Diamonds

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SUMMARY

World production of natural rough diamonds in 1995, the latest year for which statistics are available, was estimated by different sources at between 104 million and 110 million carats[1] (Mct). This compares with 110 Mct in 1994 and 105 Mct in 1993. About 70% by value and 70% by volume of world sales of rough diamonds are marketed by the Central Selling Organization (CSO), established by De Beers in support of its "single-channel" marketing of diamonds. Preliminary figures indicate that CSO sales of rough diamonds in 1996 were US$4.83 billion, compared with US$4.53 billion in 1995 and US$4.25 billion in 1994. In 1996, De Beers' diamond profits from mining operations and CSO sales were US$803 million, a 6% increase over 1995.

Major events in 1996 included: the merging of CRA, which owns part of the large Argyle diamond mine in Australia, with RTZ, which owns Kennecott Corporation, to form one of the world's largest mining groups; a considerable increase in the supply of inexpensive small rough diamonds from the CSO, Zaire, Russia and Angola and a decline in their prices; the termination in June of the De Beers sales contract with the Argyle Diamond Mines Joint Venture; the establishment of restrictions by De Beers on the availability of large rough stones and then a substantial increase in their prices in July; sales of rough diamonds by the CSO reaching a new record high; the fact that Russia did not (at least for now) renew its contract with the CSO; Russia and Angola continuing their direct sales (outside the CSO, also called "outside goods") of rough diamonds; Debswana, which is owned equally by the Botswana government and De Beers, renewing its sales contract with the CSO for a further five years starting from January 1996; Debswana's announcement that the government of Botswana and De Beers have agreed to invest US$290 million to increase capacity by approximately 6 Mct/y to 11.5 Mct/y by the year 2000 at the Orapa mine in Botswana; the abolishment in Russia of Komdragmet, which stands for the Committee for Gemstones and Precious Metals, and the transfer of responsibilities for mine-related business and industry functions to a newly created Ministry of Industry, as well as the diamond stockpile being transferred to the Ministry of Finance; and the low profitability reported at most major diamond-cutting centres.

Other important events included the opening of the first trading centre for rough diamonds (a rough bourse where diamonds will be sold in a tax-free zone) in Tel Aviv, and the commencement of a program in Israel by Diamdel, a subsidiary of De Beers, similar to the one it started some three years ago in Belgium to help youngsters make a career in diamond manufacturing (that is, cutting and polishing diamonds). Diamdel offers goods of the classic Israeli range, i.e., 2 to 8 grainers, to the youngsters at a price that is a few percentages below market prices. In addition, the first diamond bourse for the domestic market opened in Moscow, and Lazare Kaplan International (LKI), the largest U.S. diamond manufacturer, signed a 10-year agreement to buy rough diamonds from Almazy Rossii-Sakha (ARS), Russia's largest diamond mining company. Under the terms of the agreement, LKI will immediately build a diamond-cutting factory within the ARS facility in Moscow and it will be staffed by Russians, while ARS will supply to the facility a minimum of $45 million worth of large rough diamonds per year over the next 10 years.

Also, some Russian gem-quality synthetic diamonds were sold in Las Vegas, Nevada, in June by Chatham of San Francisco. Around 20 diamonds, each weighing less than 1 ct, were sold at a price of $1000 each regardless of their weight or grade. Later, about 100 cut synthetic gem diamonds were shown in Hong Kong.

In other news, moissanite, a colourless gemstone discovered by Dr. Henri Moissan in a meteorite, has been synthesized. The synthetic gemstone will soon be offered on the market as a diamond substitute by C3, Inc. of North Carolina. The gem is said to closely resemble diamond. It has a hardness of 9.25 (diamond is 10), a refractive index of 2.65 (diamond is

[1] One carat equals 0.2 grams.

2.42), a specific gravity of 3.2 (diamond is 3.52), and a thermal conductivity very close to that of diamond.

Preliminary estimates indicate that world sales of diamond jewellery in 1996 were US$52 billion. Sales declined 14% in Japan, but increased 7% in the United States. In carat terms, worldwide sales were 4% higher.

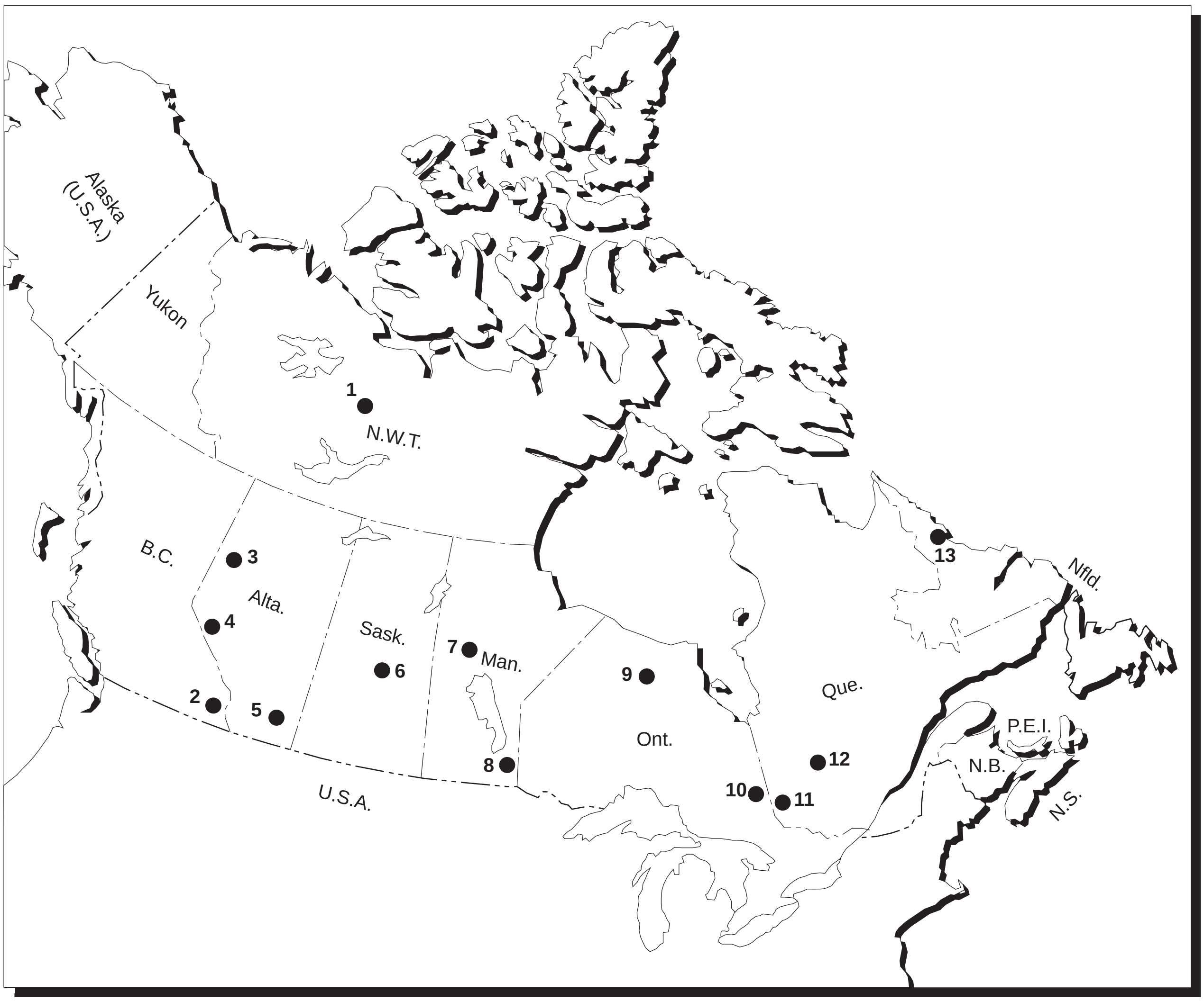
Canada is not a producer of natural diamonds. However, its potential to become a producer was further defined during the year as several companies continued extensive exploration and development work at a number of locations.

CANADIAN DEVELOPMENTS

A large area of northern and central Canada is underlain by a huge craton that forms the nucleus of the North American continent. A craton is a rigid part of the earth's crust that is ancient and stable.

Figure 1

Major Diamond Exploration Areas in Canada, 1996



Numbers refer to locations on map above.

1. Lac de Gras
2. Southeastern British Columbia
3. Peace River
4. Jasper
5. Badlands
6. Prince Albert
7. Snow Lake
8. Southeastern Manitoba
9. James Bay Lowlands
10. Kirkland Lake
11. Temiscamingue
12. Desmaraisville
13. Northern Labrador

Studies of the global distribution of diamond-bearing rocks known as kimberlites show that economic kimberlites are confined to “archons,” that is, those parts of cratons that are underlain by basement rocks of Archean age (older than 2.5 billion years), such as the ones found in Canada. In addition, diamonds and diamond indicator minerals (e.g., subcalcic high-chrome garnet, chrome diopside, high-magnesia ilmenite, and high-chrome chromite) have been found in glacial deposits in numerous locations in Canada. Together these observations suggest that, given sufficient time and funds for exploration, the chances of discovering diamonds in several regions (provinces) of Canada in commercial quantities are very good.

In 1996, exploration for diamonds continued in several regions of Canada, as shown in Figure 1. However, exploration was focussed principally in the Northwest Territories, which represented some $160 million of an estimated $170 million-$180 million spent on diamond exploration.

