990. *(See tables 8, 9, 10, 11, and 12).*

World Review

Diamond sales by De Beers Centenary AG was $3.4 billion in 1992, a decrease of 13% compared with 1991 sales of $3.94 billion. Sales during the second half of 1992 were only $1.63 billion, 12% less than the $1.84 billion sales for the second half of 1991. A De Beers official stated that the reduction in sales was the result of the world economic conditions. De Beers controls about 80% of the rough, uncut diamonds sold in the world. Sales of colored stones remained strong.

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

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 on behalf of Endiama, the Angolan state mining corporation.

Armenia.—The diamond cutting and polishing factory at Nur Adjen produced about $60 million of income during the year, despite cutbacks of rough diamonds from Yakutia. The factory worked 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 moral, and comparatively high salaries; these factors resulted in high-quality production.

Australia.—Argyle's diamond production of 39.0 million carats was a record for the mine. The Argyle partners stated that the installation of a new heavy-media separation circuit in the alluvial plant and the 2-million-ton expansion in the AK-1 treatment plant would increase production and efficiency. The largest gem-quality diamond recovered from the Argyle mine to date, a 41.7-carat elongated octahedron, was discovered in May. The peanut shell-sized diamond has not been evaluated to establish a price. However, it is not as valuable as the highly prized Argyle pink diamonds. Since the start of mining in 1983, more than 265 million carats of diamonds has been recovered from the AK 1 pipe and alluvial operations.

Ashton Mining Ltd. reported that the Australian Diamond Exploration Joint Venture had discovered 20 commercial-sized stones in the Northern Territory. The stones were from work on the Merlin anomaly.

Redfire Resources NL announced it appeared its opal mining would start in early 1993 on their Coocoran opal project in New South Wales 20 kilometers west of Lighting Ridge. Initial company estimations are that the deposit has potential for a bonanza of economic-grade opals from two separate zones.

Centenary International Mining is spending $373,000 to earn a 70% interest in the Lila Springs Claims, a boulder opal deposit in New South Wales. The company plans to raise funds for the purchase of equipment to start recovering opal to quickly establish a cash-flow. Additionally, Centenary has claims that cover about 200 kilometers of strike length along the Giralia Fault. These claims cover a fossil beach sand deposit suspected to contain diamonds.

Canada.—Sudbury Contact Mines announced the discovery of six more microdiamonds from its Diamond Lake property east of Kirkland Lake, Ontario. This brings to 14 the number of diamonds recovered from cores from 3 holes drilled during the winter of 1991-92. Sudbury drilled eight additional targets during the summer. The targets were drilled to an average depth of 150 meters.

Dia Met Minerals announced additional results from the testing of its kimberlite discovery in the Lac De Gras area of the Northwest Territories. The most recent information disclosed the recovery of 101 carats of diamonds from a 160-ton bulk sample from core drilling. About 25% of the diamonds was gem quality, and some of the stones were in the 1- to 3-carat size range.

Thermal Exploration Co. of California acquired a 70% interest in about 390,000 hectares in the Lac de Gras area of the Northwest Territories. The claims are on the same trend as Dia Met Minerals' and BHP-Utah's holdings. Kennecott Canada Ltd. can earn a 70% interest in Thermal's holding by providing 100% of the exploration costs.

Sudbury Contact Mines, which continued to explore in the Kirkland Lake mining district of northern Ontario, they sampled a second kimberlite pipe and commenced drilling late in the year.

Celtic Gold and Claude Resources secured funding to continued exploration of their joint-venture diamond project at Sturgeon Lake in Saskatchewan. Drilling is underway to examine a ring structure.

China.—Everay Jewellery Ltd. opened its sixth diamond cutting factory in Guangdong Province. The new factory is the company's largest in China and has a capacity for 1,000 workers. The factory produced round brilliants of five points and less. Everay's production of finished goods from China is just over 100,000 pieces per month.

Russia.—The Siberian Republic of Sakha (formerly Yakutia), an autonomous republic with the Russian Federation, signed an agreement with De Beers Centenary AG to exclusively market diamonds through the CSO. Under the agreement, the Republic has the right to retain up to 10% of its rough diamonds for cutting or independent sales. Sakha is responsible for 99.8% of the rough diamond production from the Commonwealth of Independent States. Additionally, De Beers agreed to furnish equipment and training to establish a cutting factory in Sakha. Called Polar Star, the plant will cut about 100,000 carats per year and produce jewelry for the domestic market.

