GEM STONES

By Gordon T. Austin

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The value of production of natural gem materials in the United States during 1989 decreased slightly to $42.9 million. The materials produced included faceting rough, lapidary rough, carving material, specimen material, natural and cultured freshwater pearls, mother of pearl, agatized coral, and coral.

The reported combined production value of synthetic and simulant materials was $18.8 million, about a 15% increase over that of 1988. Synthetic gems are manmade and have essentially the same optical, physical, and chemical properties and the same appearance as the natural gem that they represent. Synthetic gem materials produced in the United States include alexandrite, coral, diamond, emerald, garnet, lapis lazuli, quartz, ruby, sapphire, spinel, and turquoise. Simulants are manmade gem materials that have an appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. The gem simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gem stones, would be classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced.

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

DOMESTIC DATA COVERAGE

The Bureau of Mines estimates of U.S. production were from the "Natural and Synthetic Gem Material Survey," a voluntary survey of U.S. operations, and from Bureau estimates of unreported production. Of the approximately 358 operations surveyed, 82% responded, accounting for about 95% of the total production, 92% of the natural production, and 100% of the synthetic and simulant production.

The 358 operations surveyed in 1989 were an increase of about 19% compared with the number of operations surveyed in 1988. The response rate was essentially the same as that of 1988. The Bureau estimated the production by nonresponding operations, by professional collector, 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. The Bureau is totally dependent on the cooperation of the producers, brokers, dealers, and collectors for the formal voluntary survey and the informal surveys. Individuals and companies have been very cooperative and forthcoming with information. The Bureau is very appreciative of this cooperation.

PRODUCTION

Each of the 50 States produced at least $1,000 worth of gem materials. Ten States accounted for 95% of the total value of natural gem material produced. The States, in order of declining value of production, with their 1988 standing shown in parenthesis, were Tennessee (1), Arkansas (4), California (2), Arizona (3), Montana (5), Nevada (12), Oregon (6), North Carolina (7), Maine (16-17), and Utah (10). Certain States were known for the production of a single gem material (i.e., Tennessee for freshwater pearls and Arkansas for quartz). Other States produced a variety of gem materials. Arizona produced the greatest variety of gem materials. Production included agate, amethyst, antlerite, azurite, chrysocolla, fire agate, garnets, jade, malachite, obsidian, onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. California, Idaho, Montana, and North Carolina also produced a variety of gem materials. North Carolina was the only State to have ever 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 $12.5 million a year, with a high of $43.5 million in 1988 and a low of $6.9 million in 1980. The value of production for the past 10 years must be separated into two trends. The first trend was the period between 1979 to 1985, during which time approximately 24 operations reported production. Production averaged $7.5 million a year and was generally level. During the second trend, 1986 to the present, production averaged $24.2 million and was the result of an increase of 1,392% in the number of producers surveyed.

The reported production value of synthetic and simulant gem materials was $18.8 million in 1989. The reported value of production increased 15%; however, the quantity of materials produced was significantly greater. A shift in the types of materials produced, primarily a change from colored cubic zirconia to colorless cubic zirconia, resulted in the production of lower valued material. Thirteen firms, five in California, four in Arizona and one each in Massachusetts, Michigan, New Jersey, and Ohio, produced synthetic and simulant gem material. The six States, in order of declining value of production were Massachusetts, California, New Jersey, Michigan, Ohio, and Arizona.

Dia Em Resources Ltd. and LKA International Inc. completed the evaluation of their Rist and Ellis Emerald Mines at Hiddenite, NC, in 1988, and disposed of the property in 1989. LKA's plans to sell the two largest emerald crystals ever found in the United States, the 1,438-carat Stephenson and the 1,686.3-carat LKA crystal, have not been successful to date.

Crystal Exploration Inc. of Denver, CO, a subsidiary of Restech International Ltd. of Sydney, Australia, continued exploration for diamonds on mineral leases in Michigan. It purchased the leases from Dow Chemical Co. in 1988. Crystal took advantage of the north-central U.S.'s cold winter weather to explore for diamonds on the frozen grounds of swamps in Michigan and Wisconsin.

Amselco Exploration Inc., a subsidiary of British Petroleum Co. of Canada, and Exmin Corp., a subsidiary of the Belgian company Sibeka (Societe d'Entreprises et d'Investissements S.A.), continued exploration for diamonds on leased lands in Michigan and Wisconsin. Exmin also continued diamond exploration efforts in Minnesota.

Three firms continued their diamond exploration project in the State Line district on the Colorado-Wyoming border.

The Arkansas State Parks, Recreation, and Travel Commission voted 12 to 0 to enter a cooperative agreement with four mining companies to undertake a testing program at Crater of Diamonds State Park. Their vote enacted the recommendation of the Diamond Mining Task Force. The program will decide if commercial diamond mining at the park would be feasible. The four companies will pay for the testing, plus any litigation costs. Each firm also will appoint a representative to a technical advisory team that will manage the testing. The four firms are (1) Continental Diamonds, a joint venture between Continental Diamonds Inc. and Galactic Resources Ltsd., (2) Diamond Development Co., a equal ownership joint venture between Sunshine Mining Co., Rhombus Inc., Exdiam Inc., and Boulle Partnership, (3) Capricorn Diamonds Ltd., and (4) Kennecott Inc. The testing would cost about $350,000 and would include drilling about 30 core holes. Two environmental groups, the Sierra Club and Friends of the Crater of Diamonds, have promised to sue to stop the testing.

In June, the U.S. Forest Service held the first ever bid opening for quartz mining parcels in the Ouachita National Forest. A total of 76 bids, worth more than $25,000, were received on 84 parcels. The successful bids covered only 46 of the 84 parcels, representing about 522 hectares (1,289 acres) valued at $18,464. The parcels ranged in size from about 4 hectares (10 acres) to about 32 hectares (80 acres). A successful bidder will be issued a 5-year contract on the parcel and will be required to pay an annual fee to retain the contract. The revenues generated by the program, bids, and annual fees will be divided equally between the Federal and State Governments. The State plans to return its share to the county containing the lease parcel.

Mines in southern Oregon continued to produce a large amount of gem Labradorite. Production included both material that contained schiller, commonly known as sunstone, and nonschiller material, called helidorite by some. The Ponderosa Mine furnished the material to cut an extremely fine bright red color stone of over 10 carats. The mine at Opal Buttes in Morrow County continued to produce several varieties of very high-quality opal.

Hobbyist and commercial production of sapphire in Montana increased significantly during the year. Improvements in the techniques for heat treating the material and better commercial acceptance of the Montana sapphires were the major reasons for this increase. The increase in production occurred at all three of the major producing areas, the Missouri River, Rock Creek, and Yogo Gulch.

Plumbago Mining Corp. of Rumford, ME, mined amethyst for the entire permitted mining season, June through September, at the Sweden, ME, property of the Saltman family. Gems & Gemology reported production was about 2,270 kilograms, of which most was specimen quality. An officer of Plumbago reported the cutting of a 12-carat stone from material from the mine and that some material recovered would yield stones as large as 20 carats.

Sugar Hill Minerals reported the recovery of the largest gem morganite ever found in North America. The rose colored beryl was found at the company's Bennett Quarry near Buckfield, ME. The large crystal produced about 23 kilograms of varying sized blocks of gem rough for the company's gem inventory.

American Pearl Farms of Tennessee completed its third significant harvest of cultured freshwater pearls. American currently has five pearl farms under operation and purchased additional water acreage for a sixth farm to be established during 1991. The new farm will be nine times larger than the existing farms.

Pala International reported the discovery in May of the largest gem pocket found at the Himalaya Mine during the past 12 years. The pocket was approximately 0.7 by 1 by 3.7 meters and yielded about 500 kilograms of tourmaline. Approximately 50% of the material was suitable for carving or cabochons, with less than 1% suitable for faceting. The Himalaya Mine is in the Mesa Grande District of San Diego County, CA.

CONSUMPTION AND USES

Consumption of domestic gem material production was in the commercial and amateur manufacture of jewelry, for exhibit in gem and mineral collections, and for decorative purposes in statuettes, vases, and other art objects. Some industrial applications requiring clean homogeneous stones used low-quality gem diamond.