The most advanced project is the BHP Diamonds Inc./Dia-Met Minerals project near Lac de Gras in the Northwest Territories. Another interesting project, also near Lac de Gras, is the Diavik property owned by Diavik Diamond Mines Inc. (formerly Kennecott Canada, Inc.) and Aber Resources Ltd. Additional prospects in the same region include properties owned by Mountain Province Mining Inc., Lytton Minerals, Ashton Mining of Canada Inc., Winspear Resources Ltd./CRA Ltd., and Monopros Limited (a division of De Beers).

BHP Diamonds Inc. has reported that the diamonds recovered to date from five kimberlite pipes at its Lac de Gras property, about 300 km northeast of Yellowknife, compare favourably with those at other diamond mines in the world. The original capital investment is expected to be in excess of US$500 million. The size of all of the pipes except one is reported to be less than 5 ha each. The pipes are small compared to the major producing pipes in Russia (Udachnaya, 20 ha), Botswana (Jwaneng, 45 ha; Orapa, 106 ha), and South Africa (Venetia, 13 ha; Finsch, 18 ha; Premier, 32 ha). The pipes, known as Panda, Misery, Koala, Fox and Leslie, are located under lakes that will have to be drained before mining starts. At year-end, a pipe known as Sable was evaluated as a replacement for Leslie, where more drilling is necessary. The pipes will be mined by open-pit (OP) and underground (UG) methods over approximately a 20-to-25-year period. Four pipes, starting with Panda to the northeast, followed by Koala, Leslie and Fox, are aligned almost in a straight line a few kilometres from each other in the watershed area north of Lac de Gras. The fifth pipe, Misery, is located 27 km to the southeast, adjacent to Lac de Gras. Panda (OP) would be developed first, followed by Misery (OP), Koala (OP), Panda (UG), Fox (OP), Leslie (OP), and Koala (UG). Based on packages of rough diamonds sent at regular intervals to the CSO in London and to dealers in Antwerp and Tel Aviv, preliminary results on the pipes are as follows: Panda, 0.95 ct/t evaluated at an average price of US$130/ct (which is 10% less than the dealer sales prices), for a value of US$123/t of ore; Misery, 4.19 ct/t at an average price of US$26/ct, for a value of US$109/t of ore; Koala, 0.95 ct/t at an average price of US$122/ct, for a value of US$116/t of ore; Fox, 0.27 ct/t at an average price of US$125/ct, for a value of US$34/t of ore; Leslie, 0.33 ct/t at US$89/ct, for a value of US$29/t; and Sable, 0.98 ct/t at US$48-$64/ct, for a value of US$47-$63/t (the high value in the range applies if one 9-ct gem-quality stone is included in the sample).

In terms of value per carat (quality of the diamonds), Panda, Koala and Fox compare very favourably with the best pipes in South Africa, Botswana and Russia. In South Africa, the best pipes are Koffiefontein at US$125/ct, Kimberley at $110/ct, and Venetia at $90-$100/ct. In Botswana, Lethlekane is the best at US$100-$120/ct, and in Russia, Sytykan at US$120/ct. As a whole, the pipes average 1 ct/t of ore (which is high by world standards) and the diamonds average US$85-$90/ct. The pipes contain diamonds of all sizes and qualities, and up to 30% of the diamonds are reported to be gem quality.

The processing plant will receive 9000 t/d of ore during the first nine years of operation, and 18 000 t/d of ore thereafter. The cut-off grade will be a 1.0-mm particle size (about 0.01 ct). A single, centralized processing plant will be located southwest of the Koala pit. Processing will involve mainly crushing, scrubbing and dense media separation, plus some high-intensity magnetic separation and X-ray concentration, as well as sorting. No chemicals will be used in the process, and the waste rock, it is reported, has a negligible potential for acid generation. The mine and processing plant will operate 24 hours per day, 365 days per year. The work force during construction will reach 1000 at its peak.

Production at Lac de Gras will initially employ approximately 650 workers, of which up to 400 could be on shift and housed in a camp facility at the mine and processing plant site. Final decisions are expected in 1997 on the location of primary sorting and valuation, final classification and valuation, and how the rough diamonds will be marketed. Production is expected to start in the second half of 1998 at a rate of around 3 Mct/y and to reach 4-5 Mct/y in the early 2000s.

Diavik Diamond Mines Inc./Aber recovered 11 739 ct from a 2585-t bulk sample on its small (1.6-ha) A-154S pipe. This is equivalent to a grade of 454 ct per 100 t of ore, which is very high by world standards. Valuations to date give an average value of US$59.30/ct, or US$269/t. The value per carat means that the diamonds are of moderate quality, and comparable with Orapa in Botswana and Finsch in South Africa. The value per tonne, however, is very high, much higher than Jwaneng in Botswana, which is one of the richest pipes at US$130/t and is also the most profitable diamond mine in the world. At year-end, Diavik was evaluating three other small (± 1 ha each) interesting pipes: A-418, A-154N and A-21.

SIRIUS of Vancouver, British Columbia, started a diamond manufacturing plant at Sidney, near the Victoria airport in British Columbia. The plant employs 11 people, including 8 whose duties mainly include bruting, blocking and polishing good-quality rough diamonds (+2 ct/stone) that have been sawn in Antwerp.

Polar Star Diamonds Ltd. of Edmonton was established in 1996. The company has five employees, three of which are cutters/polishers. The facility is equipped with diamond saws, automatic and manual bruting machines, and modern blocking and polishing machines. The company currently purchases rough diamonds in Belgium and produces round and fancy shapes in the 0.5 to 5-ct range.

Five Star Diamonds Corp. of Montréal, in association with the Centre National du Diamant du Québec, has purchased land for its diamond-cutting factory. The factory is expected to be built in 1997 at Boisbriand near Montréal at an estimated cost of $6.9 million. Meanwhile, a temporary plant will be built where local people will be trained on how to cut and polish diamonds. The building(s) will be open to the public and will include, among other things, a diamond-cutting factory that uses the latest technology. Employment in the cutting factory is expected to eventually reach 45-60 people.

WORLD PRODUCTION

Natural Diamonds

An estimated 5000 kimberlite and lamproite pipes have been identified in the world, of which between 300 and 500 contain diamonds. Of this number, fewer than 50 have proven to be commercial, and 25 have become major producers. Currently, 15 are producing mines.

World production of natural rough diamonds in 1995 was estimated by Standard Equities of Johannesburg, South Africa, at 104 Mct valued at US$7.3 billion, for an average price of US$70/ct. Some 15-20 Mct were gem-quality (+US$80/ct) diamonds, 35-40 Mct were near-gems, and about 50-55 Mct consisted of low-value industrial diamonds. In terms of value, however, gems represent more than 75% of the total, near-gems about 20%, and industrial, 1-2%. World production of natural diamonds grew from 43 Mct in 1980 to around 105-110 Mct in the mid-1990s, representing an increase of 4-5 Mct/y. A large proportion of this increased production was absorbed through increased sales to Japan during the 1980s.

Natural diamonds are currently produced by some 20 countries. However, in recent years, almost 95% of world production by weight has come from only five countries. They are, in decreasing order, Australia (38-43 Mct), Zaire (15-19 Mct), Botswana (15-17 Mct), Russia (10-17 Mct) and South Africa (8-10 Mct).

In 1995, the value and production from the major producing countries, according to Standard Equities, were as follows: Botswana, US$1.76 billion and 16.8 Mct; Russia, US$1.4 billion and 10 Mct; South Africa, US$1.05 billion and 10 Mct; Angola, US$750 million and 3.2 Mct; Zaire, US$450 million and 15 Mct; Namibia, US$422 million and 1.4 Mct; and Australia, US$360 million and 40 Mct.

Australia and Zaire account for 50-55%, by weight, of world production; however, more than 90% of their production consists of low-value industrial and near-gem diamonds. Consequently, the decrease in prices of lower-grade goods in 1996 affected these two countries the most. Diamonds mined in recent years have averaged US$10/ct in Australia and US$22-$37/ct in Zaire. At the other end of the scale, Angola produces gems averaging around US$220/ct, and Namibia, which produces less than 2% by weight of world production, has a very high proportion (+95%) of gem-quality diamonds averaging US$300/ct.

Major Gem-Producing Countries

In 1996, the major gem-producing countries, in millions of carats, were as follows, according to Yorkton Securities: South Africa, 4.35; Russia, 4.3; Botswana, 3.75; Australia, 1.8; Namibia, 1.65; and Angola, 1.0.

Ownership in Major Producing Countries

In South Africa, the mines are privately owned, and De Beers owns about 85% of the production; in Australia, the mines are privately owned (but not by De Beers); and in Botswana and Namibia, the mines are owned 50% by the government and 50% by De Beers. In Angola, where production is from alluvial deposits, most mining is controlled by the government; in Russia, the mines are owned 100% by the government.

Grade Definition

Grade is the weight of diamonds expressed as carats per tonne (ct/t) of ore. It varies widely from one mine to another, but generally falls somewhere between 0.3 and 1.3 ct/t. Grades as low as 0.05 ct/t and as high as 7.0 ct/t have been exploited. The value of the ore per tonne equals the grade times the average value per carat of all the individual diamonds in the deposit.

Size (Weight) of Rough Stones at Mines

The average size of stones at individual mines varies from 0.01 ct (about 1 mm in size) to more than 0.7 ct.

According to De Beers, many mines in the world average about 0.4-0.5 ct per stone. The number of stones larger than 1 ct (0.2 g) produced each year is very small and, according to De Beers, only 380 000 stones weighing over 1 ct each were produced in 1993, the latest year for which statistics are available; the total weight of these stones was 510 000 ct (0.46% of world production) for an average of 1.34 ct per stone.

