2019 Minerals Yearbook

GRAPHITE [ADVANCE RELEASE]

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Graphite

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In 2019, no domestic production of natural graphite was reported, but U.S. production of synthetic graphite was 276,000 metric tons (t) valued at $1.17 billion. U.S. exports and imports of natural graphite were 5,880 t and 50,300 t, respectively. U.S. exports and imports of synthetic graphite totaled 40,800 t and 93,400 t, respectively. U.S. apparent consumption of natural and synthetic graphite was 44,400 t and 328,000 t, respectively. World production of natural graphite was estimated to be 1.10 million metric tons (Mt) (tables 1, 9).

Graphite is one of four forms of crystalline carbon; the other forms are carbon nanotubes, diamonds, and fullerenes. In graphite, the carbon atoms are densely arranged in parallel-stacked, planar honeycomb-lattice sheets. When the graphite structure is only a one-atom-thick planar sheet, it is called graphene. Graphite is used to produce graphene. Graphene is extremely light and strong. Graphite is gray to black in color, opaque, and usually has a metallic luster, although sometimes it 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 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 of 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, such as flame retardants. The foremost deposits are found in Austria, Brazil, Canada, China, Germany, Madagascar, Mozambique, Tanzania, and in Alabama, Alaska, and New York in 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 mined commercially only 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 the Republic of Korea, Mexico, and Sri Lanka, where the deposits are deep, underground mining techniques 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 a field washing plant, where it undergoes desliming to remove the clay fraction and is subjected to rough flotation to produce a concentrate with 60% to 70% carbon. This concentrate is transported to a 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 2019, but 276,000 t of synthetic graphite with a value of $1.17 billion was produced and shipped (tables 1, 3). This was a 26% increase in quantity produced and a slight decrease in value compared with that in 2018. This increase in quantity was due to large increases in the production of refractory graphite products, electric motor brushes, and machined graphite shapes.

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 it 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, 2020).

Exploration and Development

During 2019, 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., 2021a; Westwater Resources, Inc., 2021a, b). In April 2018, Westwater Resources completed the acquisition of Alabama Graphite Corp., which was the previous owner of the Bama Mine and Coosa Graphite projects (Alabama Graphite Corp., 2018).

During 2019, Westwater Resources continued exploring, evaluating, and developing its Bama Mine project, which Alabama Graphite had purchased in September 2014. The Bama Mine project encompassed more than 520 hectares (ha) (1,300 acres) in Chilton County, AL, which included the Bama Mine. The Bama Mine, the southernmost mine in the Alabama Graphite Belt, previously produced larger quantities and higher quality flake graphite than any other graphite mine in Alabama. The Bama Mine 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 access to existing road and rail infrastructure, power, and water. The mine site was located about 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., 2021a). During 2019, 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., 2021b). 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., 2021a).

During 2019, Graphite One was delineating, evaluating, and developing a massive, near-surface deposit at its Graphite Creek project, which included 176 mineral claims in a known graphite mineralization region of 9,583 ha on the Seward Peninsula in western Alaska, about 55 km (37 mi) north of Nome. The Graphite Creek deposit consisted 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 expected to generate estimated annual sales of $280 million and annual post-tax earnings of $118 million or $2,130 per metric ton assuming selling prices of $6,200 per metric ton for CSG and $1,500 per metric ton for purified graphite powders (Graphite One Resources Inc., 2021b, d).

In March 2019, Graphite One increased and updated the project's resource estimates from those of the PEA following a 2018 field program. With a cutoff grade of 5.0% Cg, inferred resources were estimated to be 91.89 Mt of 8.0% Cg for 7,340,000 t of graphitic carbon content, indicated resources were estimated to be 9.26 Mt of 7.7% Cg for 715,000 t of graphitic carbon content, and measured resources were estimated to be 1.69 Mt of 8.0% Cg for 135,000 t of graphitic carbon content (Graphite One Resources Inc., 2021d).

The PEAs of Graphite One and Westwater Resources included product manufacturing plants that were expected to produce CSG and purified micronized graphite (PMG). CSG was used in lithium-ion batteries, and PMG was used as a conductivity enhancement material for a variety of battery applications. Westwater Resources tested their process, which produced PMG material suitable for use in battery manufacturing (Westwater Resources, Inc., 2018, 2019; Graphite One Resources Inc., 2021b, c).

Consumption

The USGS obtained the consumption data in this report through a survey of companies that imported and used natural graphite in the United States. Data for nonrespondents were estimated 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 most of the graphite industry in the United States.

U.S. apparent consumption of natural graphite decreased by 27% to 44,400 t in 2019 from 60,700 t in 2018, whereas U.S. apparent consumption of synthetic graphite increased by 10% to 328,000 t in 2019 from 298,000 t in 2018. Total U.S. graphite consumption (combined natural and synthetic) increased by 4% to 372,000 t in 2019 from 358,000 t in 2018 (table 1).

