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2019 Minerals Yearbook

DIAMOND, INDUSTRIAL [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

February 2025

Diamond, Industrial

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In 2019, U.S. synthetic diamond production was estimated to be 114 million carats and had an estimated value of $44.5 million. No natural industrial diamond mining took place in the United States, but an estimated 35.8 million carats of used industrial diamond (natural and synthetic) worth about $5.78 million was recycled (secondary production). U.S. imports of natural and synthetic industrial diamond bort, dust and powder, grit, and stone totaled 313 million carats valued at $50.5 million, and exports totaled 114 million carats valued at $56.7 million. The estimated U.S. apparent consumption of natural and synthetic industrial diamond bort, dust and powder, grit, and stone totaled 350 million carats and had an estimated value of $44.1 million. Total industrial diamond output worldwide was estimated by the U.S. Geological Survey (USGS) to be 14.6 billion carats, of which about 58.0 million carats was natural industrial diamond, and the rest was synthetic industrial diamond (table 1).

Diamond is best known as a gemstone, but some of its unique properties make it ideal for many industrial and research applications. Current information on gem-grade diamond can be found in the Gemstones chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Total production and consumption quantities and values in table 1 are estimated based on past and current reported data. Trade data in this chapter are from the U.S. Census Bureau. All percentages in the chapter were calculated using unrounded data.

Production

The USGS conducts an annual survey of domestic synthetic industrial diamond producers and a survey of the U.S. firms that recover diamond wastes. Both of the U.S. synthetic industrial diamond producers responded to the USGS survey, and all three of the leading U.S. firms that recover diamond wastes responded to the USGS survey. The USGS does not conduct surveys of domestic producers of polycrystalline diamond (PCD) or chemical vapor deposition (CVD) diamond for quantity or value of annual production.

During 2019, the United States was one of the world's leading producers of synthetic industrial diamond. The United States accounted for an estimated output of 114 million carats valued at $44.5 million. Only two U.S. companies produced synthetic industrial diamond in 2019—Mypodiamond Inc. (Smithfield, PA) and Hyperion Materials & Technologies, Inc. (Worthington, OH). Hyperion Materials & Technologies, Inc. operated diamond production facilities in Worthington, OH, and Deerfield Beach, FL. By type, primary U.S. production was entirely diamond bort, dust and powder, grit, and micropowder sized materials, for which the value had been decreasing over the past few years.

In 2019, at least four U.S. companies manufactured PCD from synthetic diamond dust and powder and grit. These companies were Dennis Tool Co. (Houston, TX); MegaDiamond, A Schlumberger Company (Provo, UT); Sandvik Coromant—Precorp Inc. (Spanish Fork, UT); and US Synthetic Corp. (Orem, UT).

During 2019, an estimated 35.8 million carats of used industrial diamond (natural and synthetic) worth about $5.78 million (table 1) was recycled (secondary production) in the United States. By type, secondary production was 35.7 million carats of bort, dust and powder, and grit valued at $5.63 million and 100,000 carats of diamond stone valued at $150,000 (table 2). Recycling firms recovered most of this material from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD. The recovery and sale of used industrial diamond was the principal business of two U.S. companies in 2019—International Diamond Services Inc. (Houston, TX) and National Research Co. (Chesterfield, MI). In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

In 1954, scientists at General Electric Co. manufactured the first synthetic bits of diamond grit using a high-pressure, high-temperature (HPHT) method. In 1956, the first commercially available synthetic diamond was produced by HPHT at General Electric. High-quality diamonds of 1 carat or more are difficult to produce consistently, even in the controlled environment of a laboratory using the HPHT method. After more than 60 years of development, several synthetic diamond companies were able to produce relatively large high-quality industrial diamonds that had the same characteristics and properties as mined industrial diamonds, and billions of carats of synthetic diamonds were manufactured annually by the HPHT process, mostly for industrial applications (Linares, 2013).

In 1954, a patent was issued for a diamond growth technique using CVD. The CVD technique transforms carbon into plasma, which is then precipitated onto a substrate as diamond. Initially, the creation of gem-quality CVD synthetic diamond was not possible, but in the mid-1980s, scientists discovered how to reproducibly grow microscopic diamond crystals to cover surfaces using the CVD process (Linares, 2013). In the early 2000s, CVD process technology was further developed enabling the growth of large single, extremely pure diamond crystals. Synthetic diamond producers discovered the temperature, gas composition, and pressure combination that resulted in the growth of a single diamond crystal and were able to produce synthetic stones that ranged from 1 to 2 carats.

No commercial diamond mines operated in the United States in 2019. The Arkansas Department of Parks and Tourism operated a dig-for-fee diamond mine for hobbyists at Crater of Diamonds State Park in Murfreesboro, AR.

Consumption

Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature. Diamond is more than twice as hard as its nearest competitors, cubic boron nitride and silicon nitride. Because of its hardness, diamond has been used for centuries as an abrasive in cutting, drilling, grinding, and polishing. Industrial-grade diamond continues to be used as an abrasive for many applications. Even though it has a higher unit cost than alternative abrasive materials, diamond has proven to be more cost effective in many industrial processes because it cuts faster and lasts longer than alternatives. Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, computing, and other advanced technologies.

Both natural and synthetic diamonds have industrial uses. Synthetic industrial diamond is superior to its natural diamond counterpart because its properties can be tailored to specific applications, and it can be produced in large quantities.