Diamonds are mined from pipes (mainly kimberlites, but also lamproites), from alluvial deposits, and from beach and offshore (marine) deposits. During the transport of alluvial materials, the weak portions (cracks, inclusions, and other defects and impurities) of the diamonds are removed. This means that the gem ratio increases with transport and that, as a result, beach and offshore deposits usually have the highest gem ratio. There are currently fewer than 20 pipes being mined in the world in the following countries: Australia, Botswana, Russia, South Africa, Tanzania and Zaire. Nearly two thirds of the world's production by weight comes from only five pipes situated in Australia, Botswana, Russia and South Africa.

Production Costs

According to different sources, operating costs (excluding depreciation and interest) for kimberlites and lamproites are approximately US$10/t for large and easy-to-access diamond mines operating in good climatic conditions, and up to US$30/t for small mines located in remote areas and operating under harsh climatic conditions. The total production costs for these mines are around US$20/t and US$40/t respectively.

Synthetic Diamonds

Synthetic diamonds compete with natural industrial diamonds as an abrasive mineral, and with silicon carbide (SiC), alumina (Al_2O_3), tungsten carbide (WC) and cubic boron nitride (CBN) as a manufactured abrasive material. World production of synthetic diamonds in 1995 was estimated by the U.S. Geological Survey at 445 Mct. The value of world synthetic diamond production is estimated at US$650 million-$800 million. Most marketed synthetic diamonds are 0.6-0.8 mm and smaller. A very popular type (about 80% of the total value) of synthetic diamonds is called "Saw Diamond Abrasives," also known as "Synthetic Diamond Abrasives" (SDA). It is manufactured mostly with cobalt-based alloys and is used for sawing, drilling or milling hard stones, concrete aggregate, refractory materials, masonry and asphalt. Synthetic diamonds were invented in Sweden in 1953 and have been produced commercially since the late 1950s.

The production of synthetic diamonds using high-pressure and high-temperature methods is labour-intensive. Industry sources indicate that a plant with an annual capacity of 10 Mct requires about 60-70 employees, and a plant with an annual capacity of some 50 Mct requires about 160-170 employees. One large press of 10 000 t produces about 5-6 Mct/y of synthetic diamonds.

In such a plant, high-purity graphite powder, either natural or synthetic, is mixed with a metal (nickel, cobalt or iron) powder alloy that serves as a solvent. The temperature and pressure are raised, and liquid nickel dissolves about 4% of carbon from graphite, which is metastable. The solubility of carbon from diamond being only 3.6%, the difference cannot stay in solution and begins to crystallize out as the form of stable carbon, which is diamond. Synthetic diamonds are allowed to grow to a certain size. Then the temperature is decreased and when the crystals have somewhat cooled, the pressure is removed. Diamonds are separated from the metal alloy by using acids that dissolve the alloy. The diamonds are then separated by size, usually by selective settling in a heavy liquid, and by shape. Each production cycle lasts about half an hour. The shape (cube, mixed cube and octahedron, octahedron, etc.) of the diamonds depends on the temperature used in the process. The cube is a low-temperature shape, and the octahedron is a high-temperature shape. The size and mechanical properties, such as the friability of the diamonds, depend on the following: reaction time; temperature; pressure; type, quality and purity of graphite; and the metal solvent used. Contrary to competing abrasive materials such as silicon carbide and alumina, the production of synthetic diamonds is not as electricity-intensive. However, electricity is an important cost component, and in the process it is used mainly to raise the temperature in the presses to 1400-1600°C.

In 1996, synthetic diamonds were produced in some 20 countries. The most important producing countries were, in decreasing order of importance, the United States, Russia, South Africa, Ireland, Japan, Belarus, Sweden, Germany and China. Smaller plants exist in Serbia, Slovakia, Romania, France, Korea and Greece. The two leading producers are De Beers of South Africa and General Electric of the United States. Together these two companies control approximately 70% of world production, and both produce a full range of synthetic diamond products. The smaller producers specialize in certain sizes and types of products. Tomei of Japan and Winters of Hamburg, Germany, reportedly produce high-quality diamonds. In January 1996, De Beers acquired Winters. De Beers has plants near Johannesburg in the Republic of South Africa; at Robertsfors, Sweden; in Hamburg, Germany; and in Shannon, Ireland. General Electric has plants at Worthington, Ohio and in Dublin, Ireland. Canada does not produce synthetic diamonds using the high-pressure method, but could become a producer because energy is inexpensive and Canada is an important consumer.

The world's consumption of synthetic diamonds continues to grow at a very healthy rate of about 12%/y as the industry conversion to super-abrasives continues. Although they are expensive when compared with competing materials such as silicon carbide and alumina, synthetic diamonds are more cost-effective because they cut much faster and last much longer. In many applications, synthetic diamonds are preferred to natural industrial diamonds because they can be tailored (size and shape) to the customer's needs. In addition, synthetic diamond grit outlasts natural grit in most cases because, unlike synthetic grit, natural diamonds must be powdered in a pestle and mortar to yield grit, a process that involves severe shock and attendant cracking. The cracks are points of weakness and result in grit losses when used for cutting or grinding rocks, concrete, etc.

There are many types of synthetic diamonds, including uncoated, strong and blocky crystals for use in drilling bits and saws; or irregular and friable crystals coated with metals such as copper, nickel, titanium or chromium for incorporation into resin-bonded grinding wheels. Super-abrasives include synthetic diamonds, cubic boron nitride (CBN), polycrystalline synthetic diamond shapes (PDS), and compacts (PDC). Because heat affects the impact strength of diamond at temperatures around 900°C, other super-abrasives are preferred at high temperatures.

Canada is a producer of traditional abrasives such as alumina, silicon carbide, and tungsten carbide. Therefore, the gradual conversion from traditional abrasives to newer and better-performing super-abrasives is slowly eroding Canadian markets. Also, PDS and PDC continue to displace natural diamond stones that are used in drill bits, single- or multiple-diamond tools, diamond saws and wheels, and diamond drawing dies, as well as tungsten carbide drill bits in the mineral services sector.

In general, larger crystals are used for cutting softer materials, and smaller crystals are used for the tougher materials.

To grow large synthetic diamonds, growth starts on **seed** crystals, which are thin slices of previously grown synthetic or natural diamond. The **feed** material can be diamond (natural or synthetic) powder, grit or graphite. The seed crystals are located at the ends of a chamber, while the feed material is located in the centre of the chamber. A temperature gradient is created in the chamber where the temperature is higher in the centre than at the ends. This creates higher solubility of diamond in the molten metal solvent in the hotter centre than at the ends, and thus a steady transport of diamond feed to the seed crystals.

Due to their low prices, natural industrial-grade diamonds make a relatively insignificant contribution to the revenue of most diamond mines. However, since they are recovered along with gem-quality diamonds, mines continue to produce and sell industrial-grade diamonds.

Crystalline Manufacturing Ltd. of Calgary produces synthetic diamond films by the Chemical (also called Carbon) Vapour Deposition (CVD) method at a plant in Calgary that was built in 1993 at a cost of some $4 million, excluding research and development. The process uses methane gas, argon and electricity as the key raw materials. A high-temperature hydrogen plasma is used to activate the methane, which condenses as diamond, and to prevent any subsequent conversion of the diamond to graphite. Large quantities of electricity are required in the process. Target markets are thermal management and wear applications.

Major producers of industrial CVD products in the world are, in decreasing order, Sumitomo, De Beers, General Electric, St. Gobain (Norton), and Crystallume. Other important producers are Diamonex (Monsanto), SI Diamond Tech, Asahi, Astex, ATM, Cemecon, Idemitsu, Mitsubishi, Nachi-Fiji, and Toshiba. World sales of CVD diamonds are estimated by General Electric at around US$50 million. The industry reports that growth has slowed in recent years due to competition from polycrystalline synthetic diamonds. CVD products are used in three major fields of applications: (1) coatings on tools subject to wear; (2) optical-quality films (diamond is very hard and transparent to X rays, infrared light and visible light); and (3) heat sinks and electronic substrates (diamond dissipates thermal energy very rapidly and has a heat conductivity five times that of copper). Future growth is expected to be in the computer, medicine and thermal management fields.

THE DIAMOND-CUTTING INDUSTRY

Natural diamonds are cut in some 30-40 countries. The major diamond-cutting centres in the world are Kempen and Antwerp, Belgium; Ramat-Gan and Tel-Aviv, Israel; New York City; and Surat and Bombay, India. With the exception of India, which is a very small producer of diamonds, none of these countries mine diamonds. Other countries with important cutting centres include South Africa, Russia, Ukraine, Belarus and Uzbekistan. Newcomers include Australia, Thailand, China, Botswana, Sri Lanka, Indonesia, Malaysia and, more recently, Yakutia in Russia. Many other countries also cut diamonds, but their industries are small. Canada's cutting industry is very small, but its potential is good as Canada will soon become an important producer of gem-quality diamonds, and Canadian labour costs are in line with those in New York, Antwerp, Australia and Israel.

Belgium is known as the world's largest trading centre for rough and polished diamonds. Trade in 1996 was 260 Mct valued at close to US$23 billion. This represents a strong increase over 1995 when trade was 209 Mct valued at US$21 billion. Some 50-55% of the CSO's sales go to Antwerp.

India cuts more carats of rough diamonds than any other country and, in fiscal year 1995/96, exported US$4.59 billion worth of cut and polished stones; this compares with US$3.96 billion in 1994/95 (US$700 million in 1980). About 90% of Argyle's cuttable production is cut in India. It is reported that India accounts for 40% of global sales of polished diamonds in dollar terms, and some 70% of the market in carat equivalent.

Israel is the second largest exporting country with about US$4.0 billion exported in 1996; this compares with US$3.85 billion in 1995. Israel is also the leader in diamond-cutting technology and cuts a very wide range of diamonds.