U.S. consumption of natural graphite reported by end use increased slightly to 53,600 t in 2019 from that in 2018 (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 decreased by 4% in 2019 to 23,200 t from 24,200 t in 2018. Consumption of amorphous graphite increased by 7% in 2019 to 30,400 t from 28,400 t in 2018. The main uses of graphite during 2019 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. The leading applications for graphite were as electrodes used in steel production and as refractories. Automobile manufacturing and construction influenced steelmaking activity, which in turn influenced electrode and refractories demand. The steel industry is expected to remain the largest graphite consumer (Whiteside and Finn-Foley, 2019).

An important and potentially increasing portion of graphite use was as an anode material in batteries, as graphite is an essential component of many types of batteries. The batteries end-use category was predicted to have the largest rate of growth (15% to 25% per year), owing to increased demand for electric and hybrid vehicles and portable electronic devices, such as mobile telephones, smartphones, and tablet-sized computers (Moores and others, 2012, p. 11), although during 2019, graphite consumption in battery applications decreased slightly from that in 2018. Demand for flake graphite for use as anode material in batteries continued to be the main growth market for natural graphite in 2019. There are forecasts of rapid growth for graphite in the battery sector, where global demand is expected to grow from 165,000 t in 2018 to nearly 1 Mt by 2030 (Whiteside and Finn-Foley, 2019). Battery industry estimates suggest that about 90% of the raw material used to make battery anodes is graphite, both natural and synthetic, with anode manufacturers mixing natural material 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. The current market split of natural to synthetic graphite is estimated to be 50% and 50%, although demand for synthetic graphite was reported to be increasing more quickly than demand for natural material (Industrial Minerals, 2019). Synthetic graphite was the higher cost option for anode material, but its higher purity made it the preferred option for use in premium batteries. Most battery anode producers used a blend of synthetic and natural graphite, balancing cost and performance (Whiteside and Finn-Foley, 2019).

Tesla Motors, Inc. continued investment into its large plant called Gigafactory 1, in Sparks, NV, to manufacture lithium-ion electric vehicle battery packs; segments of the factory were operating while construction continued. Tesla partnered with battery maker, Panasonic Corp., with both companies operating parts of the factory. Panasonic manufactured battery cells, which Tesla assembled into battery packs (Valdes-Dapena, 2016). The battery packs then were installed into the vehicles at Tesla's assembly plant. When complete, the plant was expected to use 35,000 t/yr of spherical graphite, produced from 95,000 t/yr of flake graphite, 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 had reached a battery production rate of about 20 gigawatthours per year (GWh/yr). By the end of the first quarter of 2019, Gigafactory 1 battery production reached a production rate of about 23 GWh/yr, which made it the world's leading battery plant by a substantial margin. Tesla reported production of more batteries in terms of kilowatthours 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, which was the originally announced production rate. At the end of 2019, Panasonic announced that it would be able to ramp up battery cell production to 54 GWh/yr. Tesla then increased the planned total Gigafactory 1 capacity to 105 GWh/yr of battery cells and 150 GWh/yr of total battery pack production (Lambert, 2018, 2019a, b).

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 included carbon-bonded brick, castable ramming, and gunning mixtures. Carbon-magnesite brick had applications in high-temperature corrosive environments, such as iron blast furnaces, ladles, and steel furnaces. Carbon-alumina linings were used principally 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 43% of natural graphite use in the United States in 2019. It was consumed mainly in batteries, brake linings, lubricants, powdered metals, refractories, and rubber. Amorphous graphite accounted for 57% 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 was used in several areas, such as steelmaking, depending on purity and particle size.

Synthetic graphite was used in more applications in the United States than natural graphite and accounted for an 88% share by quantity and a 98% share by value of the graphite consumption in 2019 (table 1). The main market for high-purity synthetic graphite was as an additive to increase carbon content in iron and steel. This market consumed a substantial portion of the synthetic graphite. Other important uses of all types of graphite were 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 was gradually giving way to carbon black, which was more economical. High-purity natural and synthetic graphite were 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 was used as pebbles for modular nuclear reactors and in high-strength composites for wind, tide, and wave turbines. In energy storage applications, graphite was used in bipolar plates for fuel cells and flow batteries, anodes for lithium-ion batteries, electrodes for supercapacitors, high-strength composites for fly wheels, phase change heat storage, and solar boilers. In energy management applications, graphite was used in high-performance polystyrene thermal insulation and for silicon chip heat dissipation. These new energy applications used value-added graphite products such as high-carbon purity, small particle size, potato shapes called spherical graphite; expanded graphite; and graphene. Current graphite capacity may not be adequate for the increasing demands of these new energy applications and might require increasing graphite supply when fully implemented (O'Driscoll, 2010).