The United States remained one of the world's leading markets for industrial diamond in 2019. According to production estimates and trade data, U.S. apparent consumption of industrial diamond in 2019 decreased by 47% in quantity to an estimated 350 million carats valued at $44.1 million compared with 655 million carats valued at $99.3 million in 2018 (table 1). Apparent consumption was the combination of 20.5 million carats of natural industrial diamond valued at $8.44 million and 329 million carats of synthetic industrial diamond valued at $35.6 million. By type, apparent consumption was the combination of 348 million carats of diamond bort, dust and powder, and grit valued at $37.7 million and 1.71 million carats of diamond stone valued at $6.37 million (table 2). Decreases in U.S. apparent consumption of industrial diamond were due to declines in production or a lack of growth in the industries that used industrial diamond, such as construction, electronics, oil and gas, and transportation (aerospace, automotive, and maritime transport) industries. Industrial diamond was used for cutting, drilling, grinding, and polishing purposes by these industries (Grand View Research, Inc., 2019; Federal Reserve, 2021).

The major consuming industrial sectors of industrial diamond cutting and drilling tools and abrasives in the United States during 2019 were construction, machinery manufacturing, mining services (exploration drilling for minerals, natural gas, and oil), stone cutting and polishing, and transportation systems (infrastructure and vehicles). Within these sectors, highway building and repair and stone cutting, combined, accounted for most of the consumption of industrial diamond. Research and high-technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks in electronic circuits, lenses for laser radiation equipment, polishing of silicon wafers and disk drives, and other applications in the computer industry.

Diamond tools had numerous industrial functions. Diamond drilling bits and reaming shells were used principally for extraction of minerals, natural gas, and oil. Other applications of diamond bits and reaming shells included foundation testing, concrete inspection, and masonry drilling. The primary uses of point diamond tools were for dressing and truing grinding wheels and for boring, cutting, finishing, and machining applications. Beveling glass for automobile windows was another application. Cutting dimension stone and cutting and grooving concrete in highway reconditioning were the main uses of diamond saws; other applications included cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws were used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies were essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels included edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond were used by industry—diamond stone (generally larger than 60 mesh, 250 micrometers) and diamond bort, dust and powder, and grit (smaller, fragmented material). Diamond stone was used mainly in drill bits and reaming shells used by mining companies; it also was incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort was used for drill bits and as a loose grain abrasive for polishing. Other tools that incorporated natural diamond included bearings, engraving points, glass cutters, and surgical instruments.

Synthetic diamond dust and powder and grit were used in diamond grinding wheels, saws, impregnated bits and tools, and as a loose abrasive for polishing. Diamond grinding wheels can be as large as 1 meter in diameter.

Loose powders made with synthetic diamond for polishing were used primarily to finish cutting tools, drill bits, gemstones, jewel bearings, optical surfaces, reaming shells, silicon wafers, and wire-drawing dies for computer chips. Hundreds of other products made from ceramics, glass, metals, and plastics also were finished with diamond powders.

Consumption quantity and value data were not available for PCD or for CVD diamond. Two types of PCDs used by industry were polycrystalline diamond compacts (PDCs) and polycrystalline diamond shapes (PDSs). The use of PDCs and PDSs continued to increase for many of the applications cited above, including some of those that employed natural diamond. PDCs and PDSs were used in the manufacture of single- and multiple-point tools, and PDCs were used in a majority of the diamond wire-drawing dies.

Since the mid-1980s, the use of CVD diamond has seen strong growth and has been increasingly accepted by multiple industries as an enhanced material of choice owing to its properties of exceptional strength, hardness, durability, stiffness, high thermal conductivity, chemical inertness, and electrical isolation.

Early applications for CVD diamond focused largely on thin- and thick-film PCD for cutting tools and dressing applications because of the mechanical properties of diamond. Newer applications that take advantage of CVD diamond's mechanical properties include wear parts, such as watch gears and chemical mechanical polishing pad conditioners. Diamond has tremendous potential for electronics applications because of its high thermal conductivity. It can significantly improve thermal management while remaining highly cost competitive with other materials. CVD diamond was used in microelectronic components, such as high-speed processors, medical devices, wide bandgap radio frequency (RF) devices, power conversion devices, and opto-electronic devices (light-emitting diodes, laser diodes) that generate exceptionally high heat densities requiring innovative approaches to thermal management. Diamond coatings were increasingly being used in these applications because the thermal conductivity of diamond is 10 times that of silicon. Micro-electro-mechanical systems (MEMS), such as RF MEMS resonators, have design needs that can be met using diamond as a base material because of its very high resistance to being deformed elastically when a force is applied and because of its durability in harsh environments. Historically, diamond has been perceived as an expensive material, but advances in CVD diamond manufacturing, such as the development of microwave carbon plasma technology and the development of higher throughput hot filament CVD diamond reactors, have significantly reduced diamond costs and allowed for the use of CVD diamond for an increasing number of applications.

In addition to the existing opportunities for synthetic diamond for use as gemstones, research and development projects by several companies that use single-crystal CVD diamond materials in high-voltage power switches, lasers, quantum communications and computing, and water treatment and purification have been ongoing (Allusesof.com, 2019; WD Lab Grown Diamonds, 2019).

Industrial diamond also was used in medical applications and potential applications such as bionic eye implants, bioimaging, biomarking, cancer treatments, and surgical tools; in dental applications such as cavity treatments; in cosmetic applications such as beauty treatments, facial exfoliation, wrinkle treatments; in glass shaping and window production; in military uses; in sound speakers; in super lasers; and in many other applications (Allusesof.com, 2019).