New York cuts the largest and best-quality stones.

In Russia, most production of rough diamonds comes from Yakutia. As Russia wants to maximize employment, more diamonds mined in Russia are now cut in Russia. Literature reports that 7000 new jobs have been created in the Russian cutting industry since the early 1990s. While there were 7 state-owned plants in 1991, there are now about 45 cutting enterprises under all forms of ownership, including joint ventures with Belgian and Israeli companies. Yakutia has only recently established its own diamond-cutting industry, and there are at least five cutting plants with capacities varying from 30 000 to 100 000 rough ct/y. These plants have also been built as joint ventures with foreign companies, and several more plants are planned over the next few years. Yakutia sorts some of the diamonds it produces, and some of them are sold to its own cutting plants. A substantial portion of the Russian production is exported as partially facetted (semi-processed) stones to non-CSO buyers. A bourse for the domestic market opened in May 1996. Its objective is to create conditions for registration and execution of all rough and polished diamond transactions on the domestic market. The bourse plans to apply to become a member of the World Federation of Diamond Bourses.

Diamond-cutting is relatively labour-intensive when compared to many other sectors. Automated cutting techniques are increasingly being used to compete with low-wage operations. The types of automated equipment being acquired include automatic girdling machines (sometimes connected with stroboscopes), automatic facetting machines, lasers to shape the roughs, and computers that suggest an optimal cut based on the shape and dimensions of, and inclusions in, a rough stone. More recently, automatic pre-blocking machines that cone 20-25 rough stones at a time have been introduced on the markets. If the pre-blocking machines are accepted by the industry, it is likely that most manual tasks up to the coning level will be eliminated in many factories.

Major diamond-cutting centres have a very wide range of indirect jobs associated with them such as brokers, wholesalers, suppliers of machinery and equipment for cutters, bourses, insurance companies, travel agencies, jewellery manufacturing, etc.

A review of the literature suggests that, on average, an employee cuts 800 rough ct/y. However, this number varies widely depending on the size of the rough diamonds to be cut (usually more carats can be cut from bigger diamonds), the difficulty of the cut, and the level of automation in the factory. Because of high labour costs, factories in the United States usually cut bigger and better-quality diamonds. Belgium and Israel are in the middle of the labour-cost spectrum and, as a consequence, are generally involved in cutting stones of intermediate size and quality. India, with the lowest labour costs, cuts the smallest and least expensive diamonds. The literature also indicates that the average price per carat of polished diamonds produced in New York is about US$1400; from Antwerp, an estimated US$1000-$1100; from Tel Aviv, US$1000 (from roughs that cost an average of about US$500/ct); and from India, US$250 (from roughs that cost US$40/ct).

Employment related to diamond-cutting varies widely from factory to factory, running anywhere from 1 to 3000 workers. Total employment in diamond-cutting varies widely from country to country. For example, there are 500-600 cutters in the United States; 3100-3500 cutters (4000 in 1994) in 300 factories in Belgium; some 9000 cutters in 35 factories in Thailand (there were no factories in 1980); 8000 workers (compared with 10 000 in 1994) in some 500 factories (600 in 1994) in Israel; approximately 10 000 workers in some 45 factories in Russia; 1500-2000 cutters (4000 in the mid-1980s) in 150 factories in South Africa; 10 000 workers in 80 factories in China; and 600 000-800 000 workers in 30 000 factories in India.

The major steps in diamond-cutting are: (a) studying the stone to locate the flaws (i.e., inclusions and imperfections in the stone), and marking with a pen where the stone is to be cut; (b) sawing (to remove the flawed areas of the stone) with a saw impregnated with diamond dust or with a laser, or cleaving; (c) rounding or bruting (also known as girdling) to shape the diamond into a round, pear, oval or other form; (d) blocking, i.e., by grinding 8 facets above the girdle and 8 facets below the girdle; (e) facetting (also known as brillianteering) by grinding many more facets into the diamond; and (f) polishing to remove surface irregularities and to allow more light to penetrate the stone.

SORTING, CLASSIFICATION AND VALUATION OF ROUGH DIAMONDS

Sorting and Classification

The terms “sorting” and “classification” are often used interchangeably. However, primary sorting of the rough stones is often done at or near the mine and usually requires only a few sorters. Classification into detailed categories requires more people and is often done near an important city for reasons of security, access to a larger labour pool and expertise, transportation, and for general convenience.

The major classification and valuation centres are Kimberly, South Africa; Gabarone, Botswana; Windhoek, Namibia; Perth (2200 km away from the mine), Australia; Mirny (primary sorting) in Yakutia Province, and Moscow (classification), Russia. De Beers' main sorting house is in London, England, where rough diamonds are classified into some 8000 categories. De Beers also sorts rough diamonds in Lucerne, Switzerland.

Each diamond mine contains diamonds that are specific to the mine in terms of size, crystal shape, clarity, colour, surface markings, etc. The stones are classified in the following order: weight, shape, clarity and colour. The rough diamonds that are mined at different locations in the world and that are sold in whole or in part to the CSO are classified into a total of some 8000 categories by the CSO. This large sample, called the "master sample," is kept at the CSO's office in London, England. The CSO attaches a price to each category of roughs contained in the master sample. All of the prices are contained in a proprietary price book that is used by the CSO's 600 sorters in London, who sort and value all of the incoming rough diamonds, and by other valuers. The prices are changed in the book every time the CSO announces a price change.

A **simplified** method of classifying the stones from a specific deposit can be described as follows. Once the rough diamonds from a production run have been cleaned of their surface impurities with acids, they are weighed, counted, sieved for size (weight), and separated into 5 to 10 piles depending on the size distribution of the stones in the deposit. For small stones (i.e., smaller than 0.5 ct), weight is the most important classification factor. The stones are then classified according to their shape.

The major shapes in which gem-quality diamonds crystallize or are found in mines are as follows:

(a) octahedron "O";

(b) triso-O, where each face of the "O" has been replaced by three triangular faces; hexa-O, where each face of the "O" has been replaced by six triangular faces; or combinations of the above (these stones look like "boules");

(c) cleavages, which are broken crystals of the above shapes; and

(d) macles, which are twin crystals, often triangular in shape, and thick; flats, which are thin pieces, whole or broken, including thin macles; and flat elongated crystals.

The yield of each type of shape is approximately as follows: type (a), 40-48%; type (b), about 50%; type (c), 35%; and type (d), 15-25%.

De Beers uses the following system: stones are well-formed octahedrons without obvious flaws; shapes are octahedrons that are slightly deformed or flatter on the edges and lightly flawed; cleavages are broken or very irregular "misshapen" crystals; macles are crystals that are thick and often triangular; and flats are thin wedges, whole or broken, including thin macles. Yields are as follows: stones, 45-48%; shape, 40-45%; cleavage, 35%; macles, 25%; and flats, 15-25%.

Some rough dealers use the following terms to reflect decreasing quality: select, round, spotted (like stone but lightly flawed), cape (like spotted but yellowish in colour), cleavage, macles, tools and rejects.

Clarity can be divided as follows:

- "I," if inclusions can be seen with the naked eye;
- "SI," if small inclusions are easy to see with a 10 X loupe;
- "VS," if small inclusions are difficult to see with a 10 X loupe; and
- "VVS," if small inclusions are very difficult to see with a 10 X loupe.

Colour can be divided into three categories "equivalent to polished stones": (1) "H," white, if the stone appears colourless (very few diamonds in a mine are "D," "E," "F" or "G" in colour); (2) "J," off-white, when the stone has a slight milky appearance; and (3) "M," if the stone appears yellowish or brownish.

Consequently, altogether, gem-quality diamonds from a mine can be divided or classified into 250-500 categories (piles). At some mines, such as alluvial mines, the number of categories is much lower. Industrial stones only need to be classified into a few categories. After classification of a production run, each pile is weighed.

Valuation

If the production is sold to the CSO, there are different options. Two of these options are as follows. A full valuation will be used if there is a wide variation in the value (which is a function of the size, shape, clarity and colour) of the diamonds in a deposit. If there is a preponderance of smalls and inexpensive industrial diamonds, only a cut-off valuation will be used. In the first case, the stones may be classified into thousands of categories, while in the second case a much reduced number of categories will be used.

An example of a full valuation can be described as follows. The primary valuation (which determines an agreed-upon percentage of the mine's revenue) at the mine to which royalties[2] apply is determined by comparing the quality of a sample representing a percentage of the production run with that of a "working sample" that matches the "official producer sample" but consists of far fewer stones. Usually, if the quality of the stones improves, the value also improves. The "official producer sample" consists of stones representative of the diamonds in the deposit and for which an agreed-upon value "by the CSO, the mine and the government valuers" was assigned when initial production started. Official producer samples are kept under the joint seals of both the producer and the CSO. They are used for sorting, and by government-appointed valuers and the CSO. The mine production is classified into a number of categories that depend on the variations in the size, shape, clarity and colour of the stones and in accordance with the "producer sample," and is valued according to the CSO's current selling price list. It is purchased by the CSO at a price called the "realizable value" of production that is negotiated (by comparing, among other factors, the quality of a production sample with the "producer sample") between the CSO, the mine and the government valuers. The "realizable value" is the value upon which taxes[2] apply, and is also used to determine the mine's final revenue. The production is sent to London where it is checked. The diamonds are then mixed with diamonds from all over the world that are sold to the CSO. Parcels are prepared for sale to sightholders.

If the production is sold outside the CSO by tenders, or if the diamonds are sold by rough diamond dealers, the value, especially of the larger goods, can be determined by using published polished prices corresponding to each category of rough diamonds, then applying a discount or premium that depends on the supply and demand for certain category stones, and calculating back the value of the roughs for each category. However, selling prices may be quite different from valuation prices.

