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GRAPHITE [ADVANCE RELEASE]

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Graphite

By Andrew A. Stewart

Domestic survey data and tables were prepared by Annie Hwang, statistical assistant.

In 2022, no domestic production of natural graphite was reported, but U.S. production of synthetic graphite increased to 319,000 metric tons (t) valued at $1.45 billion compared with 259,000 t valued at $1.16 billion in 2021. U.S. exports and imports of natural graphite were 9,500 t and 89,200 t, respectively, which increased by 10% and 68% from those in 2021. U.S. exports and imports of synthetic graphite were 38,700 t and 151,000 t, respectively. U.S. apparent consumption of natural and synthetic graphite was 79,700 t and 431,000 t, respectively. World production of natural graphite was estimated to be 1.68 million metric tons (Mt) (tables 1, 9).

Graphite is one of four forms of crystalline carbon; the others are carbon nanotubes, diamonds, and fullerenes. In graphite, the carbon atoms are arranged densely 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 gray to black in color, opaque, and usually has a metallic luster; 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 it exhibits perfect basal (one-plane) cleavage. Graphite is flexible but not elastic, has a melting point of 3,927 degrees Celsius (°C), and is highly refractory. It has a low specific gravity. Graphite is the most electrically and thermally conductive of the nonmetals and is chemically inert. All of these properties combined make both natural and synthetic graphite desirable for many industrial applications.

Natural graphite is classified into three types—amorphous, crystalline flake, and vein or lump and chippy. 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. Large amorphous graphite deposits are found in Europe, China, Mexico, and the United States. 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, such as flame retardants. The foremost deposits of flake graphite 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 it was mined commercially only in Sri Lanka.

Natural graphite was mined from open pits and underground mines. Production from open pit operations is preferred and is less expensive where the overburden can be removed economically. Most natural graphite was mined from open pits. In the Republic of Korea, Mexico, and Sri Lanka, where the deposits are deep, underground mining techniques were required.

Beneficiation processes for graphite varied 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.

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 99.95% 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 natural graphite included 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 were used principally in continuous casting steel operations. Alumina- and magnesite-carbon brick require graphite with a particle size of 100 mesh and a purity of 95% to 99%.

Spherical purified graphite (SPG) is the specialized form of graphite used as battery anode material. SPG is produced from natural flake graphite concentrate, which has been rounded,

micronized, purified to 99.95%, and coated. Outside of pilot and testing facilities, most SPG is produced in China. Small amounts of SPG are produced by American Energy Technologies Co. (AETC) (Glenview, IL) at its facility in Arlington Heights, IL, which was established in 2018 (American Energy Technologies Co., 2018). No major SPG facilities existed outside of China; however, 12 were in development in 2022, of which 4 were in the United States (Benchmark Mineral Intelligence Ltd., undated a).

Production

The U.S. Geological Survey (USGS) obtained the production data in this chapter through a voluntary survey of 21 domestic synthetic graphite producers. A response was received from eight companies, and 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 2022, but 319,000 t of synthetic graphite with a value of $1.45 billion was produced and shipped (tables 1, 3). This was a 23% increase in quantity produced and a 25% increase in value from that in 2021. This increase in quantity produced resulted from large increases in demand for graphite in the production of 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 (EAFs) 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 (Kopeliovich, 2020).

During 2022, four companies were evaluating and developing natural graphite mining projects in the United States. Graphite One Inc. (Vancouver, British Columbia, Canada) was developing a project in Alaska, Reflex Advanced Materials Corp. (Vancouver, British Columbia, Canada) was developing a project in Montana, and South Star Battery Metals Corp. (Vancouver, British Columbia, Canada) and Westwater Resources, Inc. (Centennial, CO) were developing projects in Alabama.

