science for a changing world

2018 Minerals Yearbook

GRAPHITE [ADVANCE RELEASE]

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

May 2023

Graphite

By Donald W. Olson

Domestic survey data and tables were prepared by Chanda C. Williams, statistical assistant.

In 2018, no domestic production of natural graphite was reported, but U.S. production of synthetic (or manufactured) graphite was 219,000 metric tons (t) valued at $1.17 billion. U.S. exports and imports of natural graphite were 10,400 t and 70,700 t, respectively. U.S. exports and imports of synthetic graphite were 51,400 t and 129,000 t, respectively. U.S. apparent consumption of natural and synthetic graphite was 60,300 t and 297,000 t, respectively. World production of natural graphite was estimated to be 1.12 million metric tons (Mt) (tables 1, 9).

Graphite is one of five forms of crystalline carbon; the other forms are carbon nanotubes, diamonds, fullerenes, and graphene. In graphite, the carbon atoms are densely arranged in parallel-stacked, planar honeycomb-lattice sheets. When the graphite structure is a one-atom-thick planar sheet, it is called graphene. Graphite is used to produce graphene, which is extremely light and strong. Graphite is gray to black in color, opaque, and usually has a metallic luster, although it sometimes exhibits a dull earthy luster. Graphite occurs naturally in metamorphic rocks. It is a soft mineral with a Mohs hardness of 1 to 2, and it exhibits perfect basal (one-plane) cleavage. Graphite is flexible but not elastic, has a melting point of 3,927 degrees Celsius (°C), is highly refractory, and has a low specific gravity. Graphite is the most electrically and thermally conductive of the nonmetals and is chemically inert. These properties make both natural and synthetic graphite desirable for many industrial applications.

Natural graphite is classified into three types—amorphous, flake or crystalline flake, and vein or lump. Amorphous graphite is the lowest quality and most abundant. Amorphous refers to its very small crystal size and not to a lack of crystal structure. Amorphous graphite is used for lower value graphite products and is the lowest priced graphite. Large amorphous graphite deposits are found in Europe, China, Mexico, and the United States. The flake or crystalline form of graphite consists of many graphene sheets stacked together. Flake or crystalline flake graphite is less common and higher quality than amorphous graphite. Flake graphite occurs as separate flakes that crystallized in metamorphic rock, and high-quality flake graphite can be four times the price of amorphous graphite. Good quality flakes can be processed into expandable graphite for many uses, including flame retardants. The largest deposits are found in Austria, Brazil, Canada, China, Germany, Madagascar, Mozambique, Tanzania, and the United States. Vein or lump graphite is the rarest, most valuable, and highest quality type of natural graphite. It occurs in veins along intrusive contacts in solid lumps and is only commercially mined in Sri Lanka.

Natural graphite is mined from open pits and underground mines. Production from open pit operations is preferred because it is less expensive where the overburden can be removed economically. Mines in Madagascar are mostly open pit. In Mexico, the Republic of Korea, and Sri Lanka, where the deposits are deep, underground mines are required.

Beneficiation processes for graphite may vary from complex four-stage flotation at mills in Europe and the United States to simple hand sorting and screening of high-grade ore at operations in Sri Lanka. Certain soft graphite ores, such as those found in Madagascar, need no primary crushing and grinding. Typically, such ores contain the highest proportion of coarse flakes. Ore is sluiced to the field washing plant, where it undergoes desliming to remove the clay fraction and is subjected to a rough flotation to produce a concentrate with 60% to 70% carbon. This concentrate is transported to the refining mill for further grinding and flotation to reach 85% carbon and is then screened to produce a variety of products marketed as flake graphite that contain 85% to 90% carbon.

Production

The U.S. Geological Survey (USGS) obtained the production data in this report through a voluntary survey of U.S. synthetic graphite producers. Data were estimated for nonrespondents based on responses received in previous years, industry production trends, reports from other industry sources, and discussions with consultants within the graphite industry.

No natural graphite was mined in the United States in 2018, but 219,000 t of synthetic graphite with a value of $1.17 billion was produced and shipped (tables 1, 3). This was a 3% decrease in quantity produced but a 62% increase in value compared with that of the previous year. This value increase was due to a very large increase in the unit value of high modulus graphite fibers.

Synthetic graphite electrodes used to conduct electricity to melt scrap iron and steel or direct-reduced iron in electric arc furnaces are made from petroleum coke mixed with coal tar pitch. The mixture is extruded and shaped, then baked to carbonize the pitch, and finally graphitized by heating to temperatures approaching 3,000 °C to convert the carbon to graphite. Synthetic graphite powder is made by heating powdered petroleum coke above the temperature of graphitization (3,000 °C), sometimes with minor modifications (Kopeliovich, 2013).

Exploration and Development

During 2018, two companies were developing and evaluating graphite deposit projects in the United States. Westwater Resources, Inc. (Centennial, CO) was developing the Coosa Graphite project in Alabama, and Graphite One Resources Inc. (Vancouver, British Columbia, Canada) was developing the Graphite Creek project in Alaska (Graphite One Resources Inc., 2020a; Westwater Resources, Inc., 2020a, b). Westwater Resources completed the acquisition of Alabama Graphite Corp., which was the previous owner of the Bama Mine and

Coosa Graphite projects, in April 2018 (Westwater Resources, Inc., 2018a). The Bama Mine project and the Coosa Graphite project were within the geologic trend of high-quality graphite deposits called the Alabama Graphite Belt from which significant quantities of graphite were produced from the late 1800s through the 1950s (Westwater Resources, Inc., 2020a).

During 2018, Westwater Resources continued exploring, evaluating, and developing its Bama Mine project, which Alabama Graphite Corp. had purchased in September 2014. The Bama Mine project encompassed more than 520 hectares (ha) (1,300 acres) in Chilton County, AL. The project included the Bama Mine, the southernmost mine in the Alabama Graphite Belt, which had previously produced larger quantities and higher quality flake graphite than any other graphite mine in Alabama before it stopped production in the 1930s because a fire destroyed the mill. In the area of the Bama Mine, widespread occurrence of weathered graphitic schist is found at the surface. The Bama Mine project site had established power, rail, road, and water infrastructure, and was located 14 kilometers (km) [9 miles (mi)] from an interstate highway and less than 1.5 km (1 mi) from a major railroad (Westwater Resources, Inc., 2020a). During 2018, Westwater Resources also continued exploring and developing its 100%-owned Coosa Graphite project in Coosa County, AL. The Coosa Graphite project consisted of 17,000 ha (42,000 acres) in an area that had been a significant producer of high-grade crystal flake graphite in the past. In November 2015, Alabama Graphite released the project's completed preliminary economic assessment (PEA) based on exploration drilling and test work (Spizziri, 2015). Alabama Graphite evaluated the deposit and reported an indicated resource of 71.2 Mt grading 2.39% graphite and an inferred resource of 72.1 Mt grading 2.56% graphite (Westwater Resources, Inc., 2020b).