Sakha also signed an agreement with Reichbart Arye, an Israeli firm, which will supply diamond cutting equipment, technology, and training. Diamonds will be cut in the town of Barnaul and in Israel. Additionally, Sakha entered into an agreement with Arda Co., a Japanese jewelry firm, for diamond cutting plants in Sakha. Arda plans to cut 50,000 to 100,000 carats per year for sale in Japan, the Republic of Korea, and Taiwan.

Smolensk Gems NV is a venture between Antwerp-based PHP Diamond, Smolensk Cutting Factory, the Antwerp office of Russalmaz, and Almazjuvelierexport in Moscow. The venture will cut Russian rough into fancy cuts, mainly triangles and princess cuts. The finished goods will be sold in Antwerp.

A recent government decree created the Severoalmaz joint stock company to mine the diamond deposits discovered in the 1980's at Lomonosov in the Archangel region. The decree provides for creating a production complex to mine, sort, and cut diamonds and to make diamond instruments. Severoalmaz will include the Russian corporation Almazzoloto, the Finance Ministry, Archangel Regional Administration, and the Arkhangelskgeologiya enterprise. It is expected that foreign firms will join in providing technical and economic expertise, and assistance in construction of the mining and recovery plants.

Sierra Leone.—The National Provisional Ruling Council of Sierra Leone (which overthrew the President in April 1992) rendered invalid all diamond export licenses issued by the former regime. All sales of diamonds after July were by tender.

Sunshine Mining settled a legal dispute with Boulle Group, its former partner, and gained 100% control of the Koidu Kemberlite project, believed to contain reserves of 2.5 million carats of diamonds. Sunshine announced plans for a two phase approach to developing the project. Phase 1 would be an approximate 2-year bulk sampling project to substantiate the reserves. Phase 2 would be the construction of a full-scale mine and recovery plant at a cost of about $37 million. The project is anticipated to have a 15-year life.

South Africa, Republic of.—De Beers Consolidated Mines Ltd. brought its new Venetia Mine to full production late in the year. It is reported that the mine will produce about 5.9 million carats per year. Venetia, located in the northern Transvaal near Messina, is a low-cost, high-grade (137 carats per 100 tons) open pit mine. Production from the mine is reported to be 50% to 60% gem-quality stones. Production from the mine is equal to 70% of the country's total production in 1991.

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, rough mined in South Africa was offered to domestic cutters before being exported. 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.

Three Canadian partners, Stow Resources, Dryden Resources, and Southerera Resources, commissioned the treatment plant for the Leicester diamond mine near Kimberly. A dozen clear white gem-quality diamonds were recovered during startup, including two that are slightly more than 1 carat and one of about 6.5 carats. Previous production from the mine yielded 32,000 carats, with about 50% gem-quality and about 10% larger than 10 carats.

Tanzania.—De Beers' subsidiary Willcroft Co. Ltd. entered into a prospecting and mining agreement with the Ministry of Water, Energy and Minerals. The agreement is for prospecting and mining rights on an area of more than 22,000 square kilometers in the Mwanza, Shinyanga, and Tabora regions. The Ministry also has signed diamond exploration agreements with Reunion Mining Plc. and RZT.

In May, the Tanzania Mineral Dealers Association and the Ministry of Water, Energy, and Minerals of Tanzania held the first gemstone auction in Arusha. Sixty dealers offered goods for sale at the auction attended by 28 buyers from 9 countries. About $200,000 worth of mostly rough tanzanite, ruby, rhodolite garnet, green garnet, chrome tourmaline, and sapphire were sold.

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

Uzbekistan.—A deposit of industrial diamonds was opened in Tyan-Shan near Tashkent. The diamonds are up to 2 millimeters in diameter, but the deposit also may contain larger gem diamonds. It does allow the republic to enter the ranks of diamond-producing countries.

Zaire.—The volume and value of diamonds marketed through unofficial channels increased after the mutiny in September 1991. The value of diamonds marketed through these channels was estimated to be more than $200 million in 1991, two to five times greater than before the mutiny. The problem seems to have abated somewhat during 1992.

Zimbabwe.—Australian-based Auridiam Consolidated Ltd. recovered about 5,000 carats of diamonds, including a 17-carat gem-quality stone, from the 3-month pilot plant testwork on its Rive Ranch concession. The concession, near the Limpopo River, in southern Zimbabwe, was acquired in the past year after De Beers Consolidated Mines Ltd. and the Government of Zimbabwe could not come to terms. Based on these encouraging results, Auridiam is planning a 200,000-cubic-meter-per-year production plant that would produce about 500,000 carats per year for 10 to 15 years. The diamonds recovered to date were offered for tender in Antwerp.