Prices

Natural and synthetic industrial diamonds had prices with a range of values, depending on their crystallinity, purity, shape, size, and, in the case of synthetic diamond, the absence or presence of metal coatings. During 2019, no diamond stone was produced and the average unit value for diamond bort, dust and powder, and grit material produced was $0.39 per carat (table 2). This was a 15% decrease in value compared with that in 2018. The average unit value for recycled diamond bort, dust and powder, and grit material produced was $0.16 per carat, and the average value for recycled diamond stone material was $1.50 per carat (table 2). These values were unchanged for recycled diamond bort, dust and powder, and grit material and an 11% decrease for recycled diamond stone material compared with those in 2018.

In 2019, U.S. imports of all types of industrial diamond had an average unit value of $0.16 per carat, a 21% increase in unit value compared with that in 2018. These imports were a combination of natural diamond that had an average unit value of $1.42 per carat (a slight increase from that in 2018) and synthetic diamond that had an average unit value of $0.13 per carat (a 14% increase from that in 2018) (table 1). By type, diamond imports were the combination of diamond bort, dust and powder, and grit (natural and synthetic) that had an average unit value of $0.14 per carat (a 17% increase from that in 2018) and diamond stone (natural and synthetic) that had an average unit value of $3.87 per carat (a 35% increase from that in 2018) (table 2). These average unit values for imported diamond bort, dust and powder, grit, and stone (natural and synthetic) were lower than the average reported prices for the same size fractions of domestically produced diamond listed above.

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2019; imports were received from 26 countries or localities, and exports and reexports were sent to 48 countries or localities (tables 3–6). Although the United States has been a major producer of synthetic diamond for decades, expanding domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond have always been dependent on imports and secondary recovery operations because natural industrial diamond was not produced domestically.

During 2019, U.S. imports of industrial-quality diamond stones (natural and synthetic) decreased by 36% from those in 2018 to 1.61 million carats valued at $6.24 million (table 3). Imports of natural diamond bort, dust and powder, and grit were essentially unchanged from those in 2018 at 4.99 million carats valued at $3.43 million. Imports of synthetic diamond bort, dust and powder, and grit decreased by 46% from those in 2018 to 307 million carats valued at $40.8 million (table 4).

Reexports accounted for a significant portion of total exports; therefore, exports and reexports are listed separately in tables 5 and 6 so that U.S. trade and consumption can be calculated more accurately. During 2019, the United States exported less than 500 carats of industrial diamond stone, valued at $13,900. U.S. reexports of industrial diamond stone decreased by 42% from those in 2018 to 490,000 carats valued at $13.3 million and an average unit value of $27.30 per carat (table 5). U.S. exports of industrial diamond bort, dust and powder, and grit (natural and synthetic) decreased by 18% from those in 2018 to 114 million carats valued at $56.7 million and an average unit value of $0.50 per carat. Reexports of industrial diamond bort, dust and powder, and grit (natural and synthetic) decreased by 24% from those in 2018 to 15.7 million carats valued at $5.83 million and an average unit value of $0.37 per carat (table 6). Trade quantity and value data were not available for PCD or CVD diamond.

World Industry Structure

Global natural rough diamond production decreased by 7% in 2019 to 138 million carats from 147 million carats in 2018 (table 7). The world's leading natural rough diamond producers were as follows: Russia, producing 45.3 million carats or 33% of total world production; Botswana, 23.7 million carats (17%); Canada, 18.6 million carats (14%); Congo (Kinshasa), 13.5 million carats (10%); Australia, 13.0 million carats (9%); Angola, 9.15 million carats (7%); South Africa, 7.18 million carats (5%); and other countries, 7.16 million carats (5%). Of the 138 million carats of total natural diamond production, 79.5 million carats (58% of total diamond production) were gemstone diamond, and 58.0 million carats (42% of total diamond production) were industrial diamond (table 7). During 2019, the value of worldwide rough diamond production decreased by 6% to $13.6 billion from the 2018 value of $14.5 billion (Kimberley Process, The, 2019, 2020). Total combined natural and synthetic industrial diamond output worldwide was estimated by the USGS to be about 14.6 billion carats (table 1).

During 2019, ALROSA Group and De Beers Group UK Ltd. remained the two leading diamond producers by quantity and value. ALROSA's production was about 26% of total global quantity and 24% of total global value; De Beers' production was about 21% of total global quantity and 31% of total global value (De Beers Group UK Ltd., 2020a, p. 3).

In 2002, the international rough diamond certification system, the Kimberley Process Certification Scheme (KPCS), was agreed upon by the United Nations (UN) member nations, the diamond industry, and related nongovernmental organizations to prevent the shipment and sale of conflict diamonds. Conflict diamonds are diamonds that originate from areas controlled by forces or factions opposed to legitimate and internationally recognized Governments and are used to fund military action in opposition to those Governments or in contravention of the objectives of the UN Security Council. The KPCS monitors rough diamond trade in both gemstone and industrial diamond. The KPCS includes the following key elements: the use of forgery-resistant certificates and tamper-proof containers for shipments of rough diamonds; internal controls and procedures that provide credible assurance that conflict diamonds do not enter the legitimate diamond market; a certification process for all exports of rough diamonds; the gathering, organizing, and sharing of import and export data on rough diamonds with other participants of relevant production; credible monitoring and oversight of the international certification scheme for rough diamonds; effective enforcement of the provisions of the certification scheme through dissuasive and proportional penalties for violations; self-regulation by the diamond industry that fulfills minimum requirements; and sharing information with all other participants on relevant rules, procedures, and legislation as well as examples of national certificates used to accompany shipments of rough diamonds. India assumed the chair of KPCS from January 1 through December 31, 2019. As of December 31, 2019, the 55 participants represented 81 nations (including the 28 member nations of the European Union counted as a single participant). The participating nations in the KPCS accounted for approximately 99.8% of the global production and trade of rough diamonds in 2019 (Kimberley Process, The, 2021).