During 2018, Graphite One was delineating, evaluating, and developing a massive, near-surface deposit at its Graphite Creek project, which included 165 mineral claims in a known graphite mineralization region of 7,317 ha on the Seward Peninsula in western Alaska, about 55 km (37 mi) north of Nome. The Graphite Creek deposit consists of large-flake, high-grade graphite. In July 2017, Graphite One released the project's completed PEA based on exploration drilling and test work. The report included an economic analysis of the viability of the Graphite Creek project's mineral resources, including its inferred resources. An estimated 44 Mt of graphite mineralization at 7% graphitic carbon (Cg) would be available for mining, would process at a recovery rate of 80% Cg, and would support a project life of 40 years producing 60,000 metric tons per year (t/yr) of graphite concentrate at 95% Cg. Full production level would be reached in 6 years. The manufacturing plant was expected to convert 60,000 t/yr of concentrate into 41,850 t/yr of coated spherical graphite (CSG) and 13,500 t/yr of purified graphite powders. Graphite One assumed selling prices of $6,200 per metric ton for CSG and $1,500 per metric ton for purified graphite powders, which were expected to generate estimated annual sales of $280 million and annual post-tax earnings of $118 million or $2,130 per metric ton (Graphite One Resources Inc., 2020b, d).

The PEAs of Graphite One and Westwater Resources included product manufacturing plants that were expected to produce CSG and purified micronized graphite (PMG). CSG is used in lithium-ion batteries. PMG is used as a conductivity enhancement material for a variety of battery applications. Westwater Resources had tested their process, which produced PMG material suitable for use in battery manufacturing (Westwater Resources, Inc., 2018b, 2019; Graphite One Resources Inc., 2020b, c).

Consumption

The USGS obtained the consumption data in this report through a survey of companies that import and use natural graphite in the United States. Data were estimated for nonrespondents based on responses received in previous years, industry consumption trends, reports from other industry sources, and discussions with consultants within the graphite industry. This end-use survey represented the majority of the graphite industry in the United States.

U.S. apparent consumption of natural graphite increased by 59% to 60,300 t in 2018 from 38,000 t in 2017, whereas U.S. apparent consumption of synthetic graphite was essentially unchanged at 297,000 t in 2018 from the revised 296,000 t in 2017. Total U.S. graphite consumption (both natural and synthetic) increased by 7% to 357,000 t in 2018 from 334,000 t in 2017 (table 1).

U.S. consumption of natural graphite reported by end use increased by 30% to 51,800 t in 2018 from that in 2017 (table 2). The reported natural graphite consumption data in table 2 include a small amount of mixed natural and synthetic graphite in the amorphous graphite category. Apparent consumption in table 1 does not include unreported changes in company stocks and therefore differs from reported consumption in table 2. Reported consumption of crystalline graphite increased by 17% in 2018 to 23,100 t from 19,800 t in 2017. Consumption of amorphous graphite increased by 43% in 2018 to 28,700 t from 20,100 t in 2017. The main uses of graphite during 2018 were batteries; brake linings; carbon products, such as bearings and brushes, crucibles, moderator rods in nuclear reactors, nozzles, retorts, stoppers, and sleeves; chemically resistant materials; drilling-mud additives; electrical conductors; foundries; fuel cells; graphene; high-strength composites; lubricants; pencils; powdered metals; refractories; rubber; and steelmaking. Brake linings accounted for 8% and lubricants accounted for 7% of all forms of natural graphite consumption. Automobile manufacturing and construction influenced steelmaking activity, which in turn influenced refractories demand.

An important and potentially increasing use for graphite was as an anode material in batteries. Because of the growing demand for electric and hybrid vehicles and portable electronic devices, such as mobile telephones, smartphones, and tablet-sized computers, batteries were predicted to be the fastest growing sector for graphite use (15% to 25% per year) (Moores and others, 2012, p. 11). Graphite is an essential component of many types of batteries; battery applications accounted for

3,580 t or 7% of all forms of U.S. natural graphite consumption during 2018, which was an increase from 4% in 2017. The value of the natural graphite used in batteries in 2018 was $28.8 million, which was 21% of the total value of all forms of U.S. natural graphite consumption during 2018. Demand for flake graphite for use as anode material in batteries continued to be the main growth market for natural graphite in 2018. Battery industry estimates suggested that about 90% of the raw material used to make battery anodes was graphite, both natural and synthetic, with anode manufacturers mixing natural graphite into synthetic bases to reduce costs. Natural graphite continued to compete with synthetic for battery market share as well as use in other applications such as flame retardants. It was estimated that the market was split equally between natural to synthetic graphite, although demand for synthetic graphite was reported to be increasing more quickly than demand for natural material (Industrial Minerals, 2019).

Tesla Motors, Inc. continued construction of a large plant called Gigafactory 1, in Sparks, NV, to manufacture lithium-ion electric vehicle batteries; segments of the factory were operating while construction continued on others. Tesla partnered with battery maker, Panasonic Corp., with both companies operating different parts of the factory. Panasonic manufactured battery cells and Tesla assembled the cells into battery packs (Valdes-Dapena, 2016). When complete, the plant was expected to require 95,000 t of flake graphite per year to produce 35,000 t of spherical graphite for use as anode material for lithium-ion batteries. The factory started limited production of battery packs in the first quarter of 2016 and reached initial capacity of battery cells in January 2017 (Randall, 2017). At the end of July 2018, Gigafactory 1 battery production reached a production rate of about 20 gigawatthours per year (GWh/yr), making it the world's leading battery plant by a substantial margin. Tesla reported production of more batteries in terms of gigawatthours than the combined production of all other carmakers. Tesla planned to add three battery cell production lines, which would result in a production rate of 35 GWh/yr. Tesla increased the planned total capacity to 105 GWh/yr of battery cells and 150 GWh/yr of total battery pack production (Lambert, 2018).

Graphite has metallic and nonmetallic properties, which make it suitable for many industrial applications. The metallic properties include electrical and thermal conductivity. The nonmetallic properties include high thermal resistance, inertness, and lubricity. The combination of conductivity and high thermal stability allows graphite to be used in many applications, such as batteries, fuel cells, and refractories. Graphite's lubricity and thermal conductivity make it an excellent material for high-temperature applications because it provides effective lubrication at a friction interface while furnishing a thermally conductive matrix to remove heat from the same interface. Electrical conductivity and lubricity allow its use as the primary material in the manufacture of brushes for electric motors. A graphite brush effectively transfers electric current to a rotating armature while the natural lubricity of the brush minimizes frictional wear. Advanced technology products, such as friction materials and battery and fuel cells, require high-purity graphite. Natural graphite is purified to 99.9% carbon content for use in battery applications.

Graphite is made up of flat parallel sheets of carbon atoms in a hexagonal arrangement. It is possible to insert other atoms between the sheets, a process that is called intercalation. The insertion of other atoms makes dramatic changes in the properties of graphite. Graphite can be intercalated with sulfuric and nitric acids to produce expanded graphite from which foils are formed that are used in seals, gaskets, and fuel cells.