Graphene has been referred to as "the world's next wonder material." It consists of a single atomic layer of carbon atoms arranged in a flat honeycomb pattern. Within a 1-millimeter-thick graphite flake, there are approximately 3 million stacked sheets of graphene. Crystalline flake graphite can be processed into graphene, which has unique properties. Graphene can be used to make inexpensive solar panels, very powerful transistors, and wafer-thin tablet computers that could be the next-generation tablets (Topf, 2012). Graphene's unique properties have the potential to make high-tech products thinner, transparent, flexible, and more powerful. It has 1,000 times the current capacity of copper wire, is 200 times stronger than structural steel, has 10 times greater heat conductivity than copper, and has 20% more flexibility without any damage than copper (Desjardins, 2012).

Prices

During 2019, no prices for mesh sizes of 90% carbon natural crystalline flake graphite were available, 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 32%, median yearend prices for medium mesh size decreased by 26%, and median yearend prices for large mesh size decreased by 23% from those in 2018; the average median yearend price for all crystalline sizes combined decreased by 27%. Prices for natural amorphous powder graphite decreased by 18% compared with those in 2018. Prices for synthetic graphite could not be compared because data were not available (table 4).

Prices for crystalline and crystalline flake graphite concentrates ranged from $470 to $820 per metric ton; prices for amorphous powder ranged from $330 to $395 per ton (table 4). The average unit value of all U.S. natural graphite exports increased by 35% to $3,210 per ton in 2019 from $2,370 per ton in 2018 (tables 1, 5). The average unit value of all U.S. natural graphite imports increased by 22% to $1,120 per ton in 2019 from $913 per ton in 2018 (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 production decreased by 21% to $4,230 per ton in 2019 from $5,360 per ton in 2018 (tables 1, 3). The average unit value of U.S. synthetic graphite exports increased slightly to $5,630 per ton in 2019 from $5,520 per ton in 2018 (tables 1, 5). The average unit value of all U.S. synthetic graphite imports increased by 74% to $5,760 per ton in 2019 from $3,310 per ton in 2018 (tables 1, 8).

Graphite prices peaked in early 2018, owing to Chinese processing plant closures combined with rising demand from the lithium-ion battery industry. The price peak in early 2018 was followed by some downward readjustments because of slower-than-expected short-term growth in lithium-ion batteries, continued overcapacity in China, and increasing levels of supply in the rest of the world. Prices continued declining through 2019 until the fourth quarter, when Syrah Resources Ltd. announced plans to significantly reduce its production, at the same time lithium-ion battery demand was rising (Roskill Information Services Ltd., 2020).

Foreign Trade

Total U.S. graphite exports decreased by 23% in tonnage to 46,700 t valued at $249 million in 2019 from 60,500 t valued at $302 million in 2018. Total graphite export tonnage was 13% natural graphite and 87% synthetic graphite (table 5). Total U.S. natural graphite imports decreased by 29% in tonnage to 50,300 t in 2019 from 70,700 t in 2018, and the value decreased by 13% to $56.1 million in 2019 from $64.5 million in 2018. The decrease in natural graphite imports resulted from substantial decreases in quantity and in value of the "amorphous" graphite category during 2019. Principal import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Madagascar, and Brazil, which combined accounted for 94% of the tonnage and 91% of the value of total natural graphite imports. Mexico and Madagascar were the leading suppliers of amorphous graphite. Sri Lanka provided all the lump and chippy dust. Canada and China were the leading suppliers of high-purity, expandable graphite varieties. China, Canada, Madagascar, and Brazil were, in descending order of tonnage, the leading suppliers of crystalline flake and flake dust graphite (table 6).

Total synthetic graphite imports decreased by 28% in tonnage to 93,400 t in 2019 from 129,000 t in 2018, but the value increased by 26% to $538 million in 2019 from $428 million in 2018. Principal import sources of synthetic graphite were, in descending order of tonnage, China, Mexico, Spain, Japan, Hong Kong, France, and Switzerland, which combined accounted for 90% of the tonnage and 92% of the value of total synthetic graphite imports (table 8).

World Review

World production of natural graphite decreased slightly in 2019 to an estimated 1.10 Mt from 1.11 Mt in 2018. Of this 1.10 Mt natural graphite production, an estimated 31% was amorphous, 69% was crystalline flake, and 0.4% was vein or lump graphite. China maintained its position as the world's leading graphite producer, with an estimated 700,000 t, or 64%

of total global production. Mozambique ranked second with 107,000 t, or 10% of the total, followed by Brazil, Madagascar, India, Russia, Ukraine, Norway, and Pakistan, in decreasing order of tonnage. These 10 countries accounted for 96% of world production (table 9).