In 2019, natural industrial diamond production was reported from 13 countries (table 7). Natural industrial diamond production worldwide was estimated to be about 58.0 million carats, a 7% decrease compared with 62.2 million carats in 2018. Russia, the leading country in the production of natural industrial diamond, produced 19.9 million carats (34% of total world production); followed by Australia, 12.7 million carats (22%); Congo (Kinshasa), 10.8 million carats (19%); Botswana, 7.11 million carats (12%); South Africa, 4.31 million carats (7%); and Zimbabwe, 1.90 million carats (3%). These six countries produced 98% of the world's natural industrial diamond (table 7). Synthetic industrial diamond production worldwide was estimated to be more than 14.6 billion carats, a slight increase compared with that in 2018. China was the leading producing country, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 99% of the world's synthetic industrial diamond.

In 2019, 99% of the total global combined output of natural and synthetic industrial diamond was produced in China, Ireland, Russia, South Africa, and the United States. Synthetic diamond accounted for more than 99% of global diamond production and consumption.

The global nonferrous mineral exploration budget decreased by 3% to an estimated $9.8 billion in 2019 from $10.1 billion in 2018 (S&P Global Market Intelligence, 2020). The global diamond exploration budget was about 3% of the global nonferrous mineral exploration budget. The success rate in diamond exploration has been estimated to be less than 1% and no major new deposits have been discovered in more than 20 years (Kumar, 2019; Petra Diamonds Ltd., undated).

World Review

Australia.—Rough diamond production in Australia was 13.0 million carats in 2019, an 8% decrease compared with 14.1 million in 2018, accounting for 9% of total global production. Australia's diamond production was valued at $159 million, a 12% decrease compared with that in 2018 (Kimberley Process, The, 2019, 2020).

The Argyle diamond mine, located in the State of Western Australia, recovered a large, white octahedral-shaped 28.84-carat diamond in March 2019. The Argyle Mine was scheduled to close in 2020 (ABC News, 2019).

Botswana.—Rough diamond production in Botswana was 23.7 million carats in 2019, a slight decrease compared with the revised 24.5 million in 2018, accounting for 17% of total global production. Production was valued at $3.43 billion, a slight decrease compared with that in 2018 (Kimberley Process, The, 2019, 2020).

The Karowe Diamond Mine, owned by Lucara Diamond Corp., announced the recovery of a 1,758-carat diamond in April 2019. The diamond was of "variable quality" and larger than a tennis ball. The Karowe Diamond Mine had previously produced more than 12 diamonds larger than 300 carats (ABC News, 2019).

The Jwaneng diamond mine in the Kalahari Desert of south-central Botswana was wholly owned by Debswana Diamond Co. (Pty.) Ltd., which is a 50–50 joint venture between the Government of the Republic of Botswana and De Beers Group. The company was planning the Cut-9 expansion project to extend the mine life to 2035 and was expected to extract an additional 53 million carats of rough diamonds from 44 million metric tons of ore (De Beers Group UK Ltd., 2019a).

Canada.—Canada was the world's third-largest producer of rough diamond by both quantity and value in 2019. Canadian rough diamond production was 18.6 million carats, a 20% decrease compared with that in 2018, accounting for 14% of total global production (table 7). Rough diamond production in

Canada was valued at $1.70 billion, a decrease of 19% compared with that in 2018 (Kimberley Process, The, 2019, 2020).

The Diavik Diamond Mine in the Northwest Territories was jointly owned by Rio Tinto Group (60%) and Dominion Diamond Corp. (40%). In 2019, Diavik was Canada's largest diamond mine in terms of quantity of diamond production. The mine plan was built on four diamond-bearing kimberlite pipes. The four kimberlite pipes that were being mined in 2019, A21, A154 South, A154 North, and A418, are very high grade. Diavik began an expansion project of the A21 kimberlite pipe pit during 2016 that was in development during 2017 and 2018. The first kimberlite ore from the A21 kimberlite pipe was delivered in March 2018 and the pit reached full production level during the fourth quarter of 2018. The expansion project was done to extend the Diavik Diamond Mine's life by 2 years from 2023 to 2025 (Lazenby, 2018; Dominion Diamond Mines ULC, 2020; Rio Tinto Group, 2020).

The Ekati Diamond Mine, which opened in 1998, was Canada's first operating commercial surface and underground diamond mine, located at Lac de Gras, Northwest Territories. Dominion Diamond ULC had an 80% controlling interest in the Ekati Diamond Mine. Underground operations at the mine's Koala kimberlite pipe were ended and final reclamation was initiated and completed in February 2019. Ekati's mining of other pipes on the property continued throughout 2019. During 2019, Ekati updated the life of mine plan to include the Point Lake project development and mining and the Jay kimberlite pipe development and mining. Dominion applied to continue its diamond exploration of the Lac de Gras and Glowworn Lake regions (Dominion Diamond Mines ULC, 2019).