Refractory applications of graphite include carbon-bonded brick, castable ramming, and gunning mixtures. Carbon-magnesite brick has applications in high-temperature corrosive environments, such as iron blast furnaces, ladles, and steel furnaces. Carbon-alumina linings are principally used in continuous casting steel operations. Alumina- and magnesite-carbon brick requires graphite with a particle size of 100 mesh and a purity of 95% to 99%.

Crystalline flake graphite accounted for 45% of natural graphite use in the United States in 2018. It was consumed mainly in batteries, brake linings, lubricants, powdered metals, refractories, and rubber. Amorphous graphite accounted for 55% of natural graphite use and was mainly used in brake linings, foundries, lubricants, powdered metals, refractories, steelmaking, and other applications where additions of graphite improve the process or the end product (table 2). Lump graphite is used in a number of areas, such as steelmaking, depending on purity and particle size.

Synthetic graphite is used in more applications in the United States than natural graphite and accounts for an 83% share by quantity and a 97% share by value of the graphite consumption (table 1). The main market for high-purity synthetic graphite is as an additive to increase carbon content in iron and steel. Other important uses of all types of graphite are in the manufacture of catalyst supports; low-current, long-life batteries; porosity-enhancing inert fillers; powder metallurgy; rubber; solid carbon shapes; static and dynamic seals; steel; and valve and stem packing. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical. High-purity natural and synthetic graphite are used to manufacture antistatic plastics, conductive plastics and rubbers, electromagnetic interference shielding, electrostatic paint and powder coatings, high-voltage power cable conductive shields, membrane switches and resistors, semiconductive cable compounds, and electrostatic paint and powder coatings.

High-purity natural and synthetic graphite have played an important role in the emerging nonhydrocarbon energy sector and have been used in several new energy applications. In energy production applications, graphite is used as pebbles for modular nuclear reactors and in high-strength composites for wind, tide, and wave turbines. In energy storage applications, graphite is used in bipolar plates for fuel cells and flow batteries, in anodes for lithium-ion batteries, in electrodes for supercapacitors, in high-strength composites for fly wheels, in phase change heat storage, and in solar boilers. In energy management applications, graphite is used in high-performance polystyrene thermal insulation and in silicon chip heat dissipation. These new energy applications use value-added graphite products such as high-carbon purity, small-particle-size potato shapes called spherical graphite; expanded graphite; and graphene. Current graphite production capacity may not be adequate for the increasing demands of these new energy applications, which may require greatly increasing the current graphite supply when fully implemented.

Graphene consists of a single layer of carbon atoms, tightly bound in a flat hexagonal honeycomb lattice. Layers of graphene stacked on top of each other form graphite, with an interplanar spacing of 0.335 nanometers, meaning that within a 1-millimeter-thick graphite flake, there are approximately 3 million stacked sheets of graphene. Crystalline flake graphite can be processed by exfoliation into graphene, which has unique properties. Graphene is the thinnest compound known, the lightest weight material known (with 1 square meter weighing around 0.77 milligrams), the strongest compound discovered (between 100 and 300 times stronger than steel, the best conductor of heat at room temperature, the best conductor of electricity known, and it uniformly absorbs light across the visible and near-infrared parts of the spectrum. Graphene's unique properties have the potential to make high-tech products thinner, transparent, flexible, and more powerful. Graphene can be used to make inexpensive solar panels, very powerful transistors, and wafer-thin tablet computers. Graphene now has many applications, particularly in high-frequency electronics, bio, chemical and magnetic sensors, ultra-wide bandwidth photodetectors, and energy storage and generation. Other promising application areas for graphene are in biomedical technologies, composites, electronics, energy storage, imaging, sensors, supercapacitors, and telecommunications (Fuente, undated).

Prices

During 2018, prices for crystalline and crystalline flake graphite concentrates ranged from $650 to $1,200 per metric ton; prices for amorphous powder ranged from $400 to $480 per metric ton (table 4). Prices for 90% carbon natural crystalline flake graphite were unavailable, but prices were available for the higher quality 94% carbon natural crystalline flake graphite. Of the 94% carbon flake, the median yearend prices for fine mesh size decreased by 14%, median prices for medium mesh size decreased by 6%, and median prices for large mesh size increased by 5% from those in 2017, with the average median yearend price decreasing slightly. Median yearend prices for natural amorphous powder graphite increased by 6% compared with those in 2017. Prices for synthetic graphite could not be compared because data were not available for 2018 (table 4).

The average unit value of all U.S. natural graphite exports increased by 35% to $2,420 metric per ton in 2018 from $1,790 per metric ton in 2017 (tables 1, 5). The average unit value of all U.S. natural graphite imports decreased by 19% to $913 metric per ton in 2018 from $1,130 per metric ton in 2017 (tables 1, 6). Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The average unit value of U.S. synthetic graphite exports decreased by 4% to $5,530 metric per ton in 2018 from $5,740 per metric ton in 2017 (tables 1, 5). The average unit value of all U.S. synthetic graphite imports more than doubled to $3,410 metric per ton in 2018 from $1,650 per metric ton in 2017 (tables 1, 8).

The graphite industry enjoyed a year of relatively stable high prices in 2018, sustained by strong demand from the refractories and batteries sectors and because of restricted supplies from China. The continued environmental reforms and regulations of the Chinese Government regarding industrial pollution affected the graphite industry, restricting supply and increasing prices of natural and synthetic graphite through 2018. Government environmental improvement efforts in the steelmaking sector in China also influenced synthetic graphite demand dynamics and increased synthetic graphite prices (Roskill Information Services Ltd., 2019).

Foreign Trade

Total U.S. graphite exports increased by 13% in tonnage to 61,800 t valued at $309 million in 2018 from 54,500 t valued at $258 million in 2017. Total graphite export tonnage was 17% natural graphite and 83% synthetic graphite (table 5). Total U.S. natural graphite imports increased by 36% in tonnage to 70,700 t in 2018 from 51,900 t in 2017, and the value increased by 10% to $64.5 million from $58.5 million (table 6). The increase in natural graphite imports resulted from substantial increases in quantity and in value of the "amorphous" graphite category during 2018. Principal import sources of natural graphite, in descending order of tonnage, were India, China, Mexico, Canada, Madagascar, and Brazil, which combined accounted for 94% of the tonnage and 90% of the value of total natural graphite imports. India, Mexico, and Hong Kong were the leading suppliers of amorphous graphite to the United States. Sri Lanka provided all the lump and chippy dust graphite. Canada, China, and Japan were the leading suppliers of high-purity, expandable graphite varieties. China, Madagascar, Canada, and Brazil were, in descending order of tonnage, the leading suppliers of crystalline flake and flake dust graphite to the United States.