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

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

The estimated value of U.S. apparent consumption was a record high $3,711 million, but only a slight increase over that of 1988. The average annual estimated consumption for the past 10 years was $2,737 million, with a high of $3,711 in 1989 and a low of $1,642 in 1982. The trend for estimated consumption for the past 10 years was one of continued growth with about 199% total increase or an annual compounded growth rate of about 13%.

The value of U.S. estimated apparent consumption of diamonds increased slightly to $3.1 billion. The average annual value of apparent consumption of diamonds for the past 10 years was $2,158 million, with a high of $3,115 million in 1989 and a low of $1,642 million in 1982. The trend for the value of apparent consumption for the past 10 years was one of significant increase. The value of apparent consumption of diamonds increased 216% over the period.

The 1989 estimated apparent consumption of colored stones, led by emerald, ruby, and sapphire, was valued at $406.9 million, an increase of 31%. The annual average value of consumption of colored stones for the past 8 years was $316.0 million, with a high of $406.9 million in 1989 and a low of $252.4 million in 1982. The trend for apparent consumption of colored stones for the past 8 years was one of fluctuating increases and decreases, but the general trend was one of increased consumption.

The estimated apparent consumption of pearls—natural, cultured, and imitations—was $146.9 million, a decrease of about 18% from 1988. The value was about 53% greater than the 8-year low in 1982, but was about 18% less than the 8-year average of $178.9 million a year.

Estimated apparent consumption of synthetic and imitation gem materials decreased about 49% to $43.7 million. Average apparent consumption of synthetic and imitation gem materials for the past 8 years was $50.3 million per year, with a high of $109.1 million in 1987 and a low of $13.9 million in 1982. The trend for apparent consumption for the past 8 years was one of generally strong growth until the significant decrease in 1989. Even with the 1989 decrease, annual apparent consumption increased about 214% over the 8 years.

Estimates of U.S. diamond jewelry sales by jewelers were $11.6 billion during 1989, up slightly from the $11.3 billion in 1988.

PRICES

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

The average U.S. wholesale asking price of the top 25 grades (D-H color and IF through VS2 clarity) of a 1-carat diamond fluctuated between $7,256 and $7,202 and was $7,044 at yearend. The average value per carat of all grades, sizes, and types of gem-quality diamond imports was $408, a 9% increase compared with that of 1988. The average value of diamond imports for the past 10 years was $407 a carat, with a high of $541 in 1980 and a low of $353 in 1984. The trend for the average annual value of diamonds imported for the past 10 years was one of general decline from the 10-year high in 1980 to stable prices in 1986, 1987, and 1988, followed by the 1989 increase.

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 $3,500, unchanged from 1988. The average value of ruby imports increased 9% to $33.75 a carat. The average annual value of

TABLE 1

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

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

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

ruby imports for the past 8 years was $25.33 per carat, with a high of $34.04 in 1982 and a low of $16.42 in 1984. The trend for the value of ruby imports for the past 8 years was one of rapid decline, 52% for the period from 1982 to 1984. This was followed by a steady, moderate increase of 16% per year.

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, unchanged from 1988. The average value of sapphire imports increased 5% to $24.28 per carat. The average annual value of sapphire imports for the past 8 years was $23.43 per carat, with a high of $27.97 in 1987 and a low of $18.50 in 1984. The trend for the value of sapphire imports for the past 8 years was one of fluctuating increases and decreases. The 8-year period ended with the 1989 value slightly below the 1982 value.

The average yearend wholesale purchase price of a fine-quality 1-carat emerald, paid by retail jewelers on a per stone or memo basis, was $2,750, an increase of 6%. The average value of emerald imports decreased 23% to $61.00 per carat. The average annual value of emerald imports for the past 10 years was $56.47 per carat, with a high of $78.79 in 1988 and a low of $35.06 in 1984. The trend for the value of emerald imports for the past 10 years was one of fluctuating increases and decreases from 1980 through 1984. A steady moderate growth followed, resulting in the 1989 average value being about 55% greater than the 1980.

FOREIGN TRADE

The export value of gem materials increased 17% to $1,180 million, a record high. The quantity of diamonds exported increased 17% to 692,588 carats, and the value of diamond exports increased about 20% to $1,086.6 million. The average annual quantity of diamonds exported for the past 10 years was 369,264 carats, with a high of 590,412 in 1988 and a low of 184,871 in 1982. The trend for the quantity of diamonds exported for the past 10 years was one of moderate decline, 13%, during the first 4 years, followed by significant growth, 219%, from 1982 to 1989. The average annual value of diamond exports for the past 10 years was $521.6 million, with a high of $908.9 million in 1988 and a low of $292.8 million in 1982. The trend for the value of diamond exports for the past 10 years was one of significant decline, 113%, over 4 years, followed by a moderate growth of 32% in 3 years, and then a significant growth of 136% over the last 3 years. This resulted in record exports in 1989.

The export of other precious stones, cut but unset and other than diamonds and pearls, decreased about 36% to $43.6 million. The average annual export value for the past 8 years for these natural gem stones was $39.4 million, with a high of $68.5 million in 1988 and a low of $27.7 million in 1984. The 8-year trend for the value of exports for these types of gem materials was one of increases and decreases, but ultimately resulting in a significant total increase of 131% for the period.

Exports of synthetic gem material increased by 667%, to $46.0 million. The average annual value of exports for the past 8 years was $15.6 million, with a high of $46.0 million in 1989 and a low of $6.0 million in 1987 and 1988. The 8-year trend for the value of exports was one of extreme decline, 52%, for 1982–83, followed by steady moderate growth of 62% over the next 5 years and showing a significant gain in the last year.

Export of natural, cultured, and imitation pearls, not set or strung, increased about 55% to $3.4 million.

Reexports of gem material decreased 24% to $293.2 million. The quantity of diamonds reexported decreased about 77% to 0.4 million carat, the lowest amount in the past 10 years. The value of diamonds reexported decreased about 51% to $157.1 million. The average annual quantity of diamonds reexported for the past 10 years was 1.8 million carats, with a high of 3.0 million carats in 1981 and a low of 0.4 million in 1989. The 10-year trend for the quantity of diamonds reexported was highly mixed. The period started with 2 years of extreme increase, 171%, followed by 3 years of moderate decline, 37%, followed by 3 years of essentially stabile reexports, and then the most recent declines in 1988 and 1989. The average annual value of reexported diamonds for the past 10 years was $285.0 million, with a high of $412.8 million in 1981 and a low of $157.1 in 1989. The 10-year trend for the value of reexports was one of increase, 4%, for 1980–81, moderate decline, 55%, the next 4 years, followed by 3 years of significant increase, 72%, and then the major decrease in 1989. The value of 1989 reexports was 61% less than that of 1980.

The reexport of natural gem materials, cut but not set, other than diamonds and pearls, decreased about 92% to $4.6 million, a record low for the 8-year period for which data were available. The average annual value of reexports for the past 8 years was $33.0

TABLE 2

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

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

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

million, with a high of $55.1 million in 1988 and a low of $4.6 million in 1989. The 8-year trend for the value of reexports was one of alternating decreases and increases.

The reexport of natural gem materials not cut or set, other than diamonds and pearls, increased about 473% to $127.3 million. The extremely large increase was most likely the result of reexporting colored stones to worldwide cutting centers for cutting and reexport to the United States as finished gems. The average annual value of reexports for the past 8 years was $25.0 million, with a high of $127.3 million in 1989 and a low of $1.3 million in 1987. The 8-year trend for the value of reexports was one of extreme increases and decreases, with the value over the period increasing 1,575%.

Reexports of natural, cultured, and imitation pearls and synthetic gem materials were $3.9 million and $0.4 million, respectively.

The value of gem materials imported increased slightly to a record high of $5,115 million. The value of imported gem diamonds accounted for about 85% of the total. The average annual value of gem material imports for the past 10 years was $3,661 million, with a high of $5,115 million in 1989 and a low of $2,384 million in 1982.

The value of imported gem diamonds increased slightly to a record high of $4,358 million. The 10-year trend for the value of diamond imports was one of generally steady continuous growth with an increase of 94% for the period. During the period, the value of imported uncut diamonds decreased 44%, while the value of cut stones imported increased 203%.