The Gahcho Kué Mine in the Northwest Territories commenced commercial production in March 2017 and continued diamond production throughout 2018 and 2019. The Gahcho Kué Mine is an open pit operation, mining three kimberlite pipes: 5034, Hearne, and Tuzo. The mine, with an estimated mine life of 12 years, was jointly owned by De Beers Canada, Inc. (51%) and Mountain Province Diamonds Inc. (49%). The mine owners anticipated average annual diamond production of 4.5 million carats (Diamond Loupe, The, 2018; De Beers Group UK Ltd., 2020b).

The Renard Mine was Quebec's first diamond mine and was wholly owned by Stornoway Diamond Corp. The Renard Mine reached commercial production levels in January 2017. Stornoway announced in September 2018 that it had completed rampup of its planned sustainable underground mine production. The Renard Mine continued diamond production throughout 2019. The mine had a 14-year mine life and an average annual diamond production of 1.6 million carats (Mining Technology, 2018; Stornoway Diamond Corp., 2019).

The Victor Mine was Ontario's first diamond mine. It reached commercial production in 2008. The mine completed mining operations in March 2019, and processing of ore ended in June 2019. The mine was in the formal closure and rehabilitation phase in 2019 (De Beers Group UK Ltd., undated).

Lesotho.—Rough diamond production in Lesotho was 1.11 million carats in 2019, a 14% decrease from that in 2018, but accounted for less than 1% of total global production. Diamond production in Lesotho had a value of $290 million, a 23% decrease compared with that in 2018 (Kimberley Process, The, 2019, 2020).

The Liqhobong Diamond Mine in the Maluti Mountains of northern Lesotho began ramping up production in late 2016 and had its first full year of commercial production in 2018. During 2019, the Liqhobong Diamond Mine produced 3.7 million metric tons of ore with a grade of 22.6 carats per 100 metric tons, from which 829,000 carats of diamond were recovered. In June 2019, the Liqhobong Mine was estimated to contain probable reserves of 25.2 million metric tons with a grade of 22 carats per 100 metric tons, containing 5.623 million carats of diamond. The combined indicated and inferred resources were estimated to be 73.3 million metric tons with a grade of 28 carats per 100 metric tons, containing 20.2 million carats of diamond. The mine was owned by Firestone Diamonds plc (75%) and the Government of Lesotho (25%) (Firestone Diamonds plc, 2018; Mining Technology, 2021).

Russia.—Rough diamond production in Russia was 45.3 million carats in 2019, a 5% increase compared with that in 2018, accounting for 33% of total global production. Diamond production in Russia was valued at $4.12 billion, a 3% increase compared with that in 2018 (Kimberley Process, The, 2019, 2020). Five of the ten largest diamond mines in the world that have reserves containing more than one billion carats of diamond were in Russia. These 10 mines did not include alluvial diamond mining projects (Mining Technology, 2019).

ALROSA officially commissioned and mining was started at the Verkhne-Munskoe diamond field in Yakutiya Republic near the end of 2018. ALROSA estimated that the deposit would yield 1.8 million carats of rough diamonds per year and the estimated reserves of the Verkhne-Munskoe Diamond Field were sufficient to operate for more than 20 years. The development of the Verkhne-Munskoe diamond deposit was ALROSA's largest investment project. The first four kimberlite pipes being developed were Deimos, Komsomolskaya-Magnitnaya, Novinka, and Zapolyarnaya . Open pit mining at the Komsomolsky-Magnitnaya Mine was finished in 2019 (ALROSA Group, 2018, 2021).

South Africa.—Rough diamond production in South Africa was 7.18 million carats in 2019, a 28% decrease compared with that in 2018, accounting for 5% of total global production. Production in South Africa was valued at $873 million, a 29% decrease compared with that in 2018 (Kimberley Process, The, 2019, 2020).

De Beers Group operated the Venetia Mine in Limpopo Province, where it was conducting a $2 billion project to take the mine underground and extend its operating life into the 2040s (De Beers Group UK Ltd., 2018).

Outlook

China is expected to remain the world's leading producer of synthetic industrial diamond. The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and likely will remain a significant producer and exporter of synthetic industrial diamond as well. U.S. industrial diamond production and apparent consumption are expected to continue increasing as manufacturing sectors that use industrial diamond continue experiencing economic growth. U.S. demand for industrial diamond is likely to continue in the construction sector as the United States continues building and repairing the Nation's highway system.

Global rough diamond production decreased by 7% in 2019 from that in 2018 owing to mine closures and lower output as mines approach the ends of their mine life. The world's largest diamond mines have matured and are past their peak production levels. The Argyle Mine in Australia and Diavik Mine in Canada are expected to close by the end of 2025. As these mines are depleted, global production is expected to continue to decline in quantity. The global supply of natural diamond is forecasted to steadily decrease to about 120 million carats per year by 2030 (De Beers Group UK Ltd., 2019b, p. 7; Petra Diamonds Ltd., undated).

PCD for abrasive tools and wear parts is likely to continue to replace competing materials in many industrial applications by providing closer tolerances as well as extending tool life. For example, PDCs and PDSs will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries.

CVD technology can produce extremely pure diamond crystals that have great potential in computer technology in the production of diamond computer chips when their cost becomes competitive. These diamond computer chips work at a much higher frequency and faster speed and can be placed in higher temperature environments than the silicon chips currently used in computers. Eventually, diamond computer chips may replace silicon chips in computers. CVD diamond annealed using the low-pressure, high-temperature microwave plasma process may have applications in high-pressure research, optical applications that take advantage of the outstanding transparency of diamond, and in quantum computing to store quantum information in vacancy centers in the diamond's crystal lattice.

CVD diamond is likely to be used to provide a better and more efficient alternative process to existing water purification processes. This technology will use single-crystal diamond electrodes for electrochemical water purification.