Total synthetic graphite imports increased by 17% in tonnage to 129,000 t in 2018 from 111,000 t in 2017, and the value increased by 141% to $440 million from $183 million (table 8). Principal import sources of synthetic graphite, in descending order of tonnage, were China, Mexico, Japan, Spain, France, India, and Switzerland, which combined accounted for 91% of the tonnage and 90% of the value of total synthetic graphite imports.

World Review

World production of natural graphite increased by 24% in 2018 to an estimated 1.12 Mt from 907,000 t in 2017. China maintained its position as the world's leading graphite producer, with an estimated 693,000 t, or 62% of total global production. Mozambique ranked second with 104,000 t, or 9% of the total, followed by Brazil, Madagascar, Canada, India, Russia, Ukraine, Norway, and Pakistan, in decreasing order of tonnage. These 10 countries accounted for 97% of world production (table 9).

Brazil.—In 2018, Brazil had estimated production of 95,000 t of marketable natural graphite. Nacional de Grafite Ltda. was the only producer of natural flake graphite in Brazil from mines and plants at three sites in the State of Minas Gerais. High-grade crystalline flake graphite projects were being developed in Brazil with at least two companies conducting or considering graphite exploration and development (Roskill Information Services Ltd., 2017, p. 144–146; 2018, p. 23, 161–164, 468–470).

Canada.—In 2018, Canada had two active open pit mines with combined production of 40,000 t of natural flake graphite. About 80% of the production came from the Lac des Iles flake graphite mine in Quebec, operated by Imerys Graphite & Carbon, and approximately 20% came from the Black Crystal flake graphite quarry in British Columbia, owned by Eagle Graphite Corp.

In recent years, many potential graphite producers were exploring and developing flake graphite projects in Canada. Exploration was focused primarily on properties in Ontario and Quebec, but other graphite exploration projects were underway in British Columbia (Roskill Information Services Ltd., 2017, p. 146–150; 2018, p. 23, 164–168).

China.—In 2018, China was the world's leading producer, exporter, and consumer of natural and synthetic graphite. China was also estimated to have the largest natural graphite resources in the world. China produced 693,000 t of natural graphite, of which an estimated 416,000 t was flake graphite and the remainder was amorphous graphite; this was about 62% of the total global production. More than 60% of China's flake graphite was produced in the Heilongjiang Province, and most of the country's amorphous graphite was produced in Hunan Province (Roskill Information Services Ltd., 2017, p. 151–178). The iron and steel industry was the leading consumer of natural and synthetic graphite in China (Roskill Information Services Ltd., 2017, p. 151; 2018, p. 169–170).

The environmental reforms of the Government of China seriously affected the natural graphite industry because the mined graphite ore must be processed to increase the graphite purity necessary for products such as spherical graphite for use in lithium-ion battery anodes, as well as expandable or expanded graphite for use in fire retardants and other applications. This processing had become the subject of close examination in recent years because it used large quantities of hydrofluoric acid and other hazardous reagents. The Government of China conducted inspections of processing plants during June and October 2018 to evaluate environmental conditions, focused mainly on Heilongjiang and Shandong Provinces, which were the centers for flake and spherical graphite production. In recent years, Chinese flake graphite supply growth continued to be constrained by ongoing plant closures. The constrained growth of the Chinese flake graphite supply, combined with increased demand from the battery manufacturing sector, resulted in higher prices for natural flake graphite (averaged across flake sizes for 94–97% carbon grades) by an average of 45% from September 2017 to February 2018, and stayed higher for the remainder of 2018 (Roskill Information Services Ltd., 2019).

Government inspections resulting in closures went further upstream for synthetic graphite, with availability constraints in the supply of needle coke (the raw material for synthetic graphite) translating to a shortage in synthetic graphite and rising prices through 2017 and 2018. Prices for synthetic graphite electrodes increased by more than 800% between January and October 2017 and, although prices dropped some during 2018, they were still much higher than they were in 2017. Prices remained high owing to rapidly increasing demand from the synthetic graphite electrode manufacturing sector. The increased demand was due to China shifting to higher levels of crude steel production using electric arc furnace technology, which relies on graphite electrodes. China was the world's leading producer of synthetic graphite and accounted for nearly 50% of global synthetic graphite production. Most of this output was in the form of synthetic graphite electrodes for export (Roskill Information Services Ltd., 2017, p. 151–178; 2018, p. 35, 169–170, 184–185; 2019).

Mozambique.—Mozambique had been the focus for several natural flake graphite development projects in recent years. The planned production capacity for the country far exceeded that of any global production operation and projections for Mozambique's emerging graphite mining sector continued to increase. During 2018, Mozambique was the world's second leading graphite producer with an estimated production of 104,000 t of crystalline flake graphite. Production of natural flake graphite in Mozambique resulted from foreign investment. The Ancuabe operation in the Cabo Delgado Province was operated by Triton Minerals Ltd. (Australia). Startup of Ancuabe began in June. According to Triton Minerals, Ancuabe had the potential to become a major high-grade graphite project. The largest known graphite deposit in the world was the nearby Balama deposit owned by Syrah Resources Ltd. (Australia), also in the Cabo Delgado Province. Resources at Balama were estimated to be 1.1 billion metric tons, which was more natural graphite than that contained in all other known deposits in the world combined. Production at the project began in December 2017, and output was expected to rise rapidly in coming years as production ramped up. The Balama Mine was plagued with problems during 2018. Issues with ramping up the mine and processing facility kept production behind forecasts, although Syrah maintained its business plan, announcing in May that it would acquire a $1.23 million site in the U.S. State of Louisiana to build a spherical graphite plant. In October, however, a fire at the Balama plant forced the company to halt production for a number of weeks, leaving it unable to meet orders. Several other graphite projects were under development in Cabo Delgado. Graphite mining in the Balama District of Mozambique was projected to be relatively low cost because ores were easily accessible by open pit mining, of high quality, and 240 km (149 mi) from the deepwater port of Pemba (Economist Intelligence Unit, The, 2014; Roskill Information Services Ltd., 2017, p. 199; 2018, p. 223–225; Industrial Minerals, 2019; Syrah Resources Ltd., undated).

Tanzania.—During 2018, Tanzania produced an estimated 150 t of crystalline flake graphite. Several natural flake graphite deposits were being explored in Tanzania. Discovery Africa Ltd. (Australia), through its Tanzania Graphite project, discovered a very large high-grade flake graphite deposit in southern Tanzania. The company executed a memorandum of agreement for the acquisition of up to 80% of Hatua Resources Ltd., which held four exploration licenses in the region. Assessment and sampling of graphitic schist outcrops in all four locations graded up to 49.9% total graphitic carbon. The average samples within the licenses exhibited 15.3% total graphitic carbon (Discovery Africa Ltd., 2014; Roskill Information Services Ltd., 2017, p. 210; 2018, p. 235–236).