Reunion Mining Plc. discovered two kimberlites on its concession near Lake Kariba, 300 kilometers west of Harare. Other anomalies in the same area lead the company to believe a group or cluster of pipes may be present. Reunion has 6 additional concessions for diamond exploration in Zimbabwe.

See table 13 for world diamond production by country. *(See table 13.)*

OUTLOOK

World demand for gem diamond can be expected to rise because of increasing effective personal incomes in 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 in 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. Butterworth, 1984, pp. 46-60.
[2]Pages 61-78 of work cited in footnote 1.
[3]Pages 25-44 of work cited in footnote 1.
[4]Rapaport Diamond Report. Mar. 6, 1992, Colored Stones Section. V. 15, No 9., p. 26.

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TABLE 1

DE BEERS' CSO ROUGH DIAMOND PRICE INCREASES, BY PERCENTAGE

Sept. 1949	25.0	Nov. 1967	16.0	Aug. 1973	10.2	Sept. 1982	2.5
Mar. 1951	15.0	Sept. 1968	2.5	Dec. 1974	1.5	Apr. 1983	3.5
Sept. 1952	2.5	July 1969	4.0	Jan. 1976	3.0	Aug. 1986	7.5
Jan. 1954	2.0	Nov. 1971	5.0	Sept. 1976	5.8	Nov. 1986	7.0
Jan. 1957	5.7	Jan. 1972	5.4	Mar. 1977	15.0	Sept. 1987	10.0
May 1960	2.5	Sept. 1972	6.0	Dec. 1977	17.0	Apr. 1988	13.5
Mar. 1963	5.0	Feb. 1973	11.0	Aug. 1978	30.0	Mar. 1989	15.5
Feb. 1964	7.5	Mar. 1973	7.0	Sept. 1979	13.0	Mar. 1990	5.5
Aug. 1966	7.5	May 1973	10.0	Feb. 1980	12.0	Feb.1993	1.5

TABLE 2

DE BEERS' CSO ROUGH DIAMOND SALES AND STOCKS

(Billions of dollars)

Year	Sales	Stocks
1983	1.50	1.85
1984	1.61	1.95
1985	1.80	1.90
1986	2.56	1.85
1987	3.07	2.30
1988	4.17	2.00
1989	4.09	2.47
1990	4.17	2.68
1991	3.93	3.03
1992	3.42	3.36

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 violet 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	do.	7.5-8.0	2.63-2.80	do.	1.58	Kunzite, tourmaline, pink sapphire	Refractive index.
Calcite:										
Marble	Calcium carbonate	White, pink, red, blue, green, or brown	Any	Low	3.0	2.72	Double (strong)	1.49-1.66	Silicates, banded agate, alabaster gypsum	Translucent.
Mexican onyx	do.	do.	Any	Low	3.0	2.72	do.	1.6	do.	Banded, translucent.

See footnotes at end of table.

TABLE 3—Continued

GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Chrysoberyl:										
Alexandrite	Beryllium aluminate	Green by day, red by artificial light	Former U.S.S.R. (small), Sri Lanka (medium)	High	8.5	3.50-3.84	Double	1.75	Synthetic	Dichroism, inclusions in synthetic sapphire.
Catseye	do.	Greenish to brownish	Small to large	do.	8.5	3.50-3.84	do.	1.75	Synthetic, shell	Gravity and translucence.
Chrysolte	do.	Yellow, green, and/or brown	Medium	Medium	8.5	3.50-3.84	do.	1.75	Tourmaline, peridot	Refractive index, silky.
Coral	Calcium carbonate	Orange, red, white, black, or green	Branching, medium	Low	3.5-4.0	2.6-2.7	do.	1.49-1.66	False coral	Dull translucent.
Corundum:										
Ruby	Aluminum oxide	Rose to deep purplish red	Small	Very high	9.0	3.95-4.10	do.	1.78	Synthetics, including spinel	Inclusions, fluorescence.
Sapphire	do.	Blue	Medium	High	9.0	3.95-4.10	do.	1.78	do.	Inclusions, double refraction, dichroism.
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.

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
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	Cryptocrystalline	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.
Peridot	Iron magnesium silicate	Yellow and/or green	Any	Medium	6.5-7.0	3.27-3.37	Double (strong)	1.65-1.69	Tourmaline chrysoberyl	Strong double refraction, low dichroism.
Opal	Hydrous silica	Colors flash in white gray, black, red, or yellow	Large	Low to high	5.5-6.5	1.9-2.3	Isotropic	1.45	Glass, synthetics, triplets	Play of color.