The imports of cut diamonds increased slightly in quantity and value to 8.9 million carats and $3,805.5 million, respectively. The average annual quantity of cut diamonds imported was 6.3 million carats, with a high of 8.9 million in 1989 and a low or 1.3 million carats in 1980. The trend for cut diamond imports for the past 10 years was one of continued increases; the period ended with imports 246% greater than at the beginning of the period. The average annual value of imported cut diamonds was $2,549.6 million, with a high of $3,805.5 in 1989 and a low of $1,256.0 million in 1980. The trend for the value of imported cut diamonds for the past 10 years was of strong growth and increases. The value at the end of the period was 203% greater than at the beginning.

The value of imports of other gem materials, led by emerald, ruby, and sapphire, was $756.4 million, about the same as those of 1988. Emerald imports increased about 19% to 207.5 million. The average annual value of emerald imports for the past 10 years was $149.8 million, with a high of $207.5 million in 1989 and a low of $120.8 million in 1982. The 10-year trend for the value of emerald imports was one of fluctuating increases and decreases resulting in a 44% increase for the period.

The value of ruby imports increased 16% to 83.4 million, the fourth highest value for the past 10 years. The average annual value of imports for the past 10 years was $75.8 million, with a high of $93.8 in 1981 and a low of $58.7 in 1987. The 10-year trend for import values was one of extreme fluctuations. The period ended with values having increased 42% from the 10-year low, but still 11% below the high for the period.

The value of sapphire imports increased 23% to $100.0 million, the high

TABLE 3

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

Country	1988 Quantity (carats)	1988 Value[1] (millions)	1989 Quantity (carats)	1989 Value[1] (millions)
Exports:				
Belgium	163,246	$142.4	178,220	$187.1
Canada	24,104	18.4	24,957	30.0
France	7,946	11.4	5,577	11.4
Germany, Federal Republic of	3,736	4.7	2,717	4.4
Hong Kong	92,067	208.1	112,529	234.5
Israel	169,433	137.9	222,424	192.6
Japan	74,566	196.2	65,407	199.7
Singapore	5,135	9.2	3,274	10.1
Switzerland	23,929	141.9	16,800	133.3
Thailand	16,082	12.2	39,575	16.4
United Kingdom	3,641	20.6	7,263	44.6
Other	6,527	5.9	13,845	22.5
Total	590,412	908.9	692,588	1,086.6
Reexports:				
Belgium	833,081	104.4	101,462	29.7
Canada	5,855	1.2	765	1.1
China	14,009	0.3	677	([2])
Germany, Federal Republic of	31,236	2.6	5,523	0.9
Hong Kong	34,682	19.6	28,157	19.0
India	139,684	5.0	49,240	3.4
Israel	137,820	65.9	28,464	21.6
Japan	114,904	10.2	49,227	7.1
Netherlands	89,000	9.4	12,125	3.5
Switzerland	34,234	77.5	25,401	47.4
United Kingdom	26,929	12.6	3,188	16.0
Other	83,026	10.3	53,671	7.4
Total	1,544,460	319.0	357,900	157.1

[1] Customs value.
[2] Less than 1/2 unit.
Source: Bureau of the Census.

TABLE 4

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

Kind, range, and country of origin	1988 Quantity (carat)	1988 Value[1] (millions)	1989 Quantity (carat)	1989 Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium	305,142	$111.8	57,962	$18.0
Brazil	349,461	10.7	33,709	5.7
Israel	38,734	8.2	12,979	7.1
Netherlands	57,791	7.9	24,424	11.7
South Africa, Republic of	48,515	44.9	9,130	13.8
Switzerland	14,307	8.2	12,268	11.9
United Kingdom	619,461	317.5	747,397	254.0
Venezuela	684	.1	7,275	.9
Other	210,203	79.3	284,292	229.5
Total	1,644,298	588.6	1,189,436	552.6
Cut but unset, not over 0.5 carat:				
Belgium	1,035,452	406.7	1,531,997	962.7
Brazil	34,554	13.7	39,200	16.2
Canada	9,156	4.1	7,754	5.5
Hong Kong	285,268	63.1	101,828	48.1
India	3,758,747	886.1	3,136,459	792.4
Israel	1,109,474	532.8	1,784,444	1,104.3
Netherlands	27,588	26.8	19,227	24.1
South Africa, Republic of	5,532	5.1	10,707	15.7
Switzerland	76,169	36.8	41,986	75.6
United Kingdom	23,406	22.9	37,581	37.3
Other	160,707	37.9	138,808	57.0
Total	6,526,053	2,036.0	6,849,991	3,138.9
Cut but unset, over 0.5 carat:				
Belgium	709,527	578.9	266,164	99.0
Hong Kong	59,949	40.1	68,930	19.5
India	386,422	111.3	1,176,503	312.0
Israel	906,752	675.2	318,288	178.5
Netherlands	7,859	12.9	4,809	10.5
South Africa, Republic of	22,762	40.6	1,245	.4
Switzerland	24,281	95.1	21,420	13.4
United Kingdom	17,546	45.3	11,116	8.2
Other	92,028	81.8	151,614	25.1
Total	2,227,126	1,681.2	2,020,089	666.6

[1] Customs value.

[2] Includes some natural advanced diamond.

Source: Bureau of the Census.

value for the past 10 years. The average annual value of sapphire imports for the past 10 years was $78.7 million, with a high of $100.0 million in 1989 and a low of $50.3 million in 1980. The 10-year trend for the value of imports was one of extremely fluctuating increases and decreases. The period ended with the value 96% greater than at the beginning and at the high for the period.

The value of imported gem materials other than diamond, emerald, ruby, and sapphire decreased 15% to $365.5 million. The average annual value of imports was $314.7 million, with a high of $429.5 in 1988 and a low of $110.6 in 1980. The 10-year trend for the value of imports was one of fluctuating increases and decreases resulting in a total increase of 230% for the period.

WORLD REVIEW

Diamond sales by De Beers Consolidated Mines Ltd.'s CSO in the second half of 1989 were $1.77 billion. This was 24% less than the $2.32 billion for the first half of 1989 and 10% less than for the second half of 1988. Total diamond sales by the CSO were $4.09 billion in 1989, about 2% less than the 1988 record high of $4.17 billion. According to diamond dealers, the reduced sales were most likely the result of a sagging U.S. demand. Estimates of the annual world market for diamond jewelry are approximately $40 billion. The U.S. share of this market dropped in 1989 from the historical level of about 33% to 29%. The three largest consumers are Japan (30%), the United States (29%), and Europe (18%). The amount of diamonds in the pipeline between the CSO rough sales and the retail purchaser is of equal importance to the CSO sales. Estimates of the material in the pipeline in 1989 were about $15 to $18 billion, measured at wholesale polished prices, or 2.5 years of sales. Sales of colored gem stones remained very 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—the U.S.S.R. (Northeastern Siberia and in the Yakut, A.S.S.R.); in Australia; and in South America—Venezuela and Brazil.

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

Angola

Endiama, the Government-owned and operated diamond mining company, sold over 1 million carats of diamonds in 1989 valued at about $200 million. But when diamonds taken in UNITA raids and smuggling are considered, the county's production was most likely nearly double the official sales. UNITA representatives recently offered $10 million worth of rough for sale on the U.S. market.

De Beers signed a declaration of intent with Endiama to help in developing Angolan diamond deposits. The agreement, worth $180 million annually, is for co-operation in prospecting, mining, and marketing. Further discussions and technical studies, leading to the establishment of a joint venture, are underway. Endiama may start marketing a "significant proportion" of production through the CSO in 1990, moving toward an exclusive agreement as production increases. It is also the intentions of the parties to build a diamond sorting building in Luanda in which to sort Angolan production before its sale to the CSO.

Australia

Poseidon Exploration Ltd. purchased Freeport Bow River Properties Inc., the joint venture of Freeport-McMoRan Australia Ltd. and Gem Exploration and Minerals Ltd. The joint venture owned and operated the Bow River alluvial diamond project. Production from Bow River averages 20% gem quality, 70% near-gem quality, and 10% bort.

Argyle Diamond Mines Pty. Ltd.'s annual diamond production from the AK-1 pipe was essentially unchanged at about 34.4 million carats. Argyle's annual production accounted for about 37% of the world's production of natural diamonds.