Outlook

Worldwide demand for natural and synthetic graphite is expected to continue increasing as more nonhydrocarbon energy applications that use graphite are developed. Steel production and other types of metallurgical activity, which are important consumers of graphite, are expected to increase as well. Global graphite consumption is expected to increase owing to new technologically advanced applications, such as aerospace applications, fuel cells, graphene, lithium-ion batteries, pebble-bed nuclear reactors, and solar power. Most notable for graphite among these applications are fuel cells, lithium-ion batteries, and pebble-bed nuclear reactors. Battery production is predicted to increase and become the leading graphite market by 2027, surpassing the traditional leading graphite markets of electrodes and refractories. Electrodes and refractories are expected to decline whenever steelmaking declines (Roskill Information Services Ltd., 2017, p. 43; 2018, p. 49–55).

Batteries are expected to become the end-use sector with the largest increase in graphite use owing to growth in portable electronics and electric vehicles. These applications require larger, more-powerful, and more-graphite-intensive lithium-ion batteries. Production of spherical graphite feedstock material will need to increase to meet additional battery demand. Graphite is not dependent on the success of the lithium-ion battery, however, because natural graphite anodes are preferred in all current battery technologies. Consumption of all types of graphite used in battery applications may increase to account for about 26% of total graphite consumption by 2026 (Roskill Information Services Ltd., 2017, p. 43; 2018, p. 49–55). Globally, batteries accounted for about 14% of natural graphite consumption and 7% of total graphite consumption in 2018 but are growing such that they could account for 45% of natural graphite consumption and 25% of total graphite consumption by 2028 (Roskill Information Services Ltd., 2018). Although leading Western graphite consumers expressed an interest in establishing 100% supply chains that did not rely on China, they also have made it clear they will only shift purchasing patterns when graphite from other sources can be supplied at or near Chinese price levels (Industrial Minerals, 2019).

The ability to refine and modify graphite is expected to be the key to future growth in the graphite industry. Refining techniques have enabled the use of graphite with improved properties in electronics, foils, friction materials, and lubrication applications. Products available through advanced refining technology could increase profitability in the U.S. graphite industry in the next few years.

The demand for graphite used in rubber and plastics is increasing and continued growth is expected. The United States market for graphite in pencils has almost disappeared; most pencil "leads" now are imported from China. These markets, however, use little graphite and are not expected to have a significant impact on future consumption.

References Cited

Discovery Africa Ltd., 2014, High grade flake graphite discovered in Tanzania—Grades up to 49.9%: South Melbourne, Victoria, Australia, Discovery Africa Ltd., February 28, 7 p. (Accessed June 23, 2014, at http://www.discoveryafrica.com.au/IRM/Company/ShowPage.aspx/PDFs/1147-10000000/TanzaniaHighGradeFlakeGraphiteDiscovered.)

Economist Intelligence Unit, The, 2014, Mozambique could become new graphite mining centre: New York, NY, The Economist Group, July 1. (Accessed August 12, 2014, at http://country.eiu.com/article.aspx?articleid=641974048&Country=Mozambique&topic=Economy&subtopic=Forecast&subsubtopic=Economic+growth&u=1&pid=301744814&oid=301744814.)

Fuente, Jesus de la, [undated], Graphene – what is it?: San Sebastian, Spain, Graphenea, Inc. (Accessed March 25, 2021, at https://www.graphenea.com/pages/graphene.)

Graphite One Resources Inc., 2020a, Graphite Creek: Vancouver, British Columbia, Canada, Graphite One Resources Inc. (Accessed June 23, 2020, via http://www.graphiteoneresources.com/projects/projects-overview/.)

Graphite One Resources Inc., 2020b, Graphite One project—Overview: Vancouver, British Columbia, Canada, Graphite One Resources Inc. (Accessed June 23, 2020, at http://www.graphiteoneresources.com/projects/graphite-one-project-pea/overview/.)

Graphite One Resources Inc., 2020c, Graphite One project—Product manufacturing plant: Vancouver, British Columbia, Canada, Graphite One Resources Inc. (Accessed June 23, 2020, at http://www.graphiteoneresources.com/projects/graphite-one-project-pea/product-manufacturing-plant/.)

Graphite One Resources Inc., 2020d, Graphite resource estimates: Vancouver, British Columbia, Canada, Graphite One Resources Inc. (Accessed June 23, 2020, at http://www.graphiteoneresources.com/projects/graphite-creek/resource-estimates/.)

Industrial Minerals, 2019, Year in review—Graphite: London, United Kingdom, Industrial Minerals, January 2. (Accessed October 28, 2019, via http://www.indmin.com.)

Kopeliovich, Dmitri, 2013, Graphite manufacturing process: SubsTech Forum. (Accessed March 14, 2019, at http://www.substech.com/dokuwiki/doku.php?id=graphite_manufacturing_process.)

Lambert, Fred, 2018, Tesla confirms Gigafactory 1 battery production at '~20 GWh' more than all other carmakers combined: Electrek.co, August 2. (Accessed June 19, 2020, at https://electrek.co/2018/08/02/tesla-gigafactory-1-battery-production-20-gwh/.)

Moores, Simon, O'Driscoll, Mike, and Russell, Richard, 2012, Natural graphite report 2012—Data, analysis and forecasts for the next five years: London, United Kingdom, Industrial Minerals, December, 394 p.

Randall, Tom, 2017, Tesla flips the switch on the gigafactory: Bloomberg.com, January 4. (Accessed March 28, 2019, at https://www.bloomberg.com/news/articles/2017-01-04/tesla-flips-the-switch-on-the-gigafactory.)

Roskill Information Services Ltd., 2017, Natural and synthetic graphite—Global industry, markets and outlook to 2026 (10th ed.): London, United Kingdom, Roskill Information Services Ltd., 475 p.

Roskill Information Services Ltd., 2018, Natural and synthetic graphite—Global industry, markets and outlook to 2027 (11th ed.): London, United Kingdom, Roskill Information Services Ltd., 504 p.

Roskill Information Services Ltd., 2019, Roskill—Graphite market continuously shaped by pollution controls: London, United Kingdom, Roskill Information Services Ltd. news release, June 12. (Accessed June 15, 2020, at https://www.globenewswire.com/news-release/2019/06/12/1867350/0/en/Roskill-Graphite-market-continuously-shaped-by-pollution-controls.html.)

Spizziri, Matthew, 2015, Alabama Graphite announces positive PEA for Coosa Graphite project: Investing News Network, November 30. (Accessed June 19, 2020, at https://investingnews.com/daily/resource-investing/battery-metals-investing/graphite-investing/alabama-graphite-announces-positive-pea-for-coosa-graphite-project/.)

Syrah Resources Ltd., [undated], Overview: Melbourne, Victoria, Australia, Syrah Resources Ltd. (Accessed June 23, 2017, at http://www.syrahresources.com.au/overview.)