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
Pearl	Calcium carbonate	White, pink, or black	Small	do.	2.5-4.0	2.6-2.85	—	—	Cultured and imitation	Luster, structure, X-ray.
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 refraction, translucent.
Spinel	Magnesium aluminum oxide	Any	Small to medium	Medium	8.0	3.5-3.7	Single	1.72	Synthetic, garnet	Refractive index, single refraction, inclusions.
Spinel, synthetic	do.	Any	Up to 40 carats	Low	8.0	3.5-3.7	Double	1.73	Spinel, corundum, beryl, topaz, alexandrite	Weak double refraction, curved striae, bubbles.

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
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	do.	do.		Synthetic spinel	Do.
Tanzanite	Complex silicate	Blue	Small	High	6.0-7.0	3.30	do.	1.69	Sapphire, synthetics.	Strong trichroism.
Topaz	do.	White, blue, green	Medium	Low to medium	8.0	3.4-3.6	do.	1.62	Beryl, quartz	Refractive index.
Tourmaline	do.	All, including mixed	do.	do.	7.0-7.5	2.98-3.20	do.	1.63	Peridot, beryl, corundum, glass	Double refraction, refractive index.
Turquoise	Copper aluminum phosphate	Blue to green phosphate	Large	Low	6.0	2.60-2.83	do.	1.63	Glass, plastics	Difficult if matrix not present, matrix usually limonitic.
Zircon	Zirconium silicate	White, blue, or brown, yellow, or green	Small to medium	Low to medium	6.0-7.5	4.0-4.8	Double (strong)	1.79-1.98	Diamond, synthetics, topaz, aquamarine	Double refraction, strongly dichroic, wear on facet edges.

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

TABLE 4
SYNTHETIC GEMSTONE PRODUCTION METHODS

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

TABLE 5
VALUE OF 1992 U.S. GEMSTONE PRODUCTION, BY GEM MATERIALS

Gem materials	Value
Agate	$548,000
Beryl	323,000
Coral (all types)	122,000
Garnet	108,000
Gem feldspar	1,042,000
Geode/nodules	260,000
Fire agate	45,000
Jasper	111,000
Obsidian	4,000
Opal	756,000
Peridot	1,306,000
Petrified wood	211,000
Quartz	638,000
Sapphire/ruby	895,000
Topaz	12,000
Tourmaline	82,000
Turquoise	1,994,000
Total	8,457,000

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. 1992-Jan. 1993	Average[4] July 1992
0.25	G	VS1	$1,400- $1,400	$1,400
.25	G	VS2	1,200 - 1,200	1,200
.25	G	SI1	970 - 970	970
.25	H	VS1	1,200 - 1,200	1,200
.25	H	VS2	1,100 - 1,100	1,100
.25	H	SI1	950 - 950	950
.50	G	VS1	2,700 - 2,900	2,900
.50	G	VS2	2,500 - 2,600	2,600
.50	G	SI1	2,300 - 2,300	2,300
.50	H	VS1	2,600 - 2,700	2,700
.50	H	VS2	2,400 - 2,500	2,500
.50	H	SI1	2,100 - 2,200	2,200
.75	G	VS1	3,500 - 3,500	3,500
.75	G	VS2	3,200 - 3,200	3,200
.75	G	SI1	2,800 - 2,800	2,800
.75	H	VS1	3,100 - 3,100	3,100
.75	H	VS2	2,800 - 2,800	2,800
.75	H	SI1	2,600 - 2,600	2,600
1.00	G	VS1	4,600 - 4,600	4,600
1.00	G	VS2	4,100 - 4,100	4,100
1.00	G	SI1	3,700 - 3,700	3,700
1.00	H	VS1	4,100 - 4,100	4,100
1.00	H	VS2	3,800 - 3,900	3,900
1.00	H	SI1	3,400 - 3,600	3,600

[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. 164, No. 3, Mar. 1993, p. 148.
[4]Jeweler's Circular-Keystone. V. 163, No. 9, Sept. 1992, p. 118.