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. Diamond stones for these applications have not yet been manufactured economically. New mines and more producers selling in the rough diamond market will maintain ample supplies in the short term and competition introduced by the additional sources also may temper price increases.

Demand for synthetic diamond bort, dust and powder, and grit is expected to remain greater than for natural diamond material. Constant-dollar prices of synthetic diamond products are likely to continue to decline as production technology becomes more cost effective. The decline is even more likely if competition from low-cost producers in China and Russia continues to increase.

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TABLE 1
SALIENT NATURAL AND SYNTHETIC INDUSTRIAL DIAMOND STATISTICS, BY TYPE[1]

(Thousand carats and thousand dollars)

	2015	2016	2017	2018	2019
United States:					
Natural:					
Secondary production:[e]					
Quantity	31,700	33,000	5,600	16,200	17,800
Value	1,710	1,770	932	2,580	2,810
Exports:					
Quantity	6,050	4,710	6,710	1,750 r	3,880
Value	4,710	3,790	4,410	1,960 r	3,640
Imports for consumption:					
Quantity	6,580	4,930	6,370	6,810 r	6,520
Value	25,100 r	20,400	18,400	9,630 r	9,270
Synthetic:					
Primary production:[e]					
Quantity	119,000	125,000	129,000	184,000	114,000
Value	117,000	123,000	129,000	84,500	44,500
Secondary production:[e]					
Quantity	31,900	33,400	6,000	16,400	17,900
Value	2,170	2,310	1,790	2,800	2,960
Exports:					
Quantity	133,000	129,000	155,000	137,000 r	110,000
Value	62,800	60,000	68,700	65,300 r	53,100
Imports for consumption:					
Quantity	270,000	213,000	357,000	570,000 r	307,000
Value	52,500	47,500	54,700	67,100 r	41,200
Apparent consumption, natural and synthetic:[e, 2]					
Quantity	319,000	275,000	342,000	655,000 r	350,000
Value	131,000	131,000	131,000 r	99,300 r	44,100
World, production:[e]					
Natural	59,700 r	58,000 r	67,000	62,200	58,000
Synthetic	15,500,000	14,300,000	14,600,000	14,600,000	14,600,000
Total	15,500,000	14,300,000	14,700,000	14,700,000	14,600,000

[e]Estimated. [r]Revised.
[1]Table includes data available through November 3, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Domestic primary and secondary production plus imports minus exports.

TABLE 2
SALIENT U.S. INDUSTRIAL DIAMOND STATISTICS, BY SIZE FRACTION[1]

(Thousand carats and thousand dollars)

	2015	2016	2017	2018	2019
Bort, dust and powder, grit:					
Primary production:[e]					
Quantity	39,600	41,600	41,200	184,000	114,000
Value	20,800	21,900	22,600	84,500	44,500
Secondary production:[e]					
Quantity	63,500	66,100	11,200	32,500	35,700
Value	3,410	3,530	1,860	5,160	5,630
Exports:					
Quantity	140,000	134,000	161,000	139,000 r	114,000
Value	67,500	63,800	73,200	67,200 r	56,700
Imports for consumption:					
Quantity	275,000	216,000	362,000	574,000 r	312,000
Value	54,700	49,200	57,400	69,500 r	44,200
Apparent consumption:[2]					
Quantity	239,000	190,000	253,000	652,000 r	348,000
Value	11,400	10,900	8,610	91,900 r	37,700
Stone:					
Primary production:[e]					
Quantity	79,200	83,200	87,400	--	--
Value	96,300	101,000	106,000	--	--
Secondary production:[e]					
Quantity	185	360	392	130	100
Value	463	544	856	218	150
Exports:					
Quantity	--	--	--	--	(3)
Value	--	--	--	--	14
Imports for consumption:					
Quantity	1,310	1,370	1,230	2,520 r	1,610
Value	22,900	18,700	15,800	7,220 r	6,240
Apparent consumption:[2]					
Quantity	80,700	84,900	89,000	2,650 r	1,710
Value	120,000	120,000	123,000	7,430	6,370

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through November 3, 2020. Data are rounded to no more than three significant digits.
[2]Defined as primary and secondary production plus imports minus domestic exports.
[3]Less than ½ unit.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY OR LOCALITY[1]

(Thousand carats and thousand dollars)

	Natural industrial diamond stones[2]				Miners' carbonados and other industrial diamond, natural and synthetic[3]			
	2018		2019		2018		2019	
Country or locality	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]
Angola	395 r	5	--	--	--	--	--	--
Australia	57	514	77	254	11	99	29	162
Botswana	12	1,010	48	1,120	256 r	21	2	129
Canada	11	570	11	456	--	--	54	24
Congo (Kinshasa)	21	145 r	297	19	646 r	75 r	--	--
India	310 r	316 r	199	316	2	200	25	338
Namibia	5	19	15	53	--	--	4	17
Russia	99	74	233	258	--	--	--	--
Sierra Leone	20	12	114	5	281 r	19	58	5
South Africa	241	3,970	420	2,940	151	146	2	115
United Kingdom	--	--	22	11	--	--	--	--
Other	-- r	-- r	1	18	1 r	26 r	--	--
Total	1,170 r	6,630 r	1,440	5,450	1,350 r	586 r	174	790

rRevised. -- Zero.

[1]Table includes data available through June 4, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000 for natural industrial diamond stone.

[3]HTS codes 7102.21.1010 and 7102.21.1020 for miners' carbonados and other industrial diamond, natural and synthetic.