Valdes-Dapena, Peter, 2016, Inside Tesla's ginormous gigafactory: CNN Business, July 27. (Accessed November 21, 2016, at https://money.cnn.com/2016/07/26/technology/tesla-gigafactory/index.html.)
Westwater Resources, Inc., 2018a, Westwater Resources completes acquisition of Alabama Graphite: Centennial, CO, Westwater Resources, Inc. news release, April 23, 3 p. (Accessed November 15, 2018, at https://www.westwaterresources.net/docs/default-source/news-release/alabama-graphite-acquisition-(release-version).pdf?sfvrsn=3e3137cf_0.)
Westwater Resources, Inc., 2018b, Westwater successfully produces battery ready graphite: Centennial, CO, Westwater Resources, Inc. news release, September 6. (Accessed June 15, 2020, at https://www.westwaterresources.net/investors/news-releases/2018/09/06/westwater-successfully-produces-battery-ready-graphite.)
Westwater Resources, Inc., 2019, Westwater Resources reports 2018 results & energy minerals business update: Centennial, CO, Westwater Resources, Inc. news release, February 19. (Accessed June 15, 2020, at https://www.westwaterresources.net/investors/news-releases/2019/02/19/westwater-resources-reports-2018-results-energy-minerals-business-update.)
Westwater Resources, Inc., 2020a, Bama Mine project: Centennial, CO, Westwater Resources, Inc. (Accessed June 15, 2020, at http://www.westwaterresources.net/projects/graphite/bama-mine-project.)
Westwater Resources, Inc., 2020b, Coosa Graphite project: Centennial, CO, Westwater Resources, Inc. (Accessed June 15, 2020, at http://www.westwaterresources.net/projects/graphite/coosa-graphite-project.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Graphite. Ch. in Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, 2017.
Graphite (Natural). Ch. in Mineral Commodity Summaries, annual.
Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
Natural Graphite. International Strategic Minerals Inventory Summary Report, Circular 930–H, 1988.

Other

Graphite. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT NATURAL AND SYNTHETIC GRAPHITE STATISTICS[1]

		2014	2015	2016	2017	2018
United States:						
Natural:						
Exports:						
Quantity	metric tons	12,200	11,600	14,300	13,900	10,400
Value	thousands	$19,300	$21,600	$21,100	$24,800	$25,100
Imports for consumption:						
Quantity	metric tons	69,600	46,700	38,900	51,900	70,700
Value	thousands	$72,300	$58,600	$47,600	$58,500	$64,500
Apparent consumption:[2]						
Quantity	metric tons	57,400	35,100	24,700	38,000	60,300
Value	thousands	$52,900	$36,900	$26,500	$33,700	$39,400
Synthetic:						
Production:						
Quantity	metric tons	135,000	119,000	207,000	226,000 r	219,000
Value	thousands	$939,000	$816,000	$658,000	$726,000 r	$1,170,000
Exports:						
Quantity	metric tons	32,500	32,000	30,100	40,600 r	51,400
Value	thousands	$221,000	$177,000	$145,000	$233,000 r	$284,000
Imports for consumption:						
Quantity	metric tons	60,700	80,600	75,000	111,000	129,000
Value	thousands	$135,000	$128,000	$127,000	$183,000 r	$440,000
Apparent consumption:[2]						
Quantity	metric tons	163,000	167,000	252,000	296,000 r	297,000
Value	thousands	$852,000	$767,000	$640,000	$676,000 r	$1,330,000
World production, natural[e]	metric tons	905,000	947,000 r	866,000 r	907,000 r	1,120,000

[e]Estimated. [r]Revised.
[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Domestic production plus imports minus exports.

TABLE 2
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE[1]

End use	Crystalline Quantity (metric tons)	Crystalline Value (thousands)	Amorphous[2] Quantity (metric tons)	Amorphous[2] Value (thousands)
2017:				
Brake lining	753	$2,020	2,700	$4,760
Carbon products[3]	225	939	423	252
Foundries[4]	W	W	W	W
Lubricants[5]	806 r	3,300 r	1,320	1,470
Powdered metals	W	W	W	W
Refractories	W	W	W	W
Rubber	W	W	834	1,780
Other[6]	18,100 r	77,300 r	14,800 r	17,600 r
Total	19,800 r	83,600 r	20,100 r	25,900 r
2018:				
Brake lining	1,010	2,800	3,070	5,370
Carbon products[3]	227	1,010	W	661
Foundries[4]	W	W	1,890	2,180
Lubricants[5]	887	3,120	2,800	8,130
Powdered metals	3,250	W	W	W
Refractories	W	W	W	W
Rubber	1,180	4,800	617	1,900
Other[6]	16,600	61,300	20,300	43,700
Total	23,100	73,000	28,700	62,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in “Other.”
[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes mixtures of natural and synthetic graphite.
[3]Includes bearings and carbon brushes.
[4]Includes foundries (other) and foundry facings.
[5]Includes ammunition packings.
[6]Includes antiknock gasoline additives and other compounds, batteries, crucibles, drilling mud, electrical and electronic devices, industrial diamonds, magnetic tape, mechanical products, nozzles, paints and polishes, pencils, retorts, sleeves, small packages, soldering and welding, steelmaking, stoppers, and other end-use categories.

TABLE 3

SHIPMENTS OF SYNTHETIC GRAPHITE BY U.S. COMPANIES, BY END USE[1]

End use	Quantity (metric tons)	Value (thousands)
2017:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,000 r	$237,000 r
Unmachined graphite shapes	9,440	W
Other[2]	124,000	489,000 r
Total	226,000 r	726,000 r
2018:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,100	W
Unmachined graphite shapes	W	W
Other[2]	126,000	1,170,000
Total	219,000	1,170,000

rRevised. W Withheld to avoid disclosing company proprietary data; included in “Other.”

[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes anodes, crucibles and vessels, electric motor brushes and machined shapes, graphite articles, high-modulus fibers, lubricants (solid or semisolid), refractories, steelmaking, carbon raisers, additives in metallurgy, and other powder data.

TABLE 4

REPRESENTATIVE YEAREND GRAPHITE PRICES[1]

(Dollars per metric ton)

Type	2017	2018
Crystalline medium, 85% to 87% carbon, +100–80 mesh	400–500	NA
Crystalline fine, 90% carbon, –100 mesh	500–550	NA
Crystalline medium, 90% carbon, +100–80 mesh	550–620	NA
Crystalline large, 90% carbon, +80 mesh	600–650	NA
Crystalline fine, 94% to 97% carbon, –100 mesh	785–940	650–840
Crystalline medium, 94% to 97% carbon, +100–80 mesh	865–1,040	800–1,000
Crystalline large, 94% to 97% carbon, +80 mesh	925–1,070	900–1,200
Amorphous powder, 80% to 85% carbon	400–430	400–480
Synthetic fine, 97% to 98% carbon[2]	NA	NA
Synthetic fine, 98% to 99% carbon[2]	NA	NA

NA Not available.

[1]Prices are cost, insurance, and freight main European port, unless otherwise specified.

[2]Prices are cost, insurance, and freight Asian port.

Source: Industrial Minerals, no. 598, December 2017−January 2018, p. 34–38, 42, 53.