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

Gemstone	Carat weight	Price range per carat in 1992[2]	Average price per carat[2]	
			Jan. 1992	Jan. 1993
Amethyst	1	$8 - $18	$13.00	$13.00
Aquamarine	1	75 - 250	175.00	82.50
Emerald	1	2,500- 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 - 240	210.00	130.00
Topaz	1	5 - 12	9.00	7.00
Tourmaline, red	1	60 - 125	92.50	92.50

[1]Fine quality.
[2]Jewelers' Circular-Keystone. V. 164, No. 3, Mar. 1993, p. 148. 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	1991		1992	
	Quantity (carats)	Value[1] (millions)	Quantity (carats)	Value[1] (millions)
Exports and reexports:				
Belgium	[r]2,177,190	[r]$430.5	2,404,886	$368.6
Canada	[r]305,702	[r]32.1	413,285	30.7
France	8,746	23.7	7,455	25.2
Hong Kong	[r]291,537	[r]270.4	198,418	312.5
Israel	[r]364,495	[r]272.1	335,521	279.0
Japan	[r]125,260	[r]196.3	80,953	121.5
Singapore	[r]20,653	[r]27.5	24,213	30.9
Switzerland	[r]116,246	[r]149.7	52,447	146.4
Thailand	[r]39,748	[r]39.7	23,057	17.1
United Kingdom	[r]20,516	[r]38.5	16,156	51.7
Other	[r]240,323	[r]41.3	393,999	65.8
Total	[r]3,710,416	[r]1,521.6	3,950,390	1,449.5

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

Source: Bureau of the Census.

TABLE 9

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

Kind, range, and country of origin	1991		1992	
	Quantity (carat)	Value[1] (millions)	Quantity (carat)	Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium	455,621	$40.7	402,763	$81.9
Brazil	106,396	9.8	26,867	1.4
Israel	17,097	10.3	26,699	10.7
Netherlands	18,334	9.2	79,564	17.6
South Africa, Republic of	13,787	7.6	13,405	17.6
Switzerland	64,717	18.9	1,156	9.4
United Kingdom	625,965	249.5	685,544	189.1
Venezuela	20,580	0.3	318	0.1
Other	460,339	181.1	392,059	167.1
Total	1,782,836	527.4	1,628,375	495.0
Cut but unset, not more than 0.5 carat:				
Belgium	789,422	280.1	795,348	270.5
Brazil	41,626	17.6	15,414	6.6
Canada	4,419	1.2	6,558	2.1
Hong Kong	132,735	29.0	247,289	44.1
India	3,373,905	825.4	4,249,843	935.2
Israel	727,175	357.9	670,327	313.0
Netherlands	5,612	1.7	3,338	1.1
South Africa, Republic of	16,517	10.0	7,263	6.3
Switzerland	21,237	6.2	11,055	4.6
United Kingdom	1,424	0.7	4,779	1.4
Other	86,601	20.9	80,899	19.2
Total	5,200,673	1,550.7	6,092,113	1,604.2
Cut but unset, more than 0.5 carat:				
Belgium	592,530	793.9	589,036	776.2
Hong Kong	14,196	34.5	14,879	30.8
India	41,316	33.8	30,634	18.0
Israel	783,799	834.4	915,487	973.8
Netherlands	4,491	13.8	3,928	18.9
South Africa, Republic of	5,291	12.2	5,706	22.4
Switzerland	23,766	115.2	10,712	95.1
United Kingdom	9,018	34.8	20,061	35.1
Other	23,553	41.3	41,319	74.3
Total	1,497,960	1,913.9	1,631,762	2,044.5

[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 GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY

Kind and country	1991 Quantity (carats)	1991 Value[1] (millions)	1992 Quantity (carats)	1992 Value[1] (millions)
Emerald:				
Belgium	10,782	$1.6	4,381	$0.7
Brazil	1,554,717	6.7	125,548	4.5
Colombia	212,818	51.5	403,988	92.4
France	7,456	3.0	3,753	4.1
Germany	19,828	2.2	149,870	4.3
Hong Kong	114,521	13.4	232,025	19.2
India	1,298,384	22.7	1,208,678	16.5
Israel	134,178	21.3	116,586	21.4
Japan	2,946	0.7	125	0.2
South Africa, Republic of	206	0.3	962	0.1
Switzerland	66,283	23.3	164,283	39.6
Taiwan	414	0.1	3,452	0.3
Thailand	483,037	12.6	299,313	6.6
United Kingdom	8,755	0.9	1,957	1.2
Other	24,980	5.1	240,985	2.5
Total[3]	3,939,305	165.5	2,955,906	213.5
Ruby:				
Belgium	8,127	1.3	9,065	1.1
Brazil	11,517	0.5	6,793	0.3
Colombia	145	([3])	70	([3])
France	4,686	0.9	790	0.6
Germany	15,438	1.6	17,677	1.1
Hong Kong	38,030	4.4	99,817	3.8
India	455,938	1.9	375,745	1.7
Israel	10,736	0.8	12,094	1.5
Japan	647	0.1	3	([3])
Switzerland	72,979	16.5	36,221	23.3
Thailand	[r]1,715,520	37.3	2,008,030	39.1
United Kingdom	12,089	3.2	2,401	3.3
Other	32,128	2.4	66,233	2.1
Total[3]	[r]2,377,980	70.9	2,634,939	77.8
Sapphire:				
Australia	3,963	0.3	4,682	0.1
Austria	603	([3])	65	([3])
Belgium	5,044	1.3	6,744	0.7
Brazil	7,932	0.4	23,326	0.2
Canada	8,109	0.4	187,196	0.5
Colombia	111	([3])	82	0.1
France	4,695	1.3	597	1.4
Germany	21,882	0.8	49,194	1.3
Hong Kong	141,486	6.2	113,670	3.8
India	59,588	0.6	71,670	0.5
Israel	10,723	0.8	28,987	1.2
Japan	6,536	0.5	2,159	0.1
Korea, Republic of	1,980	([3])	NA	NA
Singapore	833	0.4	101	([3])