Brazil.—In 2019, Brazil had estimated production of 96,000 t of marketable natural graphite. Nacional de Grafite Ltda. was the leading producer of natural flake graphite in Brazil from mines and plants at three sites in the State of Minas Gerais. Extrativa Metalquímica (also known as Grafite do Brasil) also produced natural flake graphite from its mine and plant located in Bahia. High-grade crystalline flake graphite projects were being developed in Brazil with five companies conducting or considering graphite exploration and development (Roskill Information Services Ltd., 2020).

Canada.—In 2019, Canada had two active open pit mines with combined production of about 11,000 t of natural flake graphite. Most production came from the Lac des Iles flake graphite mine in Quebec, operated by Imerys Graphite & Carbon. The Black Crystal flake graphite quarry in British Columbia owned by Eagle Graphite Corp. also produced natural flake graphite.

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., 2020).

China.—In 2019, China was the world's leading producer, exporter, and consumer of natural and synthetic graphite. China also may have the largest natural graphite resources in the world. Production in China was estimated to be 700,000 t of natural graphite, of which an estimated 392,000 t was flake graphite and the remaining 308,000 t was amorphous graphite; China accounted for about 64% of global natural graphite production. More than 60% of China's flake graphite was produced in Heilongjiang Province, and most of the country's amorphous graphite was produced in Hunan Province. The iron and steel industry was the leading consuming market of natural and synthetic graphite in China (Roskill Information Services Ltd., 2020).

China accounted for about 30% of global natural graphite imports in 2019 and 46% of natural graphite exports. China accounted for 3% of global synthetic graphite imports (which included graphite and carbon electrodes) and 40% of synthetic graphite exports (Roskill Information Services Ltd., 2020).

Continuing growth in Chinese natural flake and synthetic graphite production was being driven by the global lithium-ion battery industry, which was centered in China for almost all parts of the supply chain. China was the leading producer of battery-grade graphite (which included nearly all the world's spherical graphite processed from natural flake), anode materials, and the anodes and batteries themselves. Demand for synthetic graphite also was growing with increasing levels of electric arc furnace steel production in China, resulting in rising consumption of synthetic graphite electrodes. Chinese consumption of natural amorphous graphite declined during 2019. China accounted for an increasing share of global synthetic graphite production as electrode and global spherical graphite capacity. Chinese electrode manufacturers added approximately 0.6 t/yr of new capacity since 2017 and increased electrode capacity for all types of electrodes, not just synthetic graphite (Roskill Information Services Ltd., 2020).

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 like 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 became the subject of close examination in recent years because of its use of large quantities of hydrofluoric acid and other strong and hazardous reagents. The Government of China conducted inspections of processing plants during June and October 2018 to evaluate environmental progress, focused mainly on Heilongjiang and Shandong Provinces—the centers for flake and spherical graphite production. In recent years, Chinese flake graphite supply growth had been constrained by ongoing plant closures. The constrained growth of the Chinese flake graphite supply combined with increasing demand from the battery manufacturing sector, resulted in increased prices for natural flake graphite (averaged across flake sizes for 94% to 97% carbon grades) by an average of 45% from September 2017 to February 2018, but subsequently trended downwards through 2019. This decline resulted from new flake graphite supplies in the rest of the world flooding the market, as well as some limitations on demand as China cut its electric vehicle incentives, temporarily reducing demand for lithium-ion batteries. More processing plant inspections and closures are anticipated in the coming years and may well result in further price increases, though these are expected to be less severe than the previous inspections and closures. Natural flake graphite was seen as a particularly polluting industry because of its use of strong acids and other reagents, which potentially could affect the local environment and water supply if not handled properly and because of possible particulate air pollution (Roskill Information Services Ltd., 2019, 2020).

Madagascar.—In 2019, Madagascar had estimated production of 48,000 t of natural flake graphite. Malagasy production of natural flake graphite had increased steadily in recent years from both new and existing capacity. Flake graphite production jumped significantly in 2018 and 2019 for several reasons: (1) new investment in the existing mines of Établissements Gallois, (2) Chinese investment in the mines of Madagascar Graphite Ltd., (3) redevelopment of the Graphmada operation by Australian investment, and (4) redevelopment of the Sahamamy Mine by Indian investment. Malagasy exports increased significantly to 48,000 t in 2018 and increased again to 53,400 t in 2019. Most of this additional material was sent to China, which was the destination for 27,000 t of exports in 2018 and 32,000 t in 2019. Some of these exports may have been crude graphite for processing in China because the average value of exports was fairly low—$267 per ton in 2018 and $369 per ton in 2019. Malagasy exports also increased to Germany, India, and the United States in recent years. Tirupati Graphite Group, which owns the Sahamamy Mine, is an Indian company that exported an increasing amount of material to its other operations. In 2019, 59% of Malagasy exports were to China, 12% to India, 9% to the United States, 9% to Germany, and most of the remainder to other European countries (Roskill Information Services Ltd., 2020).