TABLE 5

U.S. EXPORTS OF NATURAL AND SYNTHETIC GRAPHITE, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	Natural[3] Quantity (metric tons)	Natural[3] Value[5] (thousands)	Synthetic[4] Quantity (metric tons)	Synthetic[4] Value[5] (thousands)	Total Quantity (metric tons)	Total Value[5] (thousands)
2017:						
Belgium	475	$660	206	$1,500	681	$2,160
Brazil	82	196	322 r	2,600 r	404	2,800
Canada	8,490	4,730	5,090 r	20,300 r	13,600	25,000
China	322	888	2,340 r	37,000 r	2,660 r	37,900 r
France	44	127	3,210 r	14,100 r	3,260	14,200
Germany	151	499	1,170 r	16,600 r	1,330	17,100 r
Hong Kong	5	21	79 r	6,290 r	84 r	6,310
India	422	1,100	539 r	1,430 r	961 r	2,530 r
Italy	23	83	1,770 r	9,410 r	1,800	9,500
Japan	910	2,830	2,500 r	15,700 r	3,410	18,500
Korea, Republic of	288	1,170	2,170 r	36,600 r	2,450 r	37,700 r
Malaysia	22	88	171	2,550	193	2,640
Mexico	1,480	6,230	13,000 r	18,700 r	14,500	24,900
Netherlands	333	2,370	187 r	925 r	520	3,300
Poland	--	--	473	2,450 r	473	2,450
Saudi Arabia	47	20	1,960 r	7,290 r	2,000	7,310
Taiwan	80	281	349 r	3,810 r	429	4,090
Turkey	53	64	94	657	147	722
United Arab Emirates	4	5	83	186	87	191
United Kingdom	32	122	1,130 r	1,990 r	1,160	2,110 r
Venezuela	191	1,970	1	17	192	1,990
Vietnam	75	212	256 r	19,600 r	331 r	19,800
Other	364 r	1,170 r	3,550 r	13,700 r	3,920 r	14,900 r
Total	13,900	24,800	40,600 r	233,000	54,500 r	258,000
2018:						
Belgium	267	619	466	1,960	733	2,580
Brazil	139	290	1,320	8,680	1,460	8,970
Canada	4,690	3,310	7,860	21,800	12,600	25,200
China	313	912	3,080	52,000	3,390	52,900
France	30	97	2,690	13,500	2,720	13,600
Germany	317	1,150	1,350	17,100	1,660	18,200
Hong Kong	4	22	292	6,450	296	6,470
India	437	1,490	1,040	2,850	1,480	4,340
Italy	97	283	2,150	12,400	2,250	12,700
Japan	727	2,560	3,040	21,300	3,760	23,800
Korea, Republic of	774	3,810	1,750	22,300	2,520	26,100
Malaysia	24	116	93	2,140	117	2,250
Mexico	1,410	4,290	14,500	23,700	15,900	28,000
Netherlands	249	2,780	2,620	12,000	2,870	14,800
Poland	2	28	248	1,670	250	1,700
Saudi Arabia	--	--	3,350	12,400	3,350	12,400
Taiwan	74	223	515	5,290	589	5,510
Turkey	167	403	139	1,260	306	1,660
United Arab Emirates	2	6	440	1,070	442	1,080
United Kingdom	89	540	1,660	3,030	1,740	3,570
Venezuela	13	33	--	--	13	33
Vietnam	39	129	551	28,000	590	28,100
Other	528	2,010	2,280	13,500	2,810	15,500
Total	10,400	25,100	51,400	284,000	61,800	309,000

[r]Revised. -- Zero.

[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Numerous countries for which data were reported have been combined in "Other."

[3]Amorphous, crystalline flake, lump and chip, and natural, not elsewhere classified. The applicable Harmonized Tariff Schedule of the United States (HTS) nomenclatures are "Natural graphite in powder or in flakes" and "Other," codes 2504.10.0000 and 2504.90.0000.

[4]Includes data from applicable HTS nomenclatures "Artificial graphite," "Colloidal or semicolloidal graphite," "Preparations based on graphite," and "Graphite products containing greater than 50% graphite by weight," codes 3801.10.0000, 3801.10.5000, 3801.20.0000, 3801.90.0000, and 6903.10.0000.

[5]Values are free alongside ship.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY OR LOCALITY[1]

	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude, high-purity, expandable		Amorphous		Total	
Country or locality	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
2017:										
Brazil	4,250	$6,840	--	--	--	--	808	$760	5,050	$7,600
Canada	9,250	12,900	--	--	(3)	$2	18	23	9,270	12,900
China	20,400	24,700	--	--	1,050	2,460	5	5	21,400	27,100
Germany	44	160	--	--	48	874	--	--	92	1,030
Japan	13	66	--	--	99	1,430 r	--	--	112	1,490 r
Madagascar	1,490	1,370	--	--	--	--	574	528	2,060	1,900
Mexico	--	--	--	--	--	--	13,300	5,310	13,300	5,310
Norway	--	--	--	--	--	--	38	34	38	34
Sri Lanka	--	--	442	$840	--	--	--	--	442	840
United Kingdom	17	41	--	--	(3)	38	40	22	57	101
Other	1	4	--	--	4 r	112 r	18 r	4 r	23 r	120 r
Total	35,400	46,100	442	840	1,200	4,910 r	14,800	6,680	51,900	58,500
2018:										
Austria	5	23	--	--	--	--	39	25	43	48
Brazil	2,960	5,800	--	--	--	--	567	664	3,530	6,470
Canada	3,610	5,810	--	--	5,730	8,290	--	--	9,340	14,100
China	15,300	22,200	--	--	1,810	2,910	20	30	17,100	25,100
Germany	70	287	--	--	74	931	5	4	149	1,220
Hong Kong	--	--	--	--	--	--	1,400	1,120	1,400	1,120
India	36	61	--	--	--	--	18,000	2,410	18,000	2,470
Japan	69	275	--	--	120	1,650	--	--	189	1,920
Madagascar	4,710	3,880	--	--	--	--	378	197	5,090	4,080
Mexico	--	--	--	--	(3)	4	13,300	5,650	13,300	5,660
Mozambique	1,340	607	--	--	--	--	--	--	1,340	607
Slovakia	--	--	--	--	1	36	--	--	1	36
Sri Lanka	--	--	556	1,050	--	--	--	--	556	1,050
Sweden	--	--	--	--	2	54	--	--	2	54
Switzerland	6	39	--	--	--	--	--	--	6	39
Turkey	20	38	--	--	--	--	--	--	20	38
United Kingdom	85	160	--	--	12	47	526	302	623	509
Other	3	14	--	--	(3)	6	--	--	3	20
Total	28,200	39,200	556	1,050	7,750	13,900	34,200	10,400	70,700	64,500

[r]Revised. -- Zero.

[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs values.