See footnotes at end of table.

TABLE 10—Continued

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

Kind and country	1991 Quantity (carats)	1991 Value[1] (millions)	1992 Quantity (carats)	1992 Value[1] (millions)
Sapphire—Continued:				
Sri Lanka[4]	54,023	$3.9	85,218	$3.5
Switzerland[4]	21,096	16.2	27,608	13.6
Thailand	3,122,987	46.1	3,991,362	45.5
United Kingdom	15,895	1.4	4,210	1.2
Other	14,062	0.9	13,989	1.4
Total[3]	3,501,548	81.5	4,610,860	75.1
Other:				
Rough, uncut:				
Australia		1.1		2.1
Brazil		35.2		30.2
Colombia		1.4		4.4
Hong Kong		2.0		1.0
Nigeria	NA	0.2	NA	0.2
Pakistan		0.7		0.3
South Africa, Republic of		0.6		0.3
Switzerland		1.0		0.7
United Kingdom		1.2		0.1
Zambia		0.8		1.0
Other		11.8		13.1
Total	NA	56.0	NA	53.5
Cut, set and unset:				
Australia		3.2		3.8
Brazil		9.3		9.0
Canada		0.2		0.4
China		0.8		0.9
Germany		15.2		15.7
Hong Kong	NA	[r]16.6		17.2
India		7.4		6.9
Japan		[r]9.4		9.3
Switzerland		1.1		0.8
Taiwan		2.8		3.1
Thailand		72.3		47.5
United Kingdom		2.1		0.7
Other		[r]14.6		16.0
Total[3]	NA	[r]155.0	NA	131.4

[r]Revised. NA Not available.
[1]Customs value.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/10 unit.
[4]Erroneously omitted in 1991.

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	1991	1992
Synthetic, cut but unset:		
Australia	0.5	1.9
Austria	3.4	6.3
France	1.9	1.4
Germany	[r]8.8	10.3
Hong Kong	1.6	2.9
Japan	.7	1.2
Korea, Republic of	4.9	4.2
Switzerland	2.8	4.6
Taiwan	.5	0.9
Thailand	16.0	23.2
Other	[r]1.8	1.4
Total	[r]42.9	58.2
Imitation:		
Austria	[r]58.6	69.8
Czechoslovakia	[r]4.0	7.0
Germany	1.8	2.8
Japan	1.5	2.3
Other	3.0	2.7
Total	[r]69.0	84.6

[r]Revised.

[1]Customs value.

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

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES

(Thousand carats and thousand dollars)

Stones	1991		1992	
	Quantity	Value[1]	Quantity	Value[1]
Diamonds:				
Rough or uncut	1,783	527,424	1,628	495,003
Cut but unset	6,699	3,464,599	7,724	3,648,626
Emeralds: Cut but unset	3,939	165,508	2,956	213,497
Coral and similar materials, unworked	[r]2,554	[r]6,741	2,787	6,115
Rubies and sapphires: Cut but unset	5,880	[r]152,484	7,246	152,886
Pearls:				
Natural	NA	[r]4,645	NA	3,896
Cultured	NA	[r]16,812	NA	18,313
Imitation	NA	[r]2,492	NA	3,710
Other precious and semiprecious stones:				
Rough, uncut	338,300	43,825	408,236	41,446
Cut, set and unset	NA	[r]133,530	NA	109,233
Other	429	[r]5,435	281	5,957
Synthetic:				
Cut but unset	[r]148,203	[r]42,901	217,059	58,189
Other	NA	[r]2,099	NA	1,636
Imitation gemstone	NA	[r]66,507	NA	80,927
Total[2]	XX	[r]4,635,002	XX	4,839,43