Mexico.—In 2019, Mexico had estimated production of 9,000 t of natural amorphous graphite. Mexico produced both natural and synthetic graphite. The United States has had a long tradition of investing in the Mexican graphite industry. U.S. companies owned shares in natural graphite mines and operated synthetic production capacity in Mexico. Mexican natural graphite production declined from about 30,000 t/yr in 2000 owing to increased competition from lower cost Chinese material, and it has remained less than 10,000 t/yr though much of the last decade. The production from the State of Sonora was amorphous graphite, most of which was mined underground. Almost all Mexican production of natural graphite was exported to the United States in 2019. In 2019, Mexico imported 2,530 t of natural graphite and exported 11,000 t of natural graphite. Mexican synthetic graphite imports in 2019 were 45,000 t and came from the United States (35%), China (25%), and Germany (11%). Mexico exported 46,000 t of synthetic graphite in 2019, 83% of which went to the United States. Electrodes accounted for 38% of Mexico's synthetic graphite imports and 52% of exports during 2019 (Roskill Information Services Ltd., 2020).

Mozambique.—In 2019, Mozambique had estimated production of 107,000 t of natural flake graphite. Mozambique became a leading producer in the global graphite market during 2018 and 2019. Mozambique quickly displaced Brazil as the largest producer outside of China during these years. The largest known graphite deposit in the world was the Balama deposit, owned by Syrah Resources (Australia), and located in the Cabo Delgado Province. Flake graphite production at the Balama Mine started at the end of 2017 and ramped up quickly throughout the following year. The Balama Mine was plagued with problems during 2018. Issues with ramping up the mine and processing facility kept production behind forecasts, although the company maintained its business plan. Balama reached full production in December 2018 and declared first commercial production on January 1, 2019. Full production was at a rate of 15,000 metric tons per month (t/mo), but Balama production was scaled back significantly during the fourth quarter of 2019 to a rate of 5,000 t/mo. Resources at Balama were estimated to be 1.1 billion metric tons, which was more natural graphite than that contained in all other known global deposits combined. Production of natural flake graphite began in Mozambique because of foreign investment. The initial success of the Balama Mine and its proximity to China's growing battery market attracted additional investment, with Mozambique becoming a focus for graphite development projects in recent years, most located close to existing producers in the Cabo Delgado Province. Most of the graphite from the Balama Mine was exported to China for processing into spherical graphite. Purchasers included Shenzhen BTR New Energy Materials, which was one of the world's leading producers of lithium-ion anode materials. Syrah Resources also was developing its own 20,000-t/yr spherical graphite plant in the U.S. State of Louisiana, which it hoped to supply with material from the Balama Mine. The Louisiana spherical graphite plant produced its first purified spherical graphite in November 2019, which it sent to potential customers for testing. Syrah Resources also had agreements in place to supply large size flake to China for use in expandable graphite.

The Ancuabe operation in Cabo Delgado Province was operated by Triton Minerals Ltd. (Australia). Work at the Ancuabe project began in June 2017. According to Triton Minerals, Ancuabe had the potential to become a major high-grade graphite project. Ancuabe was located near the Balama deposit. Triton Minerals completed a definitive feasibility study on the Ancuabe graphite project in December 2017, and a mining concession was granted in May 2019. The project was planned with 60,000 t/yr of capacity from a mill feed of 0.9 to 1.1 million metric tons per year and could produce graphite concentrate at 96% to 98% total graphitic carbon for use in expanded graphite and lithium-ion batteries. The mine life was expected to be 27 years. In March 2019, Triton Minerals signed a nonbinding memorandum of understanding with Qingdao Jinhui Graphite, which could invest in 10% of the Ancuabe project, receiving up to 15,000 t/yr of concentrate as offtake. Triton Minerals had been testing its graphite for use in downstream products such as foil, refractory, and flame retardant markets with another Chinese company, Xincheng Graphite. 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 (Roskill Information Services Ltd., 2017, p. 199; 2018, p. 223–225; 2020; Industrial Minerals, 2019; Syrah Resources Ltd., undated).

Tanzania.—During 2019, Tanzania produced an estimated 150 t of crystalline flake graphite. Several natural flake graphite deposits in Tanzania have been the focus of recent graphite exploration. As of 2019, there was no commercial graphite production in Tanzania, although small amounts of graphite had been exported for testing. Development of new projects in Tanzania had been hindered by tightening Government control of the mining sector in recent years. Mining licenses were suspended from July 2017 pending a major renovation of the fiscal and regulatory regime. A new mining commission was put in place with changes that included a requirement for the state to own at least 16% of mining projects and an increase in export duties. Mining licenses for foreign graphite developers began to be assigned again in September 2018 (Roskill Information Services Ltd., 2020).

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 uses 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 2030, surpassing the traditional leading graphite markets of electrodes and refractories. Electrodes and refractories end uses are expected to decline whenever steelmaking declines (Roskill Information Services Ltd., 2020).