Many firms continued their diamond exportation efforts. Gem Exploration Ltd. reported success in a sampling program for the Kununurra Project in Western Australia, and Terres Resources NL also worked in the Kununurra area. Poseidon-Trian Minerals continued to explore in the Phillips Range in Western Australia, as did the Capricorn Resources, Copperfield, and Moonstone joint venture. Auridiam-Afro-West worked on its project at Mount Wynne in Western Australia, as

TABLE 5

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

Kind and country	1988		1989	
	Quantity (carats)	Value [1] (millions)	Quantity (carats)	Value [1] (millions)
Emerald:				
Belgium	11,963	$5.6	10,605	$1.2
Brazil	80,199	6.4	80,829	12.8
Colombia	243,521	63.8	429,390	73.1
France	13,817	3.2	5,345	4.0
Germany, Federal Republic of	34,376	2.4	23,902	3.2
Hong Kong	135,384	14.7	135,423	18.9
India	1,205,636	20.4	2,068,254	25.9
Israel	89,399	24.7	89,559	24.7
Japan	20,102	1.0	10,178	1.1
South Africa, Republic of	4	(2)	146	(2)
Switzerland	65,021	20.6	60,265	28.6
Taiwan	256	(2)	1,681	.7
Thailand	216,501	3.8	366,925	5.0
United Kingdom	8,026	2.9	6,187	2.5
Other	91,701	5.1	112,866	5.8
Total	2,215,906	174.6	3,401,555	207.5
Ruby:				
Belgium	8,926	1.3	7,760	1.1
Brazil	4,945	.2	8,093	(2)
Colombia	258	(2)	337	(2)
France	5,885	3.4	21,483	3.5
Germany, Federal Republic of	26,530	1.0	20,822	.8
Hong Kong	47,152	4.6	79,583	6.1
India	318,575	1.1	455,954	1.6
Israel	38,593	1.6	26,326	3.8
Japan	11,572	.8	796	.4
Switzerland	40,183	11.6	70,098	19.7
Thailand	1,822,557	40.5	1,778,218	38.9
United Kingdom	8,443	3.6	3,596	2.9
Other	61,703	2.3	73,345	4.6
Total	2,395,322	72.0	2,546,411	83.4
Sapphire:				
Australia	2,883	.2	30,439	.4
Austria	603	(2)	377	(2)
Belgium	20,024	.9	26,155	2.2
Brazil	9,528	.2	8,705	.2
Canada	16,177	.9	5,622	.6
Colombia	1,398	(2)	358	.2
France	46,296	2.3	7,825	1.4
Germany, Federal Republic of	26,750	1.0	31,999	1.4
Hong Kong	123,689	5.8	102,671	8.4
India	149,488	1.2	112,937	1.0
Israel	8,931	1.1	29,535	4.7
Japan	22,662	.6	2,532	.6

See footnotes at end of table.

TABLE 5—Continued

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

Kind and country	1988 Quantity (carats)	1988 Value[1] (millions)	1989 Quantity (carats)	1989 Value[1] (millions)
Sapphire—Continued				
Korea, Republic of	6,438	(2)	9,024	(2)
Singapore	4,705	$.2	481	(2)
Sri Lanka	39,259	2.4	63,184	$4.1
Switzerland	32,446	10.2	67,086	15.6
Thailand	2,878,129	50.2	3,576,666	55.1
United Kingdom	10,102	2.9	9,435	2.5
Other	110,301	1.4	34,348	1.6
Total	3,509,809	81.5	4,119,379	100.0
Other:				
Rough, uncut:				
Australia	NA	.9	NA	1.4
Brazil		29.7		36.0
Colombia		2.4		10.5
Hong Kong		.5		2.2
Nigeria		.2		.7
Pakistan		1.0		1.4
South Africa, Republic of		4.8		.2
Switzerland		1.7		1.3
United Kingdom		.6		(2)
Zambia		.9		.5
Other		5.5		11.1
Total	NA	48.2	NA	65.3
Cut, set and unset:				
Australia	NA	12.6	NA	10.7
Brazil		18.6		5.0
Canada		.4		.2
China		2.3		1.1
Germany, Federal Republic of		15.8		12.2
Hong Kong		27.4		21.2
India		5.1		3.7
Japan		144.5		118.3
Switzerland		3.1		1.3
Taiwan		11.3		1.8
Thailand		14.2		10.0
United Kingdom		1.7		2.4
Other		17.7		15.7
Total	NA	274.7	NA	203.6

NA Not available.
[1] Customs value.
[2] Less than 1/10 unit.

Source: Bureau of the Census.

TABLE 6

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

(Million dollars[1])

Country	1988	1989
Synthetic, cut but unset:		
Austria	2.0	3.7
France	.6	.4
Germany, Federal Republic of	9.1	9.4
Japan	2.1	0.4
Korea, Republic of	8.1	4.3
Switzerland	6.0	3.8
Other	5.6	7.4
Total	33.5	29.4
Imitation:		
Austria	49.4	40.0
Czechoslovakia	2.7	3.1
Germany, Federal Republic of	6.7	1.6
Japan	4.6	.4
Other	6.2	12.2
Total	69.6	57.3

[1] Custom value.

Source: Bureau of the Census.

did Stockdale, a subsidiary of De Beers, in the Ellendale area. Pemlya Mines NL and Noranda Pty. Ltd.'s joint venture searched for diamonds in the Eastern Pilbara. Cluff Resources Pacific Ltd. explored the Copeon-Bingara area of New South Wales. Cambridge Gulf Exploration NL started a search for diamonds on leases covering about 2,000 square kilometers on either side of the Ord rivermouth. Quicksilver Resources was seeking investors to finance the exploration of three diamond prospects in Western Australia, the Byro Project, Mount Edith, and Tier Range. The Mount Gipps Ltd. and Reedy Lagoon Corporation NL joint venture will begin drilling for diamonds in the Reedy Lagoon region of South Australia during 1990.

Australia held its first culture pearl auction in October at Darwin. Long the leading producer in the quantity of cultured South Sea pearls, it was time also to claim the title of number one in quality. For this reason, the nine pearl farms that account for an estimated 80% of the production decided to sell the bumper pearl crops at home instead of in Japan. The auction was a large success with 60 firms worldwide spending $33.5 million. The Japanese were the largest purchaser, buying about $23 million.[1]

A new form of gem orthoclase, named Rainbow Lattice Sunstone, was discovered in an area known as the

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF PRECIOUS AND SEMIPRECIOUS GEM STONES

(Thousand carats and thousand dollars)

Stones	1988 Quantity	1988 Value[1]	1989 Quantity	1989 Value[1]
Diamonds:				
Rough or uncut	1,644	588,611	1,189	552,557
Cut but unset	8,753	3,717,151	8,870	3,805,590
Emeralds: Cut but unset	2,216	174,623	3,402	207,546
Coral: Cut but unset, and cameos suitable for use in jewelry	NA	2,967	NA	NA
Rubies and sapphires: Cut but unset	5,905	153,552	6,666	183,344
Marcasites		1,229	NA	NA
Pearls:				
Natural	NA	3,389	NA	4,382
Cultured	NA	171,693	NA	144,335
Imitation	NA	7,198	NA	5,456
Other precious and semiprecious stones:				
Rough, uncut	NA	48,186	NA	65,298
Cut, set and unset	NA	79,056	NA	55,909
Other	NA	19,795	NA	NA
Synthetic:				
Cut but unset	81,096	28,995	99,292	29,368
Other	NA	4,485	NA	3,441
Imitation gem stone	NA	62,404	NA	57,323
Total	XX	5,063,334	XX	5,114,549

NA Not available. XX Not applicable.
[1] Customs value.
Source: Bureau of the Census.

Mud Tank Zircon Field in the Harts Range of the Northern Territory. The material was named for the unique lattice pattern of aventurescence it displays. Inclusions of ilmenite and hematite oriented on the crystal lattices causes this effect.[2]

Heavy rains during the month of March severely disrupted opal production from Coober Pedy, Mintabie, and Andamooka. The rains collapsed mine shafts and flooded tunnels and opencut mines. It will take 6 months, and in some cases a year, to get back into full production. The lost production will result in an increase in the price of Australian opal.