[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	1988 Natural Gem[2]	1988 Natural Industrial	1988 Natural Total[3]	1988 Synthetic[4]	1989 Natural Gem[2]	1989 Natural Industrial	1989 Natural Total[3]	1989 Synthetic[4]	1990 Natural Gem[2]	1990 Natural Industrial	1990 Natural Total[3]	1990 Synthetic[4]
Angola[e]	950	50	1,000	—	1,165	80	[5]1,245	—	[r]1,060	[r]73	[r]1,133	—
Australia	17,413	17,413	34,826	—	17,540	17,540	35,080	—	17,331	17,331	34,662	—
Botswana	10,660	[r]4,570	15,229	—	[r]10,680	[r]4,570	15,252	—	[r]12,150	[r]5,200	17,352	—
Brazil	[r]350	180	[r]530	—	350	150	500	—	600	900	1,500	—
Central African Republic	284	59	343	—	334	81	415	—	303	78	381	—
China[e]	200	800	1,000	15,000	200	800	1,000	15,000	200	800	1,000	15,000
Côte d'Ivoire[6]	8	3	11	—	9	3	12	—	9	3	12	—
Czechoslovakia[e]	—	—	—	5,000	—	—	—	5,000	—	—	—	5,000
France[e]	—	—	—	4,000	—	—	—	4,000	—	—	—	4,000
Gabon[e]	400	100	500	—	400	100	500	—	400	100	500	—
Ghana[7]	55	[r]465	[r]520	—	[r]124	[r]370	[r]494	—	[r]163	[r]487	[r]650	—
Greece[e]	—	—	—	1,000	—	—	—	1,000	—	—	—	1,000
Guinea[7]	136	10	146	—	[r]137	10	[r]147	—	[r]119	[r]8	[r]127	—
Guyana	1	3	4	—	3	5	8	—	[r]5	[r]13	[r]18	—
India	11	3	14	—	3	12	15	—	3	[r, e]15	[r]18	—
Indonesia[e]	7	22	29	—	7	25	32	—	7	23	30	—
Ireland[e]	—	—	—	60,000	—	—	—	60,000	—	—	—	60,000
Japan[e]	—	—	—	25,000	—	—	—	25,000	—	—	—	25,000
Liberia	67	100	167	—	62	93	155	—	40	60	[e]100	—
Namibia	[r]925	[r]50	[r]975	—	910	[r]20	[r]927	—	[r]750	[r]15	[r]763	—
Romania[e]	—	—	—	5,000	—	—	—	4,500	—	—	—	4,500
Russia[8, 9]	—	—	—	—	—	—	—	—	—	—	—	—
Sierra Leone[6]	12	6	18	—	90	39	129	—	66	12	78	—
South Africa, Republic of:												
Finsch Mine	[r]1,320	[r]2,600	3,920	—	[r]1,600	[r]3,000	4,610	—	[r]1,480	[r]2,700	4,178	—
Premier Mine	[r]700	[r]1,540	2,239	—	[r]700	[r]1,520	2,215	—	[r]720	[r]1,600	2,328	—
Venetia Mine	—	—	—	—	—	—	—	—	20	40	62	—
Other De Beers' properties[10]	[r]1,400	[r]520	1,919	—	[r]1,350	[r]530	1,880	—	[r]1,200	[r]460	[r]1,652	—
Other	[r]380	[r]40	426	—	[r]350	[r]50	411	—	[r]380	[r]100	488	—
Total	3,800	4,700	8,504	[e]55,000	4,000	5,100	9,116	[e]60,000	[r]3,800	[r]4,900	8,708	[e]60,000
Swaziland	44	29	73	—	33	22	55	—	25	17	42	—
Sweden[e]	—	—	—	25,000	—	—	—	25,000	—	—	—	25,000
Tanzania	[r]105	[r]45	[r]150	—	[r]105	[r]45	[r, e]150	—	[r]60	[r]25	85	—
U.S.S.R.[e, 9, 11]	[r]11,000	[r]11,000	[r]22,000	41,500	[r]11,500	[r]11,500	[r]23,000	41,500	[r]12,000	[r]12,000	[r]24,000	41,000
United States	—	—	—	W	—	—	—	W	—	—	—	W
Venezuela	54	[r]75	[r]129	—	70	185	255	—	88	245	333	—
Yugoslavia[e, 12]	—	—	—	5,000	—	—	—	5,000	—	—	—	5,000
Zaire	2,724	15,439	18,163	—	2,663	15,092	17,755	—	2,914	16,513	19,427	—
Total	[r]49,206	[r]55,122	[r]104,331	241,500	[r]50,385	[r]55,842	[r]106,242	246,000	[r]52,093	[r]58,818	[r]110,919	245,500

See footnotes at end of table.