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. Batteries accounted for about 7% of natural graphite consumption and 14% of total graphite consumption in 2019. The battery end-use is growing such that they could account for 25% of natural consumption and 36% of total graphite consumption by 2030 (Roskill Information Services Ltd., 2020). 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.

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TABLE 1
SALIENT NATURAL AND SYNTHETIC GRAPHITE STATISTICS[1]

		2015	2016	2017	2018	2019
United States:						
Natural:						
Exports:						
Quantity	metric tons	11,600	14,300	13,900	9,950 r	5,880
Value	thousands	$21,600	$21,100	$24,800	$23,600 r	$18,900
Imports for consumption:						
Quantity	metric tons	46,700	38,900	51,900	70,700	50,300
Value	thousands	$58,600	$47,600	$58,500	$64,500	$56,100
Apparent consumption:[2]						
Quantity	metric tons	35,100	24,700	38,000	60,700 r	44,400
Value	thousands	$36,900	$26,500	$33,700	$40,900 r	$37,300
Synthetic:						
Production:						
Quantity	metric tons	119,000	207,000	226,000	219,000	276,000
Value	thousands	$816,000	$658,000	$726,000	$1,170,000	$1,170,000
Exports:						
Quantity	metric tons	32,000	30,100	40,600	50,500 r	40,800
Value	thousands	$177,000	$145,000	$233,000	$279,000 r	$230,000
Imports for consumption:						
Quantity	metric tons	80,600	75,000	111,000	129,000	93,400
Value	thousands	$128,000	$127,000	$183,000	$428,000 r	$538,000
Apparent consumption:[2]						
Quantity	metric tons	167,000	252,000	296,000	298,000 r	328,000
Value	thousands	$767,000	$640,000	$676,000	$1,320,000 r	$1,470,000
World production, natural[e]	metric tons	917,000 r	813,000 r	880,000 r	1,110,000 r	1,100,000

[e]Estimated. [r]Revised.
[1]Table includes data available through August 25, 2020. Data are rounded to no more than three significant digits.
[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)
2018:				
Brake lining	1,010	$2,820 r	2,930 r	$5,350 r
Carbon products[3]	245 r	1,270 r	W	694 r
Foundries[4]	W	W	2,730 r	3,000 r
Lubricants[5]	844 r	3,220 r	2,730 r	8,100 r
Powdered metals	3,160 r	W	W	W
Refractories	W	W	W	W
Rubber	1,180	4,800	795 r	2,130 r
Other[6]	17,800 r	65,500 r	19,300 r	43,300 r
Total	24,200 r	77,600 r	28,400 r	62,600 r
2019:				
Brake lining	1,010	2,820	2,930	5,350
Carbon products[3]	238	1,260	W	680
Foundries[4]	W	W	2,730	3,010
Lubricants[5]	W	W	W	W
Powdered metals	W	W	W	W
Refractories	W	W	W	W
Rubber	W	W	765	2,080
Other[6]	21,900	98,200	24,700	56,200
Total	23,200	102,000	30,400	65,200

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Table includes data available through April 17, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes mixtures of natural and manufactured 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)
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
2019:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,100	W
Unmachined graphite shapes	9,000	W
Other[2]	173,000	1,170,000
Total	276,000	1,170,000

W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Table includes data available through April, 17, 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	2018	2019
Crystalline fine, 94% to 97% carbon, -100 mesh	650–840	470–540
Crystalline medium, 94% to 97% carbon, +100–80 mesh	800–1,000	640–690
Crystalline large, 94% to 97% carbon, +80 mesh	900–1,200	795–820
Amorphous powder, 80% to 85% carbon	400–480	330–395

[1]Prices are cost, insurance, and freight China to main European port.

Sources: Fastmarkets IM, December 2018 price movements; Fastmarkets IM, December 2019 price movements.

TABLE 5
U.S. EXPORTS OF NATURAL AND SYNTHETIC GRAPHITE, BY COUNTRY OR LOCALITY[1, 2]