The CSO has been successful in maintaining a balance between the supply of and demand for rough diamonds for some 60 years. It buys surplus production of rough diamonds from mines and then stockpiles them during periods of weak demand in the jewellery market, and sells off its stockpiled roughs as demand picks up. Production quotas may be applied to major producers when sales fall.

About 70% of world sales of rough diamonds are marketed by the CSO. The diamonds are released to the market in a controlled way by the CSO at "sights," which are held about every five weeks in Europe (London and Lucerne) and South Africa (Johannesburg), to about 170-180 carefully chosen buyers known as "sightholders." Diamdel, which is a De Beers subsidiary, is the largest sightholder, and it distributes rough diamonds to manufacturers that are too small to qualify for sights. Some 30-35% of the sightholders reside in Belgium, 20-25% in India, 20-25% in Israel, about 12% in the United States, 5-10% in Thailand, and 5% in South Africa. The majority of the sightholders are manufacturers with large cutting operations, but some of the largest are rough dealers that sell their goods to smaller cutting firms. Six of the top ten sightholders are companies from India representing about 25% of CSO sales per year.

Once the stones are cut and polished, they are sold to diamond merchants or wholesalers of polished diamonds. Finally, the diamonds are sold to manufacturing jewellers and retail outlets.

De Beers indicates that the minimum and maximum annual rough diamond purchases from the CSO per sightholder are respectively $5 million and 10% of the CSO's annual sales.

MARKETING OF ROUGH DIAMONDS

Large producers may sell by contract the entire production to diamantaires or to the CSO at prices determined by the CSO and shown in two books (one has buying prices, the other shows selling prices), and using standardized samples. When production is sold to the CSO, the diamonds are purchased by the CSO at the selling price less 10% to cover costs such as inventory, classification and valuation, advertising and marketing (e.g., Debswana in Botswana). Large producers may also sell most production to the CSO and market a small portion (5-20% called a "window") independently of the CSO in order to develop an in-house expertise and check market prices of both rough and polished diamonds (e.g., as in Russia).

Small- to medium-sized producers may sell by tenders. This method optimizes profits, but there is a danger of collusion when there are only a few buyers. Also, tenders are sensitive to short-term swings in the markets (e.g., Trans Hex of South Africa).

Small "alluvial" producers may sell to traders (middle-men) who have sales offices in large trading centres where dealers and manufacturers are invited to examine and buy the goods. The problem here is that valuations can be highly variable between dealers (e.g., Arslanian Frères and G. Evens of Antwerp). Small producers may also sell directly to polishers in order to avoid the middle-men.

Finally, diamonds can be sold as "brand" products to differentiate them from other types of diamonds (e.g., cognac, champagne and pinks from Argyle, Australia, or "American" diamonds from Redaurum in the United States). These diamonds are sold by tenders or at auctions.

CUT AND POLISHED DIAMONDS

To determine the value of an individual polished diamond, an appraiser looks at its combination of the four "C"s: cut, colour, clarity, and carat (weight).

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[2] Taxes and royalties are usually deducted from profits.

Cut

Polished diamonds come in a variety of shapes, the most common being round (also known as "brilliant"); other shapes (called "fancies"), in decreasing order of popularity, include marquise, pear, heart, oval, emerald, square and triangle. Polished stones also vary in terms of their number of facets (surface planes). However, more important than these two factors to the value of the diamond is the quality of its cut. This is determined by: (a) the relative proportions of the table size, the crown height, and the pavilion depth of the diamond (which determines its brilliancy, i.e., the amount of light reflected through the stone); and (b) the angles of the facets (which determine the dispersion of light that creates the fiery rainbow colours). The quality of the cut is also determined by the symmetry of the table and the girdle, and the location of the cullet (base), as well as the quality of the polish.

By far the most popular cut diamond sold in the markets is the round brilliant (58 facets). Fancy cuts represent about 10-20%, and single cuts, known as 8/8 (17 facets), represent about 10%. Single cuts are for very small diamonds, i.e., 3 points and smaller. Single-cut stones are used to add scintillation around a large stone. Full-cut stones smaller than 3 points do not scintillate because the facets are too small.

Colour

The rarest and best colour in diamonds is no colour at all. The colour grade is a measure of the amount of colour present in a diamond. Most diamonds have a tinge of some colour (most often yellow or brown). Strong (intense)-coloured diamonds called "fancies" command very high prices. Among the fancies, the browns (cognac) are the most common, followed by champagne and intense canary yellow. Purple, orange and yellowish greens are rare; pink, blue and dark green are the rarest colours and command the highest prices.

Clarity

This is a measure of the number, size, placement and nature of flaws (inclusions and/or imperfections) within and on the surface of a diamond visible at 10-power magnification. Inclusions are crystals, while imperfections are feathers, blemishes, cracks, etc.

Carat

One carat is equivalent to 0.2 grams. A carat is normally divided into 100 points. Because larger diamonds are rare, a 1-ct diamond will cost more than a cluster of 20 diamonds weighing a total of 1 carat. A carat is also subdivided into "grains," and one carat equals four grains. A one-carater therefore is also a four-grainer and refers to diamonds within a certain weight range. A four-grainer weighs 0.95-1.05 ct, a three-grainer weighs 0.72-0.76 ct, a two-grainer weighs 0.47-0.56 ct, and a one-grainer weighs 0.23-0.26 ct. Melee are small diamonds that weigh 7-15 points each.

IDENTIFICATION OF DIAMONDS

Rough and polished natural diamonds can be identified (from imitations) relatively rapidly, in a non-destructive way, with instruments such as the spectroscope, where the dark absorption bands (478 nanometres (nm) and 415 nm) characteristic of diamonds can be seen, or with instruments that measure the thermal conductivity of the stone being tested. Diamonds conduct heat faster than any other substance.

De Beers has recently developed two instruments that can differentiate natural diamonds from synthetic diamonds of cuttable quality. The "DiamondSure" can differentiate between 10-15 stones per minute and is designed to work with diamonds in the 0.5-10 ct per stone range. The DiamondSure identifies the 415-nm line that is present in most natural diamonds, but not in synthetic diamonds. If the 415-nm line is detected, the instrument displays the message "pass." If the line is not detected, the message reads "refer for further tests." In D-colour natural diamonds, and in some E-coloured diamonds, as well as in some browns, the 415-nm line is far less prevalent. In addition, the 415-nm line is absent in natural fancy blues, and in some fancy yellow and some pink diamonds. In these cases, the diamonds are referred to another instrument called the "DiamondView," which shows fluorescence patterns. The fluorescence patterns reflect growth structures. Synthetic diamonds grow essentially as cubo-octahedra, while the basic growth form of natural diamonds is octahedral. The types of inclusions and the degree of phosphorescence after excitation by ultraviolet light can also be used to differentiate synthetic diamonds from natural diamonds.

PROCESSING (REFINING) INDUSTRIAL MINERALS

Low-value natural and synthetic diamonds can be processed into higher-value products by simple methods. Processing methods for grit, powders and stones are as follows. Natural grit (about 40 microns to 1 mm) is ground, washed, dried, screened into sizes, and separated into shapes (elongated vs. short, such as octahedra, etc.) with the use of vibrating tables. The short are sold, while the elongated are ground again, and the cycle is repeated. Synthetic grit and natural and synthetic powders are separated into sizes and shapes, cleaned of their surface impurities, and dried. Stones (+1 mm) are screened, separated into shapes, and sold as such, or the stones can be lightly rounded mechanically for long life and resistance to premature breakdown; rounded mechanically and polished to resist wear, high-impact and premature breakdown; or rounded and polished with acids for resistance to severe impacts and high temperatures. There are no industrial diamond processing plants in Canada.

RECYCLING

Although Canada is an important consumer of diamonds in the form of cutting tools, and machinery and equipment such as grinding wheels, saws, dies, drilling bits, etc., diamonds are not recycled in Canada; however, they are recycled in other countries. In a recycling plant, chemicals (hydrofluoric acid, hydrochloric acid, caustic soda, soda ash, etc.) and physical processes (distillation, flotation, magnetic and electrostatic separation) are used to liberate the diamonds. The diamonds are then cleaned and classified.

USES

Gem-Quality Diamonds

Gem-quality diamonds are used in jewellery. World retail sales of diamond jewellery have increased rapidly in the 1990s, as shown in Table 6. In 1995, some 60 million pieces of diamond jewellery were sold with a total diamond content value of some US$17 billion and a diamond content weight estimated at 18-19 Mct. The major markets for diamond jewellery in 1994 in terms of diamond content value were approximately as follows: the United States, 30%; Japan, 26%; East Asia, 17%; Europe, 13%; and other countries, 14%.

About half of the world's diamond production is industrial grade, i.e., not cuttable. Since a considerable proportion of the rough stones is lost during cutting and polishing, only about 15-20% by weight of the rough stones mined end up in jewellery. However, this percentage is increasing because: (a) cutting and polishing methods are more efficient with higher yields; (b) stones that previously were classified as "non-cuttable" are now classified as "cuttable" because they can be cut profitably in some low-wage countries; and (c) smaller stones can be cut due to new and better technologies.

World retail sales of diamond jewellery were revised upwards by De Beers during the year (Table 6). World sales were US$52.7 billion in 1995, instead of US$50 billion, as previously reported. The East Asian market is growing rapidly while, since the late 1980s, the markets of Europe and Japan have shown minimal growth. The U.S. market has shown minimal growth in the late 1980s and early 1990s, but strong growth since 1993. In order to promote the use of diamonds, De Beers spent about US$190 million in 1996 on advertising in some 34 countries.