TABLE 13—Continued

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

(Thousand carats)

Country	1991				1992[e]			
	Narural			Synthetic[4]	Natural			Synthetic[4]
	Gem[2]	Industrial	Total[3]		Gem[2]	Industrial	Total[3]	
Angola[e]	[r]899	[r]62	[r] [4]961	—	935	65	1,000	—
Australia	17,978	17,978	35,956	—	21,000	21,000	42,000	—
Botswana	[r]11,550	[r]4,950	[r]16,506	—	10,000	5,000	15,000	—
Brazil	600	900	[e]1,500	—	600	900	1,500	—
Central African Republic	[r]296	[r]82	[r]379	—	296	82	378	—
China[e]	200	800	1,000	15,000	200	800	1,000	15,000
Côte d'Ivoire[6]	11	4	15	—	11	4	15	—
Czechoslovakia[e]	—	—	—	5,000	—	—	—	5,000
France[e]	—	—	—	[e]4,000	—	—	—	4,000
Gabon[e]	400	100	500	—	400	100	500	—
Ghana[7]	[r]175	[r]525	[e]700	—	175	525	700	—
Greece[e]	—	—	—	1,000	—	—	—	750
Guinea[e] [7]	[r]91	6	[r]97	—	90	5	95	—
Guyana	[r]7	[r]38	[r] [e]45	—	8	42	50	—
India	3	[r]15	[r]18	—	3	15	18	—
Indonesia[e]	8	24	32	—	6	21	27	—
Ireland[e]	—	—	—	60,000	—	—	—	60,000
Japan[e]	—	—	—	30,000	—	—	—	30,000
Liberia	40	60	[e]100	—	60	90	150	—
Namibia	1,170	[r]20	[r]1,187	—	1,500	50	[5]1,549	—
Romania[e]	—	—	—	4,500	—	—	—	4,000
Russia[8] [9]	—	—	—	—	9,000	9,000	18,000	60,000
Sierra Leone[6]	[r]160	[r]83	243	—	165	85	250	—
South Africa, Republic of:								
Finsch Mine	[r]1,200	[r]2,280	[r]3,483	—	1,200	2,250	[5]3,446	—
Premier Mine	700	[r]1,550	[r]2,250	—	740	1,700	[5]2,444	—
Venetia Mine	100	200	303	—	660	1,200	[5]1,868	—
Other De Beers' properties[10]	[r]1,500	[r]400	[r]1,897	—	1,350	500	[5]1,849	—
Other	400	[r]100	[r]498	—	450	100	[5]549	—
Total	[r]3,900	[r]4,530	[r]8,431	[e]60,000	4,400	5,750	10,156	60,000

See footnotes at end of table.

TABLE 13—Continued

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

(Thousand carats)

Country	1990				1991[e]			
	Narural			Syn- thetic[4]	Natural			Syn- thetic[4]
	Gem[2]	Indus- trial	Total[3]		Gem[2]	Indus- trial	Total[3]	
Swaziland	r34	r23	r57	—	36	24	60	—
Sweden[e]	—	—	—	25,000	—	—	—	25,000
Tanzania	r70	r30	r100	—	70	30	100	—
U.S.S.R.[e 9 10]	r10,000	r10,000	r20,000	60,000	—	—	—	—
United States	—	—	—	90,000	—	—	—	90,000
Venezuela	r102	r112	r214	—	108	115	223	—
Yugoslavia[e 12]	—	—	—	5,000	—	—	—	5,000
Zaire	3,000	r14,814	r17,814	—	3,000	12,000	15,000	—
Total	r50,694	r55,156	r105,855	359,500	52,063	55,703	107,771	358,750

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

[1]Table includes data available through May 25, 1993. 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 (1988-90), and Central African Republic (1988-90), 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 independant rounding.

[4]Includes all synthetic diamond production.

[5]Reported figure.

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

[7]Figures do not include smuggled artisanal production.

[8]Formerly part of the U.S.S.R..

[9]All production in the U.S.S.R. from 1988-91 came from Russia.

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

[11]Dissolved in Dec. 1991.

[12]Dissolved in Apr. 1992; however, information is inadequate to formulate reliable estimates of individual country production.

FIGURE 1
PRINCIPAL FORMS OF CRYPTOCRYSTALLINE AND CRYSTALLINE GEMSTONE CUTS