	Natural[3]		Synthetic[4]		Total	
Country or locality	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)
2018:						
Belgium	267	$619	466	$1,960	733	$2,580
Brazil	139	290	1,250 r	8,060 r	1,390 r	8,350 r
Canada	4,420 r	2,670 r	7,300 r	18,300 r	11,700 r	21,000 r
China	269 r	808 r	3,080	52,000	3,350 r	52,800 r
France	30	97	2,690	13,500	2,720	13,600
Germany	317	1,150	1,250 r	16,900 r	1,560 r	18,100 r
India	422 r	1,410 r	1,040	2,810 r	1,470 r	4,220 r
Italy	97	283	2,150	12,400	2,250	12,700
Japan	727	2,560	3,040	21,200 r	3,760	23,800
Korea, Republic of	759 r	3,700 r	1,750	22,300	2,510 r	26,000 r
Mexico	1,320 r	3,750 r	14,300 r	22,800 r	15,600 r	26,600 r
Netherlands	249	2,780	2,620	12,000	2,870	14,800
Saudi Arabia	--	--	3,350	12,300 r	3,350	12,300 r
Taiwan	73 r	211 r	515	5,290	587 r	5,500 r
United Kingdom	89	540	1,660	3,030	1,740	3,570 r
Vietnam	39	129	552 r	28,000	591 r	28,100
Other	739 r	2,620 r	3,490 r	25,800 r	4,220 r	28,400 r
Total	9,950 r	23,600 r	50,500 r	279,000 r	60,500 r	302,000 r
2019:						
Belgium	248	861	433	4,340	681	5,200
Brazil	315	741	1,180	6,040	1,490	6,780
Canada	1,180	909	6,650	21,500	7,830	22,400
China	325	1,050	3,270	37,600	3,600	38,700
Colombia	253	406	296	822	550	1,230
France	17	48	1,320	6,110	1,330	6,160
Germany	432	1,130	1,800	15,600	2,230	16,700
India	334	1,100	790	2,420	1,120	3,520
Italy	52	131	1,220	10,700	1,270	10,800
Japan	602	2,310	2,870	22,800	3,470	25,200
Korea, Republic of	1,000	5,640	1,390	16,200	2,390	21,800
Mexico	479	939	12,100	24,700	12,600	25,600
Poland	17	65	634	3,920	651	3,980
Saudi Arabia	1	11	1,280	6,480	1,280	6,490
United Arab Emirates	--	--	554	1,090	554	1,090
United Kingdom	47	179	1,350	2,860	1,390	3,040
Other	574	3,340	3,650	46,600	4,220	49,900
Total	5,880	18,900	40,800	230,000	46,700	249,000

[r]Revised. -- Zero.
[1]Table includes data available through May 11, 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)
2018:										
Austria	1 r	$5 r	--	--	--	--	39	$25	40 r	$30 r
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	2,940 r	2,800 r	--	--	--	--	2,150 r	1,270 r	5,090	4,080
Mexico	--	--	--	--	(3)	4	13,300	5,650	13,300	5,660
Mozambique	1,340	607	--	--	--	--	--	--	1,340	607
Sri Lanka	--	--	556	$1,050	--	--	--	--	556	1,050
Switzerland	6	39	--	--	--	--	--	--	6	39
Turkey	20	38	--	--	--	--	--	--	20	38
United Kingdom	85	160	--	--	12	47	526	302	623	509
Other	3	14	--	--	3 r	96 r	--	--	6 r	110 r
Total	26,400 r	38,100 r	556	1,050	7,750	13,900	36,000 r	11,500 r	70,700	64,500
2019:										
Austria	--	--	--	--	--	--	169	113	169	113
Belgium	63	101	--	--	--	--	--	--	63	101
Brazil	2,620	4,980	--	--	--	--	21	24	2,640	5,010
Canada	3,960	5,430	--	--	6,590	8,810	--	--	10,600	14,200
China	12,900	14,400	--	--	4,440	8,130	28	25	17,400	22,500
Germany	69	233	--	--	64	826	--	--	132	1,060
Japan	205	418	--	--	102	1,570	--	--	307	1,990
Madagascar	3,450	2,610	--	--	--	--	2,040	1,390	5,480	4,000
Mexico	--	--	--	--	(3)	8	11,200	5,070	11,200	5,080
Mozambique	1,330	765	--	--	--	--	--	--	1,330	765
Netherlands	--	--	--	--	(3)	7	127	88	127	95
Norway	5	11	--	--	--	--	20	25	25	36
Sri Lanka	--	--	252	601	--	--	--	--	252	601
Turkey	1	6	--	--	--	--	20	28	20	34
United Kingdom	7	17	--	--	5	46	531	301	543	364
Vietnam	--	--	--	--	--	--	39	20	39	20
Other	5	20	--	--	3	83	--	--	8	103
Total	24,600	29,000	252	601	11,200	19,500	14,200	7,080	50,300	56,100

[r]Revised. -- Zero.
[1]Table includes data available through May 11, 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)
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
2019:		
Austria	4,650	54,300
China	9,140	41,100
France	673	3,060
Germany	2,220	24,400
India	21,200	51,600
Israel	102	1,170
Italy	3,190	31,400
Japan	7,570	96,800
Malaysia	980	8,590
Mexico	18,800	74,000
Poland	2,370	10,500
Russia	7,570	29,400
Spain	3,500	30,400
Ukraine	2,000	14,600
United Kingdom	784	5,240
Other	72	1,080
Total	84,800	478,000