Brazil

Glencairn Explorations Ltd. received a positive feasibility study on the Feijao Cru diamond deposit in Bahia. It was estimated that production would be 42,000 to 84,000 carats annually and would average 80% gem quality. The original discovery was made by Mineracao Piracicaba Ltd., a Brazilian company. Glencairn can earn 50% interest in Piracicaba by investing an additional $250,000. There are about 25 small mines operating in the Chapada Diamantina region of Bahia.

Mineracao Tejucana, the joint venture between Sibeka's wholly owned Sibradiam Participacoes Ltda. and Union Miniere, produced more than 34,000 carats of diamonds and 107 kilograms of gold from its dredging operations on the Jequitinhoha River. The joint venture operated four dredges on the Lamarao flat and a fifth dredge was located outside of the main production area.

A discovery of tourmaline of unusual colors was made in Paraiba. The material, called "Paraiba" tourmaline, ranged in color from a highly saturated medium bluish green to medium dark blue-green and to a dark blue to violetish blue. The saturation and depth of color is outstanding. The stones demand a high price with 30 to 50 point stones selling for as much as $150 per carat and 5-carat stones going for as much as $2,500 per carat.

Canada

Cameco and Uranerz Exploration and Mining reportedly found seven kimberlite pipes on their joint-venture Fort a la Corne property east of Prince Albert, Saskatchewan. Microdiamonds were found in one pipe. The two firms have staked 170,000 hectares for exploration in the Fort a la Corne area. Additionally, Uaranerz is acquiring land to the north in the Choiceland-Snowden-Smeaton area for exploration. The race to claim land for diamond exploration in Saskatchewan is growing. The staking of a 200,000 hectare parcel between Prince Albert and Saskatoon increased the total amount of land held for diamond exploration to 647,000 hectares. Monopros, the Canadian exploration arm of De Beers, started the staking rush in 1988.

Corona Corp. discovered kimberlite rocks on the Sturgeon Lake exploration property of Claude Resources. A drill intersected kimberlite at a depth of 37 meters and was still in kimberlite at 111 meters. To date, there is no indication that the kimberlite contains diamonds; additional work will be necessary to determine if diamonds are present. The property is located north of Prince Albert, Saskatchewan.

Central African Republic

A joint venture, founded in 1987 between Osborne & Chappel Goldfields and Societe d'Enterprise et d'Investissements SA, continued their diamond exploration program with encouraging results. The joint venture has exploration rights for alluvial diamonds along a 170-kilometer stretch of the Mamber River. To date, reconnaissance drilling, geophysical testwork, and small-scale bulk sampling has been completed.

China

The production of colored gem stones increased about 30% in the past year. The five most commonly mined gem stones were aquamarine, tourmaline, sapphire, topaz, and nephrite jade. Other gem materials produced include amazonite, amber, amethyst, andalusite, aventurine, azurite, bowenite, diopside, garnets, jet, kunzite, malachite, peridot, quartz, ruby, turquoise, and zircon.[3]

Ashton Mining Ltd. of Australia was granted exclusive exploration, mining, and marketing rights for diamonds in the Hunan Province. The company will share equally in any production, processing, and sale of diamonds with the provincial government. A cutting factory will be established in Hunan when diamond production begins.

In Laioning Province, the Wafandian diamond deposit, potentially the largest in China, is being developed for mining and is scheduled to begin operation in late 1990. Production is forecasted to be 118,000 carats per year. The Wafandian Mine would be China's fifth diamond mine, joining the Bin-Hai also in Laioning Province, and the Chang Ma, Tao Cheng, and Linshu Mines in Shandong Province.

Columbia

At the Muzo emerald mine in Boyaca, two major leaseholders, Tecminas and Coesminas, have begun using shafts and underground tunnels in addition to strip mining to recover emeralds. The relative flatness of the Muzo mining area and the accumulation of hundreds of years of mine tailings resulted in limiting access to some areas for production and exploration. The shafts and tunnels may allow the producers to relocate some of the old production veins and to discover new productive areas. The tunnels have encountered problems both with ground support and the inflow of water.[4]

Finland

The Finnish Geological Survey (GSI) reported the discovery of a 2,250-carat emerald. The totally transparent gem was estimated to be valued at approximately $250,000. The GSI drew up plans to intensify the exploration work in a 2-hectare area.

Guinea

A 255.61-carat diamond, recovered from the Aredor Mine, was purchased for slightly more than $10 million. At $39,300 per carat, it was not the highest per carat price ever paid for a rough diamond; a 181.77-carat rough diamond from Aredor sold for $47,400 per carat in 1988. However, the total purchase price was the highest ever paid for a rough diamond. In February, Aredor was granted a 405-square-kilometer extension to its mining lease. The new ground is believed to contain high-quality alluvial reserves.

India

During fiscal year April 1, 1988, to March 31, 1989, the value of finished diamonds exported increased 75% to $2.95 billion. The value was the greatest for any country and accounted for about 28% of the value of diamonds and 70% of the stones used in diamond jewelry. The increase was the result of a general increase in demand for diamonds, a depreciation of the rupee, falling labor costs, and favorable Government policies aimed at boosting exports. India plans to increase its share of the market to near 50% of the value within 2 years. The diamond industry employs approximately 1 million skilled and semi-skilled workers.

The Indian Minerals Exploration Corp. Ltd. and the French BRGM company entered into an agreement to explore for diamonds and develop any commercial deposits discovered in the Pana, Krishna, and Vajnakarur areas.

Israel

Diamond imports and exports increased for the year. Imports increased about 6% to $2.6 billion and exports were approximately $2.7 billion, an increase of over 7% compared with that of 1988. Approximately 43% was exported to the United States and about 35% to the Far East.

Dov Riger of Israel and Tasaki Shinju of Japan opened a joint-venture automated polishing factory at Beit Shean, in northern Israel. The factory employs 30 workers using automatic piermatic polishing machines. The entire output of the factory is committed to the Japanese parent company. Tasaki Shinju has annual sales of about $200 million.

Namibia

Consolidated Diamond Mines of South-West Africa (CDM), the De Beers Consolidated Mines, Ltd. subsidiary that controls the majority of the diamond mining concessions in Namibia, began development of two new diamond operations. The Elizabeth Bay operation will recover about 250,000 carats per year of small stones from windblown deposits. The mine is located about 30 kilometers south of the town of Luderirtz and will mine and process about 4 million metric tons per year during its projected 10-year life. Production is scheduled to begin in March 1991. The Auchas Mine along the Orange River will recover about 40,000 carats per year of large stones. The mine is scheduled to begin production in July 1990. CDM also is undertaking offshore diamond recovery research at depths of up to 90 meters in its offshore concessions.[5]

The Namibian West Coast Diamond Co. started a major exploration program in the deep-sea area of its concession. The concession starts about 2 kilometers offshore, continues to about 10 kilometers, and is roughly 90 kilometers long. A 250-ton survey and research vessel was purchased to survey, test, and map the deepwater area. In the past 2 years, the company has recovered about 26,000 carats of diamonds from the concession. However, it is estimated that large-scale commercial mining of the concession is still 10 years in the future.

It was reported that in Swakopmund, fake diamond octahedra and imitation tsavorite garnet rough were being sold to gem stone buyers. The fake diamonds were made from cubic zirconia and the tsavorites from cut green bottle glass.

Sierra Leone

In January, the Ministry of Mines began issuing export licenses to private firms and individuals for the export of diamonds. The Ministry granted 26 licenses for diamond exporting, 11 of which were granted to foreign individuals or companies. Applicants must pay a fee for the licenses, a fixed fee and/or a royalty, post a performance bond of $500,000, and must achieve a performance goal of exporting 250,000 in diamonds monthly, or forfeit the bond. The new regulations eliminate the diamond dealers and recognizes only two legal players in the diamond fields—the miners and the exporters. The Ministry believes that privatization will increase diamond production as well as increasing diamonds sold or exported through official markets.

South Africa, Republic of

The Kim Diamond Cutting Works, currently under construction, will process 30,000 carats of rough a week. The cutting factory will employ at least 1,280 workers. Using local rough, it will process stones from 1 to 30 points for the overseas market. The factory is scheduled for completion by the end of April 1990.

A new open pit diamond mine, the Samanda, is being developed in the Orange Free State Province. The mine is forecasted to begin production in the second quarter of 1990. The developer is apparently a private concern.