Industrial Diamonds

Industrial diamonds are diamonds that do not meet the standards of gem-quality diamonds because of their colour, clarity, size or shape. Industrial diamonds include natural and synthetic diamonds.

Diamonds are the hardest substance known. For this reason, the major use of industrial diamonds is as an abrasive. Industrial diamonds are used in equipment that drill, cut, grind and polish rocks (such as granite and marble), other materials (such as nonferrous metals, carbon fibre and composites), and a range of nonmetallic materials (such as glass, refractories, ceramics, concrete, plastics, and masonry bricks). Natural and synthetic diamonds are widely used in the automotive, advanced technology and aerospace industries. The two principal types of natural industrial diamonds are *stones* and *bort*.

Natural industrial stones are usually larger than 800 microns. They are used mainly in drilling bits, single or multiple-point diamond tools, diamond saws, diamond wheels, and wire-drawing dies. Bort consist of stones that are small, irregular in shape, and have flaws and imperfections. Drilling bort are stones that are suitable for use in drilling bits. The low-grade bort are usually crushed and used as a loose abrasive for lapping and polishing.

Today, in many of the above applications, synthetic diamonds are preferred to natural diamonds because customers have a much greater choice in terms of size, shape, price, etc.

Diamond dies, which have cores of polycrystalline diamond ("sintered"/"bonded" diamond powder) surrounded by a cemented tungsten carbide ring, are also widely used in wire drawing where they replace natural stones. Other interesting properties of diamonds include their heat conductivity and transparency to electromagnetic (EM) waves. Diamonds conduct heat faster than any other material and, therefore, are used in small quantities as heat sinks, i.e., to move heat away from sensitive parts in electronic equipment; to detect the heat emitted by some objects; and as thermometers to detect minute temperature changes. Because of their transparency to EM waves, diamonds are used as "windows" to allow signals (heat, radar, etc.) to reach a sensor without interference. In many of these smaller applications, such as in heat sinks and windows, which are products made of synthetic diamonds, the diamonds are produced by the CVD method.

PRICES

Published average mine prices of rough diamonds in recent years have varied widely across producing countries: US$8-$10/ct in Australia, US$22-$37/ct in Zaire, US$90-$105/ct in both South Africa and Botswana, US$100-$140/ct in Russia, US$140-$170/ct in the Central African Republic, US$150-$200/ct in Guinea, US$160-$200/ct in Sierra Leone, US$180-$230/ct in Angola, and US$300/ct in Namibia. This wide variation in prices is mainly a function of the proportion of gem-quality diamonds produced by each country. As an example, in Australia the diamonds have a very low gem ratio, while in Namibia the gem ratio is very high. The kimberlite mines in South Africa produce rough diamonds that individually average US$55/ct (Finsch mine) to US$125/ct (Koffiefontein mine). In 1995, the average value of production in the three major producing countries, according to Standard Equities of Johannesburgh, was as follows: US$140/ct in Russia, US$105/ct in Botswana, and US$105/ct in South Africa.

Taking into account losses during cutting and polishing, as well as commissions paid to intermediaries, the price of a diamond sold to a manufacturing jeweller is estimated to be about 5-6 times the price of the rough stone at the mine. Intermediary costs include costs such as for sorting, advertising, sightholders' brokers, cutting and polishing, and polished diamond dealers/wholesalers.

Natural Diamonds

Natural industrial diamonds vary in price from about 30¢/ct for crushing bort to about $7-$10/ct for industrial stones.

Gem-quality rough diamonds: The price of a rough stone depends on its carat weight, shape, clarity and colour. The prices vary widely, but the following table is an indication of the prices paid at cutting and polishing factories for gem-quality (**fine-quality**) rough stones.

PRICES OF HIGH-QUALITY GEM ROUGH DIAMONDS

Weight/Stone (carats)	Price (US$/carat)
0.5	200-**300**
1	500-**600**
2	1 000-**1 200**
3-4	1 500-**2 500**
5-6	1 800-**3 000**
10-20	3 000-**4 500**
100	**10 000+**

Sources: Hasenfield-Stein, New York; Five Star Diamonds Corp., Montréal.
Note: Prices for fine-quality rough diamonds are shown in bold characters.

Polished diamonds: The price of a polished diamond depends on its carat weight, clarity, colour, cut and shape.

The *Rapaport* publication shows some 1600 high-cash asking prices (spot cash New York) for "well-cut," round brilliant-cut diamonds. The prices shown are used as starting points for negotiations, and discounts of 20% to over 30% may apply depending on market conditions. The diamonds vary in size from 0.01 to 5.99 ct, from "D" to "M" in colour, and from "IF" (internally flawless) to "I_3" for clarity. As an example, the price at year-end for the smallest and lowest-quality stones (i.e., in the 0.01-0.03-ct range, "N" colour, and "I_3" clarity) was US$170/ct. In the *Rapaport* publication, the most expensive stones were in the 5.00-5.99-ct range, "D, IF" valued at US$56 200/ct. Stones in the 0.50-0.69-ct range varied in prices from US$600/ct for "M, I_3" to US$2300/ct for "J, SI_1," and to US$8100/ct for top-quality "D, IF." Stones in the 1.00-1.49-ct range varied from US$1000/ct to US$16 400/ct. A pear shape in the 0.50-0.69-ct range and "J, SI_1" has a high cash asking price of US$2100/ct.

The *Rapaport* publication also shows a total of about 4200 prices for pears, marquises, and emerald-cut polished diamonds.

Synthetic Diamonds

There are several hundred prices for synthetic industrial diamonds depending on their size, shape, crystallinity, and whether or not the diamonds are coated with a metal, etc. Generally speaking, synthetic diamonds used in grinding and polishing vary in price from 30¢/ct (could be as low as 10¢/ct for cheap quality) up to $1/ct. Strong and blocky material for use in sawing and drilling, and known in the trade as SDA and MBS (produced respectively by De Beers and General Electric), sells for $3-$4/ct. Large crystals with excellent structure for use in specific applications sell for several hundred dollars per carat.

OUTLOOK

Worlwide, the demand for good-quality gems is expected to continue to be strong, and the surplus of cheap gems should continue for a few years.

On a constant-dollar basis, prices of synthetic diamonds for use as abrasives (which is the largest use) should continue to decline as world production continues to increase rapidly and production becomes more cost-efficient. However, if the industry consolidates through acquisitions, prices may stabilize. Prices for natural industrial diamonds should continue to decline if world production remains at its present level, or increases, due to strong competition from synthetic diamonds.

On the consumption side, strong growth is expected in the construction industry in North America during the next five years as infrastructure is being repaired and improved. In the longer term, the consumption of synthetic diamonds as an abrasive material will continue to be strong worldwide as more uses are being developed.

Synthetic diamonds will continue to replace natural industrial diamonds.

PRODUCTION AND CONSUMPTION FORECAST

It is difficult to forecast world production and consumption of diamonds with certainty. Production by certain countries is difficult to estimate because: (a) the information released by governments is often vague or inaccurate; (b) smuggling in alluvial operations is common practice in many countries of Africa, and it is estimated that smuggling accounts for some 10% by carat of world production, equivalent to over $600 million per year in recent years; (c) stockpiles of rough diamonds held by the CSO are published only in dollar value (US$4.67 billion as of December 31, 1995, which was re-evaluated recently by Deutsche Morgan Grenfell, who claims that the current replacement cost is US$8.4 billion) at cost, and not in carats; and (d) Russia has a stockpile of rough gems that, it is believed, is rapidly being depleted, but still remains unknown outside of Russia. Changes in either the CSO or Russian stockpiles can affect world prices and, consequently, production.

However, some general comments can be made concerning future world diamond production. Factors leading to a possible decline in production include: (a) the current rapid depletion of the reserves of certain mines in Russia and the Republic of South Africa; (b) the exhaustion of on-shore alluvial deposits in South Africa and Namibia; (c) unstable conditions in certain countries of Africa that are inhibiting production; and (d) a likely decline in production at the Argyle mine in Australia in the year 2003 as the grade continues to decline and the open pit becomes uneconomic. The above factors may be partially or totally offset by the following supply developments: (a) increased exploration in the world that may lead to a major discovery; (b) increased offshore production in South Africa and Namibia; (c) expansions at some mines in Botswana (Jwaneng) and the Republic of South Africa (Venetia); (d) the likely development of new mines in Canada, Russia and Angola; and (e) increased production of synthetic (industrial and gem-quality) diamonds. During the next few years, most of the increase in world production is likely to come from an expansion of the Orapa mine in Botswana, and new mine developments (BHP and possibly Diavik) in Canada.

On the consumption side, the growth in diamond sales in East Asia and China is expected to continue in response to increased advertising for diamond jewellery by De Beers, and increases in the Gross National Product per capita in these countries.

Diamond sales in the Western World, especially diamonds used in mass-market jewellery, are increasing rapidly and may soon spread to Southeast Asian countries. Growing markets are expected to be those countries with large populations that are also large gold consumers (i.e., India, China, the Arabian Gulf States, Turkey and Pakistan). This seems to indicate that new production will be absorbed rapidly.

Notes: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 70. (2) Information in this review was current as of March 31, 1997.