[3]Less than ½ unit.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION
OF GRAPHITE ELECTRODES, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	Quantity (metric tons)	Value[3] (thousands)
2017:		
Austria	1,160	$2,530
Brazil	292	1,930
Canada	345	185
China	7,700	58,200 r
Germany	4,670	12,500
Hong Kong	510	12,600
India	7,830 r	17,400 r
Indonesia	174	1,580
Japan	12,300	33,400
Malaysia	1,560	3,430
Mexico	20,800 r	41,200 r
Poland	3,460	9,850
Russia	11,300	24,100
Spain	677	1,310
Switzerland	136	606
Ukraine	1,140	2,010
United Kingdom	1,220 r	4,900 r
Other	17 r	148 r
Total	75,400 r	228,000
2018:		
Austria	567	5,160
Belgium	293	1,690
Brazil	89	831
Canada	144	465
China	16,600	230,000
Germany	3,650	36,700
India	41,100	99,600
Italy	669	4,550
Japan	10,600	78,900
Malaysia	270	1,670
Mexico	27,800	75,800
Poland	4,250	13,000
Russia	17,200	50,900
Singapore	81	1,180
Spain	1,520	12,300
Ukraine	1,760	11,300
United Kingdom	703	5,910
Other	104	513
Total	127,000	630,000

[r]Revised.
[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]The applicable Harmonized Tariff Schedule of the United States (HTS) nomenclature is “Graphite electrodes, not exceeding 425 mm in diameter, of a kind used for furnaces,” “Graphite electrodes, exceeding 425 mm in diameter, of a kind used for furnaces,” and “Carbon electrodes of a kind used for furnaces, excluding graphite,” codes 8545.11.0010, 8545.11.0020, and 8545.11.0050.
[3]Customs values.

Source: U.S. Census Bureau.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF SYNTHETIC GRAPHITE, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2017 Quantity (metric tons)	2017 Value[3] (thousands)	2018 Quantity (metric tons)	2018 Value[3] (thousands)
Austria	(4)	$19	631	$4,530
Belgium	28	460 r	83	739
Brazil	1,280 r	1,760 r	921	1,250
Canada	930 r	4,170 r	1,440	5,280
China	70,500	55,700 r	65,400	120,000
Czechia	34	932 r	5	65
France	5,970 r	15,900 r	7,670	60,400
Germany	1,160	10,600 r	1,630	13,600
Hong Kong	2,690	1,380 r	1,480	1,260
India	3,750	5,460 r	6,930	11,900
Italy	25 r	571 r	544	2,440
Japan	8,090	54,800 r	10,800	94,200
Korea, Republic of	259	2,750 r	635	6,800
Malaysia	736	893 r	698	898
Mexico	5,130	6,470 r	12,400	21,800
Netherlands	52	240 r	1,300	1,660
Norway	285	222 r	758	701
Poland	97	124 r	280	731
Russia	201 r	202 r	926	723
South Africa	12	38 r	(4)	4
Spain	5,610	8,160 r	10,700	78,300
Sweden	227 r	253 r	135	445
Switzerland	3,370	10,900 r	2,910	10,900
Taiwan	78 r	275 r	78	286
United Kingdom	39 r	400 r	185	992
Other	13	169 r	522	648
Total	111,000	183,000 r	129,000	440,000

rRevised.

[1]Table includes data available through September 8, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Synthetic graphite data is for Harmonized Tariff of the United States codes 3801.10.1000, 3801.10.5000, 3801.20.0000, 3801.90.0000, and 6903.10.0000.

[3]Customs values.

[4]Less than ½ unit.

Source: U.S. Census Bureau and the U.S. International Trade Commission.

TABLE 9

NATURAL GRAPHITE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons)

Country or locality[2]	2014	2015	2016	2017	2018
Australia, crystalline flake	--	500	--	--	--
Austria, amorphous[e]	500	700	800	1,000	1,000
Brazil, crystalline flake	87,026	81,762	80,000 [e]	90,000 [e]	95,000 [e]
Canada, crystalline flake[e]	30,000	30,000	35,000	40,000	40,000
China:[e]					
Amorphous	250,000	275,000	300,000	275,000	277,000
Crystalline flake	425,000	450,000	325,000	350,000	416,000
Total	675,000	725,000	625,000	625,000	693,000
Germany, crystalline flake[e]	500	400	500	800	800
India:[e, 3]					
Amorphous	2,300	2,700	3,000	3,500	3,500
Crystalline flake	21,000	24,200	27,000	31,500	31,500
Total	23,300	26,900	30,000	35,000	35,000
Korea, North:[e]					
Amorphous	1,000	1,000	1,000	1,000	1,080
Crystalline flake	4,500	4,500	4,500	4,500	4,920
Total	5,500	5,500	5,500	5,500	6,000
Madagascar, crystalline flake	5,705 [r]	8,006	9,224	14,529 [r]	46,900 [e]
Mexico, amorphous	9,200	8,100	8,500 [e]	9,000 [e]	9,000 [e]
Mozambique, crystalline flake	--	--	--	1,042 [r]	104,000
Namibia, crystalline flake	--	--	--	2,216	3,456
Norway, crystalline flake	8,308 [r]	9,185 [r]	10,000 [r]	11,000 [r, e]	16,000 [e]
Pakistan, crystalline flake	14,300	2,900	10,000 [e]	14,000 [e]	14,000 [e]
Russia:					
Amorphous	8,000	8,000	9,500 [r]	12,000 [r]	12,000 [e]
Crystalline flake	7,000	7,900 [r]	9,900 [r]	13,200 [r]	13,200 [e]
Total	15,000 [e]	15,900 [r]	19,400 [r]	25,200 [r]	25,200 [e]
Sri Lanka, vein	3,800 [r]	4,200 [r]	3,900 [r]	3,900 [r, e]	4,000 [e]
Sweden, crystalline flake	--	100	--	--	--
Tanzania, crystalline flake	--	--	--	127	150 [e]
Turkey, amorphous[e, 4]	1,400	1,800	2,000	2,300	2,000
Ukraine, crystalline flake	13,800	14,500	15,000 [e]	20,000 [e]	20,000 [e]
Uzbekistan, crystalline flake[e]	100	100	100	100	100
Vietnam, crystalline flake[e]	5,000	5,000	5,000	5,000	5,000
Zimbabwe, crystalline flake	6,853	6,362	5,622	1,577	2,000 [e]
Grand total[e]	905,000	947,000 [r]	866,000 [r]	907,000 [r]	1,120,000
Of which:					
Amorphous[e]	272,000	297,000	325,000 [r]	304,000 [r]	306,000
Crystalline flake[e]	629,000	645,000	537,000	600,000 [r]	813,000
Vein or lump	3,800 [r]	4,200 [r]	3,900 [r]	3,900 [r, e]	4,000 [e]

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

[1]Table includes data available through October 9, 2019. All data are reported unless otherwise noted. Grand 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, other countries may have produced graphite, but available information was inadequate to make reliable estimates of output.

[3]Indian marketable production is estimated to be 10% to 20% of run-of-mine production.

[4]Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.