De Beers announced that, in cooperation with Saturn Mining Ltd. of the Anglovaal group, it will open a new diamond mine on the Venetia farm in The Transvaal. The mine will cost approximately $280 million and will be the largest investment De Beers has ever made in a single mine. The mine is scheduled to begin production in the second half of 1990 at a rate of about 4 million carats per year.

Gemgold Mining Ltd. commenced mining diamonds from a open pit mine in the Cape Province. The company expects to produce about 40,000 carats in 1990 and 100,000 carats in 1991.

Tanzania

Williamson Diamonds Co. received a $4.7 million loan from Willcroft Co. Ltd. The funds will be used to modernize Williamson's diamond treatment plant, which has been in operation for over 30 years. The condition of the treatment plant has adversely affected Tanzania's diamond production for a number of years.

Zaire

In April, the Government of Zaire enacted new regulations on the purchase and export of diamonds. The purchasers of artisanal diamonds, called comptoirs, were required to pay a license fee and deposit of $300,000, compared with the old fee and deposit of $100,000. Additionally, comptoirs were allowed to purchase diamonds in Kinshasa if stones were offered for sale. Because Kinshasa is not an official buying location, there are not the same controls that are present in the interior where representatives from the National Evaluation Center are required to be present at all transactions.

Pilfering and smuggling from the diamond-producing areas was rampant according to the Societe Miniere de Bakwanga (Miba). Miba estimated that illegal mining and trafficking of diamonds in the two Kasai provinces cost the Government somewhere between $140,000 and $350,000 every month. Tough security measures are difficult to enforce because state security men connive with the smugglers, giving them protection as they go about their business. The law allows Zairian nationals the freedom to mine industrial diamonds anywhere in the country as long as the diamonds are sold through Miba. The system is no longer working because of access to better markets outside of Miba.

A substantial diamond deposit was reportedly discovered at a rubber plantation owned by the Amcit Blattner family at Kaparata. The plantation was sealed off by soldiers, which denied the owners access. The Blattners may enter into an agreement with a well-known diamond firm to exploit the deposit. It is possible that local residents are digging diamonds after gaining access by bribing the soldiers that are guarding the plantation.

Zambia

The Government of Zambia centralized the future marketing of emeralds by allowing the export only of cut and polished stones. Gem-Impex Ltd. of Zurich, Switzerland, was appointed the sole distributor of emeralds cut and polished in Zambia to implement the centralization. Gem-Impex will market Zambian emeralds worldwide for the state-owned Zambian Emerald Industries Ltd. Zambian Emerald, which operates a 50-cutter factory in Ndola, has the exclusive right to cut and polish emeralds produced in Zambia. Production from the Ndola factory was about 5,000 carats per month in a variety of shapes and sizes.

CURRENT RESEARCH

Mr. Zvi Yehuda of Ramat Gan, Israel, developed a new diamond enhancement process. The process improves the apparent clarity of diamonds by filling surface-reaching cleavages and fractures. The process replaces the air that normally fills the cleavages and fractures with a transparent material that has an index of refraction near that of diamond. The result is that the cleavages and/or fractures are less visible and thus the appearance and apparent clarity of the diamond is improved. The treatment can be detected using a standard darkfield-equipped gemological microscope. The orange and blue flash effects, flow structures, and flattened, trapped gas bubbles evident in the filled areas are easily detected. Yehuda also has founded a firm in the United States that uses a similar procedure to improve the appearance and apparent clarity of emeralds.[6]

The technology to improve the apparent color of diamonds in the very light to light yellow color ranges has been used occasionally to increase the value of a stone. The addition of a grayish or bluish material to the surface of "J" or "K" color stones can give the stone the appearance of a "G" color. This deceptive treatment could affect the value of a 1.00 carat "VS1" "K" stone by as much as $1,600 by changing its appearance to that of a "VS1" "G." The coating may be a fluoride compound similar to that used for lens coating in optics. The coating generally can be detected by careful examination under 30 to 45 power magnification.

Miners from Santa Terezinha de Goias, Brazil, developed a new process for treating rough and cut emeralds to improve their appearance, similar to the use of oil and Canada balsam on emeralds in the past. The treatment is based on the filling of the fractures that reach the surface of the stones. The stones are cleaned, dried, heated, and then treated with a synthetic fracture sealant marketed under the trade name Opticon. Individuals in the United States have improved and expanded upon the process to include treating stones, primarily cut emeralds, with Opticon in a heated vacuum vessel.

OUTLOOK

World demand for gem diamond can be expected to rise because of the rising average personal income of the population of the United States and other industrialized countries. Demand is expected to increase because of highly effective promotional campaigns. These promotions are changing social customs in many Far East countries, particularly in the use of diamond engagement rings.

TABLE 8

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

(Thousand carats)

Country	Natural												Synthetic[3]	Natural			Synthetic[3]
	1985			1986			1987			1988[p]				1989[e]			
	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total		Gem[2]	Industrial	Total	
Angola	464	250	714	240	10	[e]250	180	10	[e]190	950	50	[e]1,000	—	950	50	1,000	—
Australia	4,242	2,828	7,070	13,145	16,066	29,211	13,650	16,683	30,333	17,517	17,517	35,034	—	17,540	17,540	35,080	—
Botswana	6,318	6,317	12,635	9,590	3,500	[r]13,090	9,368	3,840	13,208	10,660	4,569	15,229	—	10,676	4,576	[4]15,252	—
Brazil	233	217	450	310	315	625	320	325	645	353	180	533	—	350	200	550	—
Central African Republic	190	87	277	259	99	358	304	108	412	284	59	343	—	280	60	340	—
China[e]	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	15,000	200	800	1,000	15,000
Cote d'Ivoire (formerly Ivory Coast)[e] [5]	15	5	20	10	4	14	15	6	21	[r]8	[r]3	[r]11	—	11	4	15	—
Czechoslovakia	—	—	—	—	—	—	—	—	—	—	—	—	[e]5,000	—	—	—	5,000
France	—	—	—	—	—	—	—	—	—	—	—	—	[e]4,000	—	—	—	4,000
Ghana[6]	60	576	636	88	498	[r]586	65	400	465	165	495	[r][e][7]660	—	168	452	[7]620	—
Greece	—	—	—	—	—	—	—	—	—	([8])	—	([8])	[e]1,000	—	—	—	1,000
Guinea[6]	123	9	132	190	14	204	163	12	175	136	10	146	—	[4]138	[4]10	[4]148	—
Guyana[e]	4	7	11	3	6	[4]9	[r]2	[r]5	[r]7	1	3	[4]4	—	2	3	5	—
India	14	2	16	13	3	16	13	3	[r]16	12	3	15	—	3	11	14	—
Indonesia[e]	5	22	27	[r]6	22	[r]28	[r]7	[r]22	[r]29	[r]7	[r]22	[r]29	—	7	25	32	—
Ireland	—	—	—	—	—	—	—	—	—	—	—	—	[r]60,000	—	—	—	60,000
Japan	—	—	—	—	—	—	—	—	—	—	—	—	[e]25,000	—	—	—	25,000
Liberia	66	72	138	63	189	252	60	190	[e]250	67	100	167	—	68	102	170	—
Namibia	865	45	910	970	40	1,010	971	50	1,021	901	37	938	—	970	30	1,000	—
Romania	—	—	—	—	—	—	—	—	—	—	—	—	[e]5,000	—	—	—	4,500
Sierra Leone[5]	243	106	349	215	100	315	150	75	225	100	75	[e]175	—	100	75	175	—
South Africa, Republic of:																	
Finsch Mine	1,770	3,184	4,954	1,821	3,208	5,029	1,455	2,701	4,156	1,372	2,548	3,920	—	1,613	2,997	[4]4,610	—
Premier Mine	820	1,864	2,684	882	1,977	2,859	772	1,713	2,485	696	1,543	2,239	—	689	1,526	[4]2,215	—
Other De Beers' properties[9]	1,500	569	2,069	1,428	529	1,957	1,427	546	1,973	1,388	531	1,919	—	1,360	520	[4]1,880	—
Other	460	35	495	342	41	383	409	30	439	361	65	[r][e]426	—	348	63	411	—
Total	4,550	5,652	10,202	4,473	5,755	10,228	4,063	4,990	9,053	[r]3,817	[r]4,687	[r][e]8,504	[r][e]55,000	4,010	5,106	9,116	60,000
Swaziland	13	8	21	23	16	39	[r]48	[r]32	[r][e]80	44	29	73	—	33	22	[4]55	—
Sweden	—	—	—	—	—	—	—	—	—	—	—	—	[e]25,000	—	—	—	25,000
Tanzania	165	71	236	133	57	190	105	45	[e]150	105	45	[e]150	—	105	45	150	—
U.S.S.R.[e]	4,400	6,400	10,800	4,400	6,400	10,800	4,400	6,400	10,800	4,500	6,500	11,000	41,500	4,500	6,500	11,000	41,500
United States	—	—	—	—	—	—	—	—	—	—	—	—	W	—	—	—	W
Venezuela	35	180	215	45	189	234	35	63	98	55	53	108	—	55	60	115	—
Yugoslavia	—	—	—	—	—	—	—	—	—	—	—	—	[e]5,000	—	—	—	5,000
Zaire	4,032	16,127	20,159	4,661	18,643	23,304	3,885	15,540	19,425	2,734	15,493	18,227	—	2,850	16,150	19,000	—
Total	[r]26,237	[r]39,781	66,018	[r]39,037	[r]52,726	[r]91,763	38,004	49,599	87,603	42,616	50,730	93,346	[e]241,500	43,016	51,821	94,8372	46,000