TARIFFS

Item No.	Description	Canada MFN	Canada GPT	Canada USA	United States Canada
7102.10	Diamonds, unsorted, whether or not worked, but not mounted or set	Free	Free	Free	Free
7102.21	Diamonds, industrial, unworked or simply sawn, cleaved or bruted, but not mounted or set				
7102.21.10	Bort and black diamonds, for borers	Free	Free	Free	Free
7102.21.90	Other	Free	Free	Free	Free
7102.29	Diamonds, industrial, other, worked, not mounted or set				
7102.29.10	Bort and black diamonds, for borers	Free	Free	Free	Free
7102.29.90	Other	Free	Free	Free	Free
7102.31	Diamonds, non-industrial, unworked or simply sawn, cleaved or bruted	Free	Free	Free	Free
7102.39	Diamonds, non-industrial, other	Free	Free	Free	Free
7105.10.10	Diamond dust for borers; dust mixed with a carrier in cartridges or in tubes	Free	Free	Free	Free
7105.10.91	Natural diamond dust or powder	8.1%	4%	Free	Free
7105.10.92	Synthetic diamond dust or powder	Free	Free	Free	Free

Sources: Customs Tariff, effective January 1997, Revenue Canada; Harmonized Tariff Schedule of the United States, 1997.

TABLE 1. CANADA, DIAMOND TRADE, 1994-96

Item No.		1994		1995		1996p	
		(carats)	($000)	(carats)	($000)	(carats)	($000)
EXPORTS							
7102.10	Diamonds, unsorted, whether or not worked but not mounted or set						
	United States	. .	160	. .	320	. .	341
	India	–	–	–	–	. .	48
	Belgium	–	–	. .	19r	–	–
	Total	. .	160	. .	339r	. .	389
7102.21	Diamonds, industrial, unworked or simply sawn, cleaved or bruted						
	Romania	–	–	–	–	9 698	145
	United States	6 298	40	4 069	26	1 091	46
	Total	6 298	40	4 069	26	10 789	191
7102.29	Diamonds, industrial, other, worked not mounted or set						
	Belgium	–	–	–	–	19 047	116
	Israel	–	–	12 000	82	25 078	93
	United States	85	55	5 090	89	115	41
	Ireland	–	–	1 800	18	3 000	18
	Hong Kong	–	–	–	–	2 241	18
	Other countries	13 000	533	500	10	–	–
	Total	13 085	588	19 390	199	49 481	286
7102.31	Diamonds, non-industrial, unworked or simply sawn, cleaved or bruted						
	United States	–	–	345	45	712	110
	Belgium	–	–	–	–	2 272	34
	Total	–	–	345	45	2 984	144
7102.39	Diamonds, non-industrial, other						
	United States	15 576	11 735	6 854	7 627	22 229	12 954
	Belgium	–	–	5 708	8 417	3 387	1 654
	Israel	–	–	123	293	808	783
	United Kingdom	–	–	–	–	9	178
	India	–	–	–	–	778	95
	Other countries	2 737	5 360	1 309	2 083	24	38
	Total	18 313	17 095	13 994	18 420	27 235	15 702
7105.10	Diamond dust or powder						
	United States	167 675	258	171 124	115	107 491	82
	Bulgaria	29 600	30	–	–	–	–
	Total	197 275	288	171 124	115	107 491	82
IMPORTS							
7102.10	Diamonds, unsorted, whether or not worked, but not mounted or set						
	Belgium	. .	8 991	. .	6 636	. .	9 824
	United States	. .	15 365	. .	10 811	. .	9 489
	Israel	. .	8 015	. .	5 485	. .	6 999
	India	. .	4 909	. .	4 097	. .	6 245
	Barbados	. .	440	. .	1 573	. .	1 558
	Other countries	. .	1 508	. .	2 777	. .	2 064
	Total	. .	39 228	. .	31 379	. .	36 179
7102.21.10	Diamonds, industrial, bort and black, for borers, unworked or simply sawn, cleaved or bruted, but not mounted or set						
	United States	338 908	1 168	332 821	1 018	176 522	641
	Belgium	42 627	348	127 940	793	53 471	535
	Ghana	15 673	152	42 080	240	58 958	393
	Ireland	135 673	509	40 998	186	94 081	281
	Germany	–	–	87 342	254	91 681	242
	Zaire	88 524	405	113 052	443	31 697	197
	United Kingdom	18 106	80	33 233	195	19 857	143
	Other countries	43 417	284	36 402	228	41 376	144
	Total	682 928	2 946	813 868	3 357	567 643	2 576

TABLE 1 (cont'd)

Item No.		1994		1995		1996p	
		(carats)	($000)	(carats)	($000)	(carats)	($000)
IMPORTS (cont'd)							
7102.21.90	Diamonds, industrial, other than bort and black, for borers, unworked or simply sawn, cleaved or bruted, but not mounted or set						
	United States	3 879	39	6 252	62	35 457	140
	Ireland	19 000	89	–	–	24 212	99
	Other countries	–	–	3 331	34	12 893	131
	Total	22 879	128	9 583	96	72 562	370
7102.29.10	Diamonds, industrial, bort and black, for borers, worked, but not mounted or set						
	Ireland	659 211	2 312	305 256	1 001	847	324
	United States	49 936	230	101 918	345	43 379	161
	Other countries	57 795	280	65 806	287	38 431	122
	Total	766 942	2 822	472 980	1 633	82 657	607
7102.29.90	Diamonds, industrial, other than bort and black, for borers, worked, but not mounted or set						
	Ireland	41 493	199	176 494	562	1 155 991	4 359
	United States	1 587	15	14 590	259	345 842	2 228
	United Kingdom	–	–	–	–	14 551	233
	Other countries	1 000	5	7 022	47	27 736	316
	Total	44 080	219	198 106	868	1 544 120	7 136
7102.31	Diamonds, non-industrial, unworked or simply sawn, cleaved or bruted, not mounted or set						
	Belgium	912	224	466	526	738	803
	Ghana	–	–	–	–	135	113
	United States	296	181	281	185	345	47
	Israel	–	–	39	6	–	–
	Total	1 208	405	786	717	1 218	963
7102.39.00.10	Diamonds, non-industrial, worked, of a weight not exceeding 0.5 carats each						
	Israel	13 359	8 858	36 077	23 863	37 241	28 832
	Belgium	54 793	25 257	33 340	19 289	20 584	13 732
	United States	34 243	23 197	13 470	10 783	7 686	6 477
	India	9 585	4 122	3 819	1 392	7 524	2 781
	Iceland	325	294	168	165	75	106
	Other countries	24 939	8 938	6 442	6 262	429	293
	Total	137 244	70 666	93 316	61 754	73 539	52 221
7102.39.00.20	Diamonds, non-industrial, worked, of a weight exceeding 0.5 carats each						
	Belgium	35 749	29 251	39 077	28 769	39 695	30 649
	Israel	18 119	18 018	38 976	22 495	25 345	23 392
	United States	16 185	16 210	12 922	10 287	14 723	14 312
	India	13 618	4 530	20 932	6 573	34 679	8 497
	Barbados	400	556	1 136	1 663	528	1 065
	Other countries	22 604	29 745	4 915	5 093	2 418	1 491
	Total	106 675	98 310	117 958	74 880	117 388	79 406
7105.10.10	Diamond dust for borers; dust mixed with a carrier in cartridges or in tubes						
	United States	306 241	599	366 934	785	914 754	2 325
	Ireland	16 994	74	9 018	26	72 767	244
	Zaire	1 909	10	–	–	8 651	41
	Other countries	30 873	110	23 257	82	18 031	61
	Total	356 017	793	399 209	893	1 014 203	2 671
7105.10.91	Natural diamond dust or powder						
	United States	929	6	5 955	9	39 369	125
	Zaire	–	–	4 100	6	2 987	18
	Other countries	–	–	–	–	15 357	17
	Total	929	6	10 055	15	57 713	160

TABLE 1 (cont'd)

Item No.		1994		1995		1996p	
		(carats)	($000)	(carats)	($000)	(carats)	($000)
IMPORTS (cont'd)							
7105.10.92	Synthetic diamond dust or powder						
	United States	2 071 474	5 429	1 790 218	5 545	1 796 748	4 860
	Ireland	687 063	2 527	1 463 147	4 072	954 114	2 975
	Italy	–	–	228 610	670	112 887	377
	Other countries	603 905	646	262 509	803	127 595	297
	Total	3 362 442	8 602	3 744 484	11 090	2 991 344	8 509

Source: Statistics Canada.
– Nil; . . Not available; p Preliminary; r Revised.
Note: Numbers may not add to totals due to rounding.

TABLE 2. CANADIAN DIAMOND IMPORTS, 1991-96

	1991	1992	1993	1994	1995	1996
SYNTHETIC DIAMOND DUST OR POWDER						
Weight (ct millions)	7.36	5.32	2.11	3.36	3.74	2.99
Value ($ millions)	4.45	4.24	5.38	8.60	11.09	8.50
GEM-QUALITY AND INDUSTRIAL DIAMONDS						
Value ($ millions)	189	187	173	215	175	182

Source: Natural Resources Canada.
Note: Some 90% of the imports of gem-quality and industrial diamonds were estimated to be gem-quality diamonds.

TABLE 3. DE BEERS' CSO ROUGH DIAMOND SALES AND STOCKS, 1985-96

Year	Sales	Stocks
	(US$ billions)	
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	3.76
1993	4.37	4.12
1994	4.25	4.38
1995	4.53	4.67
1996p	4.83	4.70

Source: Central Selling Organization (CSO).
p Preliminary.