[4]Customs value.

Source: U.S. Census Bureau.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF DIAMOND BORT, DUST AND POWDER, AND GRIT, BY COUNTRY OR LOCALITY[1]

(Thousand carats and thousand dollars)

	Natural[2]				Synthetic[3]			
	2018		2019		2018		2019	
Country or locality	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]
Australia	--	--	58	40	211	163	87	55
Austria	--	--	--	--	25	15	34	11
Belgium	26	20	--	--	636	199	369	131
Canada	--	--	--	--	--	--	18	30
China	600	307	313	152	492,000 r	43,200 r	248,000	23,400
Finland	--	--	--	--	98	60	41	59
Germany	60	15	41	12	1,030	156	524	116
Hong Kong	2	4	--	--	622 r	190 r	3,750	122
India	2,780 r	1,430	2,550	1,150	917 r	226 r	70	33
Ireland	--	--	18	13	28,400	9,810	17,500	6,230
Israel	51	85	--	--	34	9	124	44
Japan	14	6	20	9	795	674	760	802
Korea, Republic of	155	55	--	--	23,100	6,330	20,400	5,180
Mexico	62	41	3	5	--	--	--	--
Romania	--	--	21	35	3,410 r	1,460 r	946	553
Russia	243	118	--	--	14,700	2,210	9,220	1,520
South Africa	73	49	89	42	21	14	5	4
Switzerland	251	124	389	295	1,630 r	1,440 r	2,750	1,720
United Kingdom	637	424	1,480	1,660	1,060 r	480 r	1,880	707
Other	18 r	32 r	10	16	191 r	114 r	72	45
Total	4,970	2,710	4,990	3,430	569,000 r	66,800 r	307,000	40,800

rRevised. -- Zero.

[1]Table includes data available through June 4, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States (HTS) codes 7105.10.0011 and 7105.10.0015 for natural diamond.

[3]HTS codes of the United States codes 7105.10.0020, 7105.10.0030, and 7105.10.0050 for synthetic diamond.

[4]Customs value.

Source: U.S. Census Bureau.

TABLE 5

U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL UNWORKED DIAMOND STONES, BY COUNTRY OR LOCALITY[1, 2]

(Thousand carats and thousand dollars)

Country or locality	2018 Quantity	2018 Value[3]	2019 Quantity	2019 Value[3]
Exports, Canada	--	--	(4)	14
Reexports:				
Belgium	92	3,900	73	1,660
Canada	86 r	860 r	94	620
Germany	4	217	3	152
Hong Kong	10	205	2	43
India	6	5	--	--
Indonesia	7	31	3	14
Ireland	--	--	20	57
Israel	--	--	130	53
Japan	87 r	5,650 r	99	6,800
Korea, Republic of	12	731	10	692
Mexico	6	119	7	139
Taiwan	20	403	16	553
Thailand	1	58	1	30
United Arab Emirates	--	--	2	1,700
United Kingdom	522	1,360	21	766
Other	-- r	-- r	9	75
Total	851 r	13,500 r	490	13,300
Grand total	851	13,500 r	490	13,400

[r]Revised. -- Zero.

[1]Table includes data available through June 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States code 7102.21.0000.

[3]Free alongside ship value.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6

U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND BORT, DUST AND POWDER, AND GRIT, BY COUNTRY OR LOCALITY[1, 2]

(Thousand carats and thousand dollars)

	Natural				Synthetic			
	2018		2019		2018		2019	
Country or locality	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Exports:								
Austria	--	--	--	--	3,260	841	6,900	2,220
Belgium	108 [r]	242 [r]	--	--	58 [r]	10 [r]	35	7
Brazil	-- [r]	-- [r]	--	--	1,260 [r]	481 [r]	1,300	451
Canada	767 [r]	532 [r]	1,490	994	4,700 [r]	2,630 [r]	4,110	2,960
China	2 [r]	5 [r]	55	37	15,500 [r]	9,830 [r]	13,700	6,360
Germany	22	20	18	16	7,710 [r]	1,520 [r]	3,270	843
India	--	--	21	46	2,790	937 [r]	2,260	818
Indonesia	--	--	--	--	447	116	320	75
Israel	116 [r]	51 [r]	187	179	1,980 [r]	799 [r]	2,050	829
Italy	49	49	16	46	1,060	316	1,050	328
Japan	-- [r]	-- [r]	161	80	41,300 [r]	20,700 [r]	25,200	11,900
Korea, Republic of	96	21	404	86	19,400 [r]	7,570 [r]	10,800	4,730
Mauritius	--	--	--	--	298	437	185	203
Mexico	99 [r]	138 [r]	117	149	566 [r]	168 [r]	1,000	350
Netherlands	11	26	8	20	17,400	6,570	3,530	1,220
Philippines	--	--	--	--	217	67	142	46
Singapore	--	--	2	3	1,660 [r]	3,550 [r]	1,680	3,590
South Africa	--	--	--	--	536	380	57	32
Switzerland	147	67	324	105	3,700 [r]	2,980	6,710	5,740
Taiwan	-- [r]	-- [r]	--	--	6,300	3,050	8,070	3,810
Thailand	2 [r]	6 [r]	--	--	3,600 [r]	1,200 [r]	2,870	1,030
Turkey	--	--	--	--	585	204	1,460	412
United Kingdom	130 [r]	272 [r]	386	452	1,520 [r]	452 [r]	1,830	559
Vietnam	--	--	--	--	140	41	122	31
Other	203 [r]	534	691	1,420	916 [r]	468 [r]	11,300	4,490
Total	1,750 [r]	1,960 [r]	3,880	3,630	137,000 [r]	65,300 [r]	110,000	53,100
Reexports:								
Belgium	44	32	--	--	21	7	19	3
Canada	927 [r]	574 [r]	334	229	6,180 [r]	2,810 [r]	6,270	2,480
China	49	10	6	15	2,160	581	1,040	267
Germany	--	--	--	--	293	66	693	175
Israel	15	6	--	--	22	4	6	7
Japan	155	331	166	322	8,220	2,180 [r]	5,200	1,300
Korea, Republic of	--	--	--	--	1,220	555	1,260	674
Mexico	31	30	11	10	443	130	458	126
Peru	--	--	--	--	267	76	--	--
Singapore	--	--	--	--	2	5	--	--
Thailand	2	5	4	17	80	103	82	125
United Kingdom	5	5	--	--	139	29	40	15
Other	7 [r]	6	3	7	269 [r]	124 [r]	72	61
Total	1,230 [r]	999 [r]	524	600	19,300 [r]	6,660 [r]	15,100	5,230
Grand total	2,990 [r]	2,960 [r]	4,410	4,230	156,000 [r]	71,900 [r]	125,000	58,300