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

[1] Table includes data available through May 16, 1990. Total diamond output (gem plus industrial) for each country actually is reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1985-87), Botswana (1987), Brazil (1987), Central African Republic (1985-88), Guinea (1985-89), and Liberia (1985-86), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural, and for most countries, is based on the best available data at time of publication. Estimated distribution figures have been revised as necessary to correspond to reported total production figures.

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

[3] Includes all synthetic diamond production.

[4] Reported figure.

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

[6] Figures do not include smuggled artisanal production.

[7] Includes estimates for artisanal production.

[8] Revised to zero.

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

The changes are resulting in significant growth in the diamond market.

Demand for other precious gems will continue to grow as diamonds become more expensive and the popularity and acceptance of colored stone increases. Demand for synthetic and simulant gem materials for both personal and industrial consumption is expected to increase. The diversity of sizes, types, uses, and values of gem materials precludes any meaningful forecasting of future demand.

BACKGROUND

The history of production and preparation of gem stones begins with the wearing of items for personal adornment in prehistoric times. This preceded even the wearing of clothes. Amber was mined in the Baltic countries for use as a gem material before 25000 B.C. Later, the Phoenicians in their writings described trade routes to the Baltic for amber and to areas in Asia and Africa for other gem materials. The voyages of Columbus brought increased interest in gem deposits, especially emerald, in South America. The discovery of diamond in Africa in 1859 focused major interest on Africa. More recently, the discovery of diamond in Western Australia in 1967 has resulted in the development of one of the largest deposits in the world.

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

Definitions, Grades, and Specifications

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

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

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

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

Products for Trade and Industry

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

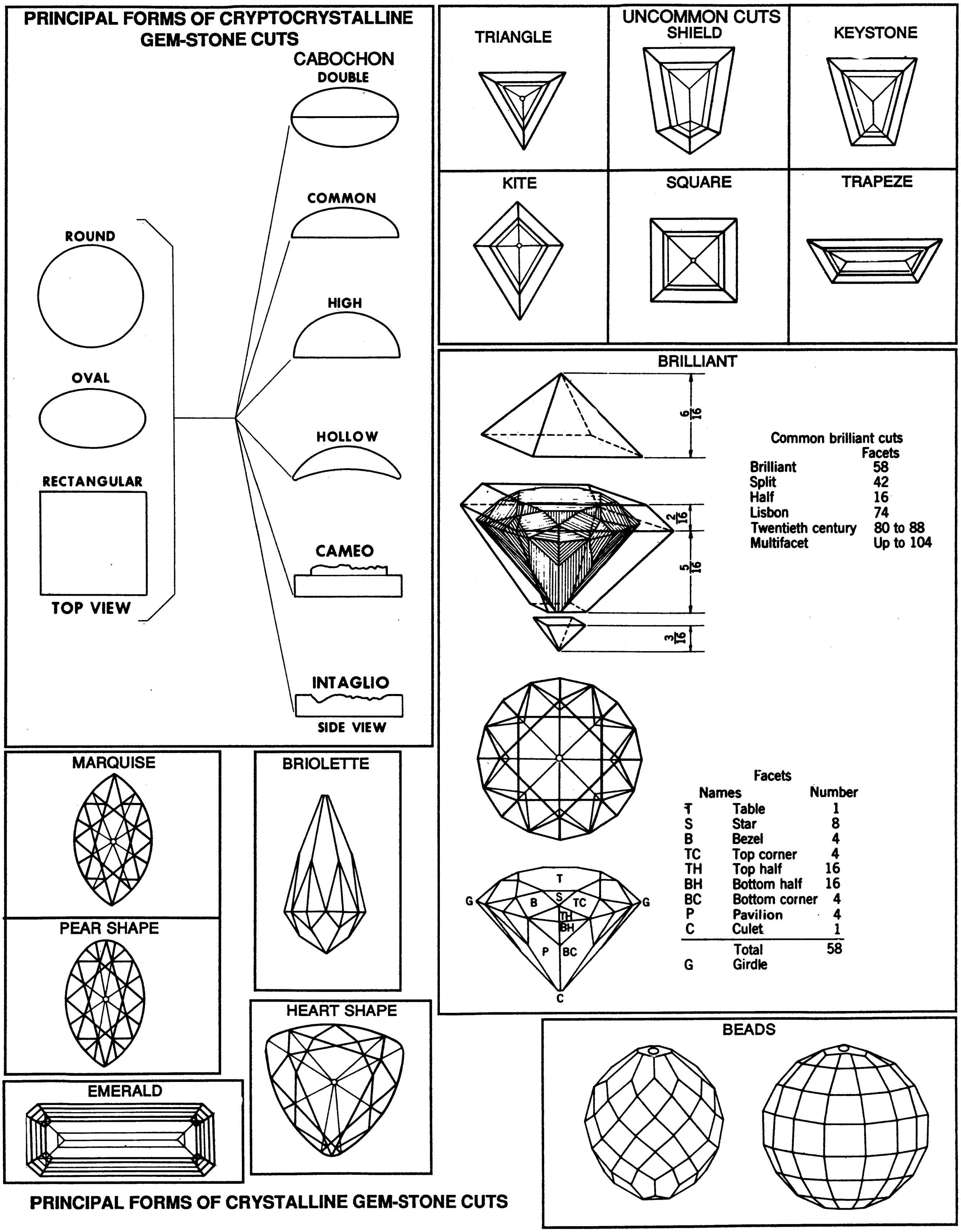
Cabochons are cut in four operations: sawing, grinding, sanding, and polishing. Sawing, the initial step in cutting, is customarily done with a diamond saw to obtain a slab or slice of the desired size and thickness from the rough gem material. The cabochon outline is scribed onto a flat surface, most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

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

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

FIGURE 1

PRINCIPAL FORMS OF CRYPTOCRYSTALLINE AND CRYSTALLINE GEM STONE CUTS



"round brilliant" and some other common cuts are illustrated in figure 1.

Industry Structure

The world market for diamonds is controlled by De Beers Consolidated Mines Ltd. It is by far the most strictly controlled of the world's commodity markets. An estimated 80% to 85% of gem and natural industrial diamond is marketed by De Beers' wholly owned subsidiary, the Diamond Corp. Ltd. The marketing is done through the CSO by the Diamond Trading Co. Ltd. and the Industrial Distributors Ltd., divisions of the CSO. The CSO sells uncut gem diamonds on behalf of De Beers and most other major producers at sights (approved bidder viewings) in London, England; Lucerne, Switzerland; and Kimberley, Republic of South Africa.

Diamonds reach the CSO sights through three channels. First, South African and Namibian production goes directly to the Diamond Producers Association. The principal members of this association are De Beers, the South African Government, and the Namibian administration. Second, contractual sales by foreign producers are handled by the Diamond Corp. Ltd., which represents the foreign producers on the Diamond Producers Association. Third, open-market competitive sales and West African sales go directly through the Diamond Trading Co.