[1]Table includes data available through April 17, 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	2018 Quantity (metric tons)	2018 Value[3] (thousands)	2019 Quantity (metric tons)	2019 Value[3] (thousands)
Austria	631	$4,440 r	81	$80
Belgium	83	722 r	7	247
Brazil	921	1,130 r	479	621
Canada	1,440	5,230 r	1,220	4,740
China	65,400	116,000 r	28,500	191,000
Egypt	89	256	18	19
France	7,670	60,100 r	4,640	34,700
Germany	1,630	13,200 r	1,800	15,500
Hong Kong	1,480	1,150 r	4,900	1,690
India	6,930	11,000 r	1,940	6,790
Italy	544	2,340 r	1,490	2,750
Japan	10,800	89,900 r	10,600	99,500
Korea, Republic of	635	6,520 r	695	7,200
Malaysia	698	777 r	69	279
Marshall Islands	415	145	--	--
Mexico	12,400	21,300 r	20,800	66,100
Netherlands	1,300	1,370 r	45	401
Norway	758	619 r	57	64
Poland	280	692 r	420	1,020
Russia	926	639 r	172	149
Spain	10,700	78,200 r	11,300	89,600
Sri Lanka	10	48	222	407
Sweden	135	409 r	58	148
Switzerland	2,910	10,400 r	3,350	12,100
Taiwan	78	267 r	57	266
United Arab Emirates	--	--	72	127
United Kingdom	185	949 r	409	1,690
Other	14 r	192 r	32	293
Total	129,000	428,000 r	93,400	538,000

[r]Revised. -- Zero.

[1]Table includes data available through April 17, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

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

[3]Customs values.

Sources: 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	2015	2016	2017	2018	2019
Australia, crystalline flake	500	--	--	--	--
Austria, amorphous[e]	700	800	1,000	1,000	1,000
Brazil, crystalline flake	81,762	61,687 [r]	90,000 [e]	95,000 [e]	96,000 [e]
Canada, crystalline flake	NA	NA	14,000 [r]	11,000 [r]	11,000
China:[e]					
Amorphous	275,000	300,000	275,000	305,000 [r, 2]	308,000 [2]
Crystalline flake	450,000	325,000	350,000	388,000 [r, 2]	392,000 [2]
Total	725,000	625,000	625,000	693,000 [2]	700,000 [2]
Germany, crystalline flake[e]	400	500	800	800	800
India:[3]					
Amorphous[e]	2,700	3,000	3,500	3,500 [4]	3,500 [4]
Crystalline flake	24,200 [e]	27,000 [e]	31,500 [e]	44,207 [r]	31,500 [e, 4]
Total	26,900	30,000	35,000	47,700 [r]	35,000 [4]
Korea, North:[e]					
Amorphous	1,000	1,000	1,000	1,080 [5]	1,080 [5]
Crystalline flake	4,500	4,500	4,500	4,920 [5]	4,920 [5]
Total	5,500	5,500	5,500	6,000	6,000
Madagascar, crystalline flake	8,006	9,200 [r]	13,300 [r]	47,900 [r]	48,000 [e]
Mexico, amorphous	8,100	8,500 [e]	9,000 [e]	9,000 [e]	9,000 [e]
Mozambique, crystalline flake	--	--	1,042	106,773 [r]	107,000 [e]
Namibia, crystalline flake	--	--	2,216	3,456	-- [6]
Norway, crystalline flake	9,185	10,000	11,000 [e]	16,000 [e]	16,000 [e]
Pakistan, crystalline flake	2,900	10,000 [e]	14,000 [e]	14,000 [e]	14,000 [e]
Russia:[e, 7]					
Amorphous	8,000	9,500	12,000	12,000	12,000
Crystalline flake	7,900	9,900	13,200	13,200	13,100
Total	15,900	19,400	25,200	25,200	25,100
Sri Lanka, vein	4,200	3,900	3,800 [r]	3,800 [r, e]	4,000 [e]
Sweden, crystalline flake	100	--	--	--	--
Tanzania, crystalline flake	--	1,191 [r]	128 [r]	150 [e]	150 [e]
Turkey, amorphous[e, 8]	1,800	2,000	2,300	2,000	2,000
Ukraine, crystalline flake	14,500	15,000 [e]	20,000 [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	6,362	5,622	1,577	-- [r]	-- [6]
Grand total[e]	917,000 [r]	813,000 [r]	880,000 [r]	1,110,000 [r]	1,100,000
Of which:					
Amorphous	297,000	325,000	304,000	334,000 [r]	337,000
Crystalline flake	615,000 [r]	485,000 [r]	572,000 [r]	771,000 [r]	760,000
Vein or lump	4,200	3,900	3,800 [r]	3,800 [r]	4,000

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]Table includes data available through August 25, 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]About 44% amorphous and 56% crystalline flake graphite.

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

[4]About 10% amorphous and 90% crystalline flake graphite.

[5]About 18% amorphous and 82% crystalline flake graphite.

[6]The mine entered care-and-maintenance status.

[7]About 48% amorphous and 52% crystalline flake graphite.

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