[r]Revised. -- Zero.

[1]Table includes data available through June 11, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States codes 7105.10.0010 for natural and 7105.10.0025 for synthetic.

[3]Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 7

DIAMOND (NATURAL): WORLD PRODUCTION, BY COUNTRY OR LOCALITY AND TYPE[1]

(Thousand carats)

Country or locality and type[2]	2015	2016	2017	2018	2019
Gemstones:					
Angola[e, 3]	8,110	8,120	8,490	7,570	8,230
Australia[e, 4]	271	279	343	281	260
Botswana[e, 5]	14,600 r	14,700 r	16,000 r	17,200 r	16,600
Brazil, unspecified[6]	32	184	255	251	166
Cameroon, unspecified[7]	2	1	2	2	2
Canada, unspecified	11,677	13,036	23,234	23,194	18,638
Central African Republic[8]	--	9 e	38 e	11 e	21 e
China, unspecified	150 e	127 e	230	99	51
Congo (Brazzaville)	40	12	47	48	3
Congo (Kinshasa)[e, 9]	3,190	3,160	3,800	3,030	2,670
Côte d’Ivoire, unspecified	15	20	7	6	4
Ghana, unspecified	174	142	82	54	38
Guinea[e, 10]	134	90	145	234	183
Guyana, unspecified	118	140	52	62	55
India[11]	9 e	9	11	11 e	17 e
Lesotho, unspecified	304	342	1,126	1,294	1,114
Liberia[12]	41	38	43 e	48 e	33 e
Namibia, unspecified	2,053	1,718	1,948	2,397	2,018
Russia[e, 13]	23,500	22,600	23,900	24,200	25,400
Sierra Leone[e, 10]	400	439	231	593	649
South Africa[e, 14, 15]	3,290	3,320	3,880	3,960 r	5,740
Tanzania[e, 16]	184	205	259	328	313
Togo, unspecified	--	--	(17)	--	(17)
Zimbabwe[e, 18]	349	210	251	326	211
Total	68,600 r	68,900 r	84,400 r	85,200 r	82,400
Industrial:					
Angola[e, 3]	902	902	944	841	915
Australia[e, 4]	13,300	13,700	16,800	13,800	12,700
Botswana[5]	6,220 r, e	6,250 r, e	6,900 r, e	7,300 r, e	7,110
Central African Republic[8]	--	2 e	10 e	3 e	6 e
Congo (Kinshasa)[e, 9]	12,600	12,400	15,300	12,100	10,800
Guinea[e, 10]	33	23	36	59	46
India[e, 11]	25	24	30	29	45
Liberia[12]	27	25	29 e	32 e	22 e
Russia[e, 13]	18,400	17,700	18,800	19,000	19,900
Sierra Leone[e, 10]	100	110	58	148	162
South Africa[e, 14, 15]	4,940	4,980	5,820	5,950 r	1,440
Tanzania[e, 16]	33	36	46	58	104
Zimbabwe[e, 18]	3,140	1,890	2,260	2,930	1,900
Total	59,700 r	58,000 r	67,000	62,200 r	55,200
Grand total	128,000	127,000	151,000	147,000	138,000

See footnotes at end of table.

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through August 20, 2020. All data are reported unless otherwise noted. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]In addition to the countries and (or) localities listed, Belarus, Germany, Ireland, the Republic of Korea, Nigeria, and Sweden may have produced natural diamond, but available information was inadequate to make reliable estimates of output.

[3]About 90% gem quality and 10% industrial quality.

[4]About 2% gem quality and 98% industrial quality.

[5]About 70% gem and near-gem quality and 30% industrial quality.

[6]Private sector and artisanal mining. Includes near-gem and cheap-gem qualities.

[7]From artisanal mining.

[8]About 79% gem quality and 21% industrial quality.

[9]About 20% gem quality and 80% industrial quality; the majority of production is from artisanal mining.

[10]About 80% gem quality and 20% industrial quality.

[11]About 27% gem quality and 73% industrial quality.

[12]About 60% gem quality and 40% industrial quality.

[13]About 56% gem quality and 44% industrial quality.

[14]Includes artisanal mining.

[15]About 40% gem quality and 60% industrial quality.

[16]About 85% gem quality and 15% industrial quality.

[17]Less than ½ unit.

[18]About 10% gem quality and 90% industrial quality.