The Diamond Producers Association funnels the production of the first two groups into the Diamond Purchasing and Trading Co. (50% held by De Beers), part of the CSO. From this point, the diamonds go through the Diamond Trading Co. The Diamond Trading Co. markets diamond to South African cutters at a 10% discount on world prices; and, through its branch in London, diamonds are sold at sights on world markets. The third group's production is handled directly by the Diamond Trading Co.'s London Branch.

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

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

Geology-Resources

Gem materials occur in a large variety of igneous, metamorphic, and sedimentary rocks and mineral deposits, usually as a small fraction of the total deposit. The origins are as varied as the occurrences. Principal formation of gem materials is by precipitation from watery solutions, by crystallization from molten rock, and by metamorphic processes. Approximately one-third of gem minerals are composed of silicate minerals, about one-fifth of alumina-silicates, and nearly one-seventh of oxides. The remaining compositional groups include the sulfides, phosphates, borosilicates, carbonates, and, in the single case of diamond, an element. The composition of selected gem materials is included as one of the items in table 10.

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

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

World resources of gem materials are nearly all unevaluated. However, world gem diamond reserve is estimated to be about 300 million carats, including

TABLE 9

DE BEERS CSO ROUGH DIAMOND PRICE INCREASES, BY PERCENTAGE

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

TABLE 10

GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWERLY

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

See footnotes at end of table.

TABLE 10—Continued

GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWERLY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Corundum—Continued										
Sapphire	Aluminum oxide	Blue	Medium	High	9.0	3.95–4.10	Double	1.78	Synthetics, including spinel	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, 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, blue, or red	Up to 20 carats	Low	9.0	3.95–4.10	do.	1.78	Synthetic spinel, glass	Curved strae, bubble inclusions.
Diamond	Carbon	White, blue-white, yellow, brown, green, pink, blue	Any	Very high	10.0	3.516–3.525	Single	2.42	Zircon, titania, cubic zirconia	High index, dispersion, single refraction, hardness, cut, luster.
Feldspar:										
Amazonstone	Alkali aluminum-silicate.	Green	Large	Low	6.0–6.5	2.56	—	1.52	Jade	Cleavage, sheen, vitreous to pearly, opaque, grid.
Labradorite	do.	Gray with blue and bronze sheen color play	do.	do.	6.0–6.5	do.	—	1.56	do.	do.
Moonstone	do.	White	do.	do.	6.0–6.5	2.77	—	1.52–1.54	Glass or white onyx	Blue sheen, opalescent.
Garnet	Complex silicate	Brown, black, yellow, green, ruby red, or orange	Small to medium.	Low to high	6.5–7.5	3.15–4.30	Single strained	1.79–1.98	Synthetics, spinel, glass	Single refraction, anomalous strain.
Jade:										
Jadeite	do.	Green, yellow, black, white, or mauve	Large	Low to very high	6.5–7.0	3.3–3.5	Crypto-crystalline	1.65–1.68	Onyx, bowenite, vesuvianite, grossularite	Luster, spectrum, translucent to opaque.
Nephrite	Complex hydrous silicate.	do.	do.	do.	6.0–6.5	2.96–3.10	do.	1.61–1.63	do.	do.

See footnotes at end of table.

TABLE 10—Continued

GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWERLY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Peridot	Iron magnesium silicate	Yellow or green	Any	Medium	6.5–7.0	3.27–3.37	Double (strong)	1.65–1.69	Tourmaline chrysoberyl	Strong double refraction, low dichroism.
Opal	Hydrous silica	Colors flash in white, gray, black, red, or yellow	Large	Low to high	5.5–6.5	1.9–2.3	Isotropic	1.45	Glass, synthetics, triplets	Play of color.
Pearl	Calcium carbonate	White, pink, or black	Small	do.	2.5–4.0	2.6–2.85	—	—	Cultured and imitation	Luster, structure, X-ray.
Quartz:										
Agate	Silica	Any color	Large	Low	7.0	2.58–2.64	—	—	Glass, plastic, Mexican onyx	Crypto-crystalline, 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.	do.	7.0	2.65–2.66	do.	do.	do.	Do.
Crystal, rock	do.	Colorless	do.	do.	7.0	2.65–2.66	do.	do.	do.	Do.
Jasper	do.	Uniform or spotted red, yellow, or green	do.	do.	7.0	2.58–2.64	—	—	do.	Opaque, vitreous.
Onyx	do.	Many colors	do.	do.	7.0	2.58–2.64	—	—	do.	Uniformly banded.
Rose	do.	Pink, rose red	do.	do.	7.0	2.65–2.66	Double	1.55	do.	Refractive index, double refraction, translucent.
Spinel	Magnesuim aluminum oxide	Any	Small to medium	Medium	8.0	3.5–3.7	Single	1.72	Synthetic, garnet	Refractive index, single refraction, inclusions.
Spinel, synthetic	do.	do.	Up to 40 carats	Low	8.0	3.5–3.7	Double	1.73	Spinel, corundum, beryl, topaz, alexandrite	Weak double refraction, curved striae, bubbles.
Spodumene:										
Kunzite	Lithium aluminum silicate	Pink to lilac	Medium	Medium	6.5–7.0	3.13–3.20	do.	1.66	Amethyst, morganite	Refractive index.
Hiddenite	do.	Yellow to green	do.	do.	do.	do.	do.		Synthetic spinel	Do.

See footnotes at end of table.

TABLE 10—Continued

GUIDE TO SELECTED GEM STONES AND GEM MATERIALS USED IN JEWERLY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Tanzanite	Complex silicate	Blue	Small	High	6.0–7.0	3.30	Double	1.69	Sapphire, synthetics.	Strong trichroism.
Topaz	do.	White, blue, or 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, 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—over 50 car.
[2] Low—up to $25 per carat; medium—up to $200 per carat; high—over $200 per carat.

near-gem and cheap-gem qualities. Nearly all of the reserves are in Australia, Africa, and the U.S.S.R. (Siberia). The estimates for diamond reserves are of limited value because data needed for reliable estimates are not available from the producers. Reserve data on other gem materials are even less available than for diamond.

Technology

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

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

Other techniques involve solid- or liquid-state reactions and phase transformations for jade and lapis lazuli; vapor phase deposition for ruby and sapphire; ceramics for turquoise, lapis lazuli, and coral; and others for opal, glass, and plastics. However, the Verneuil, Czochralski, and scull melting processes are the melt techniques most often used for gem materials. The various synthetics and the method of production are shown in table 11.

Enhancement of Gem Stones.—Enhancement of all types of gem materials through chemical and physical means has become much more commonplace and in the past few years has included a wider variety of gem materials. Irradiation by electromagnetic spectrum (X-rays, gamma rays, etc.,) and by energetic particles (neutrons, electrons, alphas, etc.) is being used to enhance or change the color of diamonds, topaz, tourmaline, quartz, beryl, sapphire, zircon, scapolite, and pearls. Blue topaz is normally irradiated, but this does not imply that all of these gem materials are regularly irradiated.[7]

A number of gem materials can be enhanced by chemical treatment or impregnations. The treatments may alter the bulk of the gem material or only penetrate the surface. This includes bleaching, oiling, waxing, plastic impregnations, color impregnations, and dying. The treatments that alter only the surface of the gem material include

TABLE 11

SYNTHETIC GEM STONE PRODUCTION METHODS

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

surface coatings of various types, interference filters, foil backings, surface decoration, and inscribing. Chemical treatment is more widespread than the common dying of quartz, treatment of turquoise, and oiling of emeralds. Chemical treatment and impregnations have been used to enhance chalcedony, coral, ivory, pearl, tiger's eye, emerald, lapis lazuli, opal, ruby, sapphire, turquoise, beryl, quartz, jade, diamonds, and amber.[8]

The oldest and most common method of gem material enhancement is heat treating. Heat treatment of gem materials was used in Greece and Rome well before the Christian Era. Heat treatment can cause color change, structural change, and improve clarity. In the past, heat treatment was common for quartz and gem corundum. Today, materials that are heat treated to enhance their appearance include sapphire, topaz, beryl, tourmaline, quartz, zircon, amber, diamond, and zoisite.[9]

Mining

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

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

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

Processing

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

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