TABLE 4. NATURAL DIAMONDS, WORLD PRODUCTION, BY TYPE AND COUNTRY,[1,2] 1991-95

(000 carats)

Country	1991 Gem[e,3]	1991 Industrial[e]	1991 Total[4]	1992 Gem[e,3]	1992 Industrial[e]	1992 Total[4]
Angola[5]	899	62	961	1 100	80	1 180
Australia	17 978	17 978	35 956	18 078	22 095	40 173
Botswana	11 550	4 950	16 500	11 160	4 790	15 950
Brazil	600	900	1 500[e]	653	665	1 318
Central African Republic	296	82	378	307	107	414
China	200	800	1 000[e]	200	800	1 000[e]
Gabon	400	100	500[e]	400	100	500[e]
Ghana	560	140	700[e]	570	140	710[e]
Namibia	1 170	20	1 190	1 520	30	1 550
Russia	n.a.	n.a.	n.a.	9 000	9 000	18 000
Sierra Leone[6]	160	83	243	180	116	296
South Africa	3 800	4 600	8 400[r]	4 600	5 600	10 200
U.S.S.R.[7]	10 000	10 000	20 000[e]	n.a.	n.a.	n.a.
Venezuela	102[8]	112[8]	214	302[8]	176[8]	478
Zaire	3 000	14 814	17 814	8 934	4 567	13 501
Other	275[r]	116[r]	441[r]	305[r]	218[r]	524[r]
Total	51 000	54 800	106 000	57 300	48 500	106 000

Country	1993 Gem[e,3]	1993 Industrial[e]	1993 Total[4]	1994[e] Gem[e,3]	1994[e] Industrial[e]	1994[e] Total[4]
Angola[5]	130	15	145	270	30	300
Australia	18 844	23 032	41 876	19 485	23 815	43 300
Botswana	10 310	4 420	14 730	10 550[r,8]	5 000	15 550[r,8]
Brazil	600	900	1 500[e]	600	900	1 500
Central African Republic	370	125	495	400[r]	131[r]	531[r]
China	230	850	1 080[e]	230	850	1 080
Gabon	400	100	500[e]	400	100	500
Ghana	570	140	710[e]	580	145	725
Namibia	1 120	20	1 140	1 312[r,8]	–	1 312[r,8]
Russia	8 000	8 000	16 000	8 500	8 500	17 000
Sierra Leone[6]	90	68	158	155	100	255
South Africa	4 600	5 700	10 300	4 340[r]	5 343[r]	9 683[r]
U.S.S.R.[7]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Venezuela	146[r,8]	155[8]	301	203[r,8]	214[r,8]	417[r,8]
Zaire	2 006	13 620	15 626	4 000	13 000	17 000
Other	296[r]	218[r]	513[r]	333[r]	221[r]	554[r]
Total	47 700	57 400[r]	105 000	51 400[r]	58 300[r]	110 000[r]

Country	1995[e] Gem[e,3]	1995[e] Industrial[e]	1995[e] Total[4]
Angola[5]	450	50	500
Australia	18 312	22 381	40 693
Botswana	11 502	5 300	16 802[8]
Brazil	600	900	1 500
Central African Republic	400	130	530
China	230	900	1 130
Gabon	400	100	500
Ghana	580	145	725
Namibia	1 382[8]	–	1 382[8]
Russia	9 000	9 000	18 000
Sierra Leone	113[8]	100	213[8]
South Africa	4 300	5 383	9 683[8]
U.S.S.R.[7]	n.a.	n.a.	n.a.
Venezuela	229[8]	64[8]	293[8]
Zaire	4 000	13 000	17 000
Other	363	246	609
Total	51 900	57 700	110 000

Source: U.S. Geological Survey.
[e] Estimated; n.a. Not applicable; [r] Revised.
[1] Table includes data available through June 21, 1996. [2] World totals are rounded to three significant digits; may not add to totals shown. [3] Includes near-gem and cheap-gem qualities. [4] Total natural diamond output (gem plus industrial) for each country is actually reported, except where indicated to be an estimate. [5] Figures do not include smuggled artisanal production. [6] Figures are estimated based on reported exports and do not include smuggled diamonds. [7] Dissolved in December 1991. [8] Reported figure.

TABLE 5. DIAMONDS, PRINCIPAL CUTTING CENTRES

Country	Type of Diamonds Cut: Near Gems[1]	Type of Diamonds Cut: Gems[2]
MAJOR CENTRES		
Belgium (Antwerp, Kempen)		√
United States (New York)		√
Israel (Ramat Gan, Tel Aviv)		√
India (Bombay, Surat)	√	√
Russia (Smolensk, Moscow)		√
Ukraine		√
INTERMEDIATE CENTRES		
Republic of South Africa		√
Thailand	√	√
China, People's Republic of	√	√
Sri Lanka	√	
MINOR CENTRES		
Armenia	√	√
Australia		√
Botswana		√
Brazil		√
Central African Republic	√	√
Puerto Rico	√	√
Hong Kong	√	√
Taiwan	√	√
South Korea	√	√
Japan		√
Singapore	√	√
Indonesia	√	√
Vietnam	√	
Malaysia	√	
Mauritius	√	

Sources: Natural Resources Canada; De Beers Centenary AG.
√ Minor production; √ Major production.
1 Near gems (technical goods/Indian goods) are rough diamonds valued at approximately US$5-$80/ct. 2 Gems are rough diamonds with a value greater than US$80/ct.
Note: The categories "major, intermediate and minor" are defined by a combination of quantity (ct) and value of the rough diamonds cut.

TABLE 6. RETAIL SALES OF DIAMOND JEWELLERY, 1986-95

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995p
	(US$ millions)									
United States	11.9	13.4	14.1	14.7	13.4	13.0	13.4	14.8	15.6	16.8
Japan	8.5	11.0	14.4	14.2	14.1	15.1	14.5	15.3	15.8	16.9
Europe	4.0	5.4	6.4	7.2	8.2	7.9	8.3	7.1	7.0	7.1
East Asia	1.1	1.4	1.9	2.1	2.1	2.5	3.1	3.3	3.7	3.7
Other	5.5	6.5	7.2	7.5	7.6	7.9	7.8	7.9	8.1	8.1
Total world	31.1	37.7	44.0	45.7	45.4	46.5	47.0	48.3	50.1	52.7

Source: De Beers Consumers Advertising Division Research, unadjusted for inflation.
p Preliminary.

TABLE 7. PRICES OF COLOURLESS DIAMONDS VS. FANCY-COLOURED DIAMONDS

Colourless Diamonds				Price	Fancy-Coloured Diamonds				Price
Carats	Shape	Colour	Clarity	Per Carat	Carats	Shape	Colour	Clarity	Per Carat
				(US$)					(US$)
(C) 5.05	Rectangular	G	IF	13 600	(C) 4.72	Rectangular	Pink	VS1	140 400
(C) 23.25	Pear-shaped	F	IF	33 700	(S) 20.17	Emerald	Blue	VS2	490 952
(S) 11.00	Pear-shaped	D	IF	35 227	(C) 10.64	Circular (round)	Yellow	VS	7 250
(C) 4.13	Pear-shaped	E	IF	18 500	(S) 3.09	Emerald	Blue	VS1	132 524
(C) 30.75	Rectangular	D	IF	79 000	(S) 28.59	Oval	Yellow	VVS1	12 399
(C) 14.13	Rectangular	D	VVS1	32 900	(C) 12.02	Modified rectangular	Light yellow	IF	10 275
(C) 5.46	Rectangular	F	VVS2	15 600	(C) 5.94	Square	Intense yellow	VS1	41 200

Source: The Diamond Registry Bulletin, October 31, 1994, p. 5.
Notes: Sales results from both Sotheby's and Christie's major fall jewellery auctions show that fancy-coloured diamonds commanded substantially higher prices per carat – sometimes more than ten times the price fetched by stones of superior clarity including internally flawless stones or potentially internally flawless stones (if a small impurity can be removed through cutting). A notable exception: light yellow diamonds clearly command a lower price than pinks or blues. Auction houses are represented by (S) for Sotheby's or (C) for Christie's.

TABLE 8. SYNTHETIC DIAMONDS, ESTIMATED WORLD PRODUCTION BY COUNTRY[1,2] 1991-95

Country	1991	1992	1993	1994	1995
			(000 carats)		
Belarus	n.a.	30 000	30 000	25 000	25 000
China	15 000	15 000	15 500	15 500	15 500
Czech Republic	n.a.	n.a.	5 000	5 000	5 000
Czechoslovakia[3]	10 000	10 000	n.a.	n.a.	n.a.
France	4 000	3 500	3 500	3 500	3 000
Germany	n.a.	n.a.	n.a.	n.a.	n.a.
Greece	1 000	750	1 000	1 000[r]	1 000
Ireland	60 000	60 000	65 000[r]	65 000	60 000
Japan	30 000	30 000	32 000	32 000	32 000
Romania	3 000	3 000[r]	5 000	5 000	5 000
Russia	n.a.	80 000	80 000	80 000	80 000
Serbia and Montenegro	n.a.	5 000	5 000[4]	5 000	5 000
Slovakia	n.a.	n.a.	5 000	5 000	5 000
South Africa	60 000	60 000	60 000	60 000	60 000
South Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Sweden	25 000	25 000	25 000	25 000	25 000
Turkey	n.a.	n.a.	n.a.	n.a.	n.a.
U.S.S.R.[5]	120 000	n.a.	n.a.	n.a.	n.a.
Ukraine	n.a.	10 000	10 000	8 000	8 000
United States	90 000	90 000	103 000	104 000	115 000
Yugoslavia[6]	5 000	n.a.	n.a.	n.a.	n.a.
Total	423 000	422 000[r]	445 000[r]	439 000	445 000

Source: U.S. Geological Survey.
n.a. Not applicable; [r] Revised.
[1] Data are rounded to three significant digits; numbers may not add to totals shown. [2] Table includes data available through July 12, 1996. [3] Dissolved December 31, 1992. [4] Reported figure. [5] Dissolved in December 1991. [6] Dissolved in April 1992.