In 2022, Graphite One continued to evaluate and develop the Graphite Creek project, located in the Kigluaik Mountains on the Seward Peninsula in western Alaska. The Graphite Creek deposit is the largest known graphite resource in the United States and one of the largest globally (Case and others, 2023, p. 940). In April, Graphite One announced a memorandum of understanding (MOU) with Lab 4 Inc. (Dartmouth, Nova Scotia, Canada) to develop a lithium-ion battery recycling facility in Washington. The facility would be built adjacent to the anode manufacturing plant that Graphite One was also developing. In August, the company completed a prefeasibility study for the Graphite Creek project. Using a cutoff grade of 2.0% graphitic carbon (Cg), measured resources were estimated to be 4.67 Mt of 5.8% Cg for 272,000 t of graphite content, and indicated resources were estimated to be 27.9 Mt of 5.2% Cg for 1.44 Mt of graphite content. In 2022, Graphite One announced an MOU with Sunrise (Guizhou) New Energy Material Co., Ltd. (Zibo, China) to share expertise and technology for the design and operation of a secondary treatment plant. At full capacity, the plant was expected to produce about 7,590 metric tons per year (t/yr) of purified graphite for the specialty graphite market, 18,600 t/yr for the unpurified traditional graphite market, and 51,200 t/yr of anode material for the electric vehicle and energy storage markets. The company was exploring several locations in Washington for the plant (Graphite One Inc., 2022a; 2022b, p. 37, 42, 63).

Reflex continued to develop the Ruby Graphite project, located in Beaverhead County, MT. The project encompasses the historical Ground Hog and Bird's Nest Mines, which produced about 2,200 t of flake and vein graphite at an estimated 14% to 27% Cg. Graphite was discovered at the site in 1887, and mining operations and sales began in 1903. Mining ceased in 1918, at the conclusion of World War I. The mine was reopened in 1939, at the beginning of World War II, and continued production through 1950. In 2022, Reflex completed initial exploration at the site, which included geologic mapping, sampling, photogrammetry and elevation modeling, electromagnetic surveying, and an induced potential survey for identifying graphite-bearing intervals. Reflex announced that it would use the findings to determine drill targets for its 2023 drilling campaign (Reflex Advanced Materials Corp., 2023a; 2023b, p. 9, 24–26).

In 2022, South Star Battery Metals Corp. continued to develop the BamaStar graphite project in Alabama. The project covered approximately 200 hectares (500 acres) located in the Alabama graphite belt and included the Ceylon Graphite Mine, which was historically mined during World Wars I and II. In December, South Star completed its maiden drilling campaign, and the initial resource estimate was expected in early 2023 (South Star Battery Metals Corp., 2023).

During 2022, Westwater continued evaluating and developing the Bama Mine and Coosa graphite projects. The projects were within the Alabama graphite belt, high-quality graphite deposits from which significant quantities of graphite were produced from the late 1800s through the 1950s. In 2022, Westwater updated the mineral resource estimate from that obtained during a preliminary economic assessment (PEA) in 2015. Using a cutoff grade of 1.98% Cg, indicated resources were estimated to be 23.6 Mt of 2.89% Cg for 684,000 t of graphite content, and inferred resources were estimated to be 88 Mt of 3.08% Cg for 2.7 Mt of graphite content. In April 2022, Westwater began construction of the Kellyton processing plant, scheduled to begin operations in late 2023. During phase one, the company expected to produce 7,500 t/yr of coated SPG, expanding to 40,500 t/yr during phase two (Westwater Resources, Inc., 2022a, b, 2023).

Spherical Graphite Processing Facilities

In addition to the two SPG facilities in development by Graphite One and Westwater, two standalone facilities were under development in the United States. In 2022, Syrah Resources Ltd. (Melbourne, Victoria, Australia) continued construction of a spherical graphite plant in Vidalia, LA, expected to be operational by 2024. Capacity was expected to be 11,250 t/yr of SPG initially, expanding to 45,000 t/yr. In 2021, Syrah signed an offtake agreement to supply 8,000 t/yr of spherical graphite to Tesla Motors, Inc. (Austin, TX). In 2022,

Tesla exercised an option under the offtake agreement to acquire an additional 17,000 t/yr of spherical graphite from the Vidalia facility. Additionally, Syrah executed a nonbinding MOU for offtake supply with Ford Motor Company (Dearborn, MI) and SK On Co., Ltd. (Seoul, Republic of Korea) [a subsidiary of SK Innovation Co. Ltd. (Seoul, Republic of Korea)] in July, and LG Energy Solution, Ltd. (Seoul, Republic of Korea) in October. In 2022, Syrah received a $102 million loan from the U.S. Department of Energy (DOE) to fund the initial production of the Vidalia facility. Additionally, Syrah was selected for a $220 million grant from the DOE for the expansion project (Syrah Resources Ltd., 2023a, p. 8, 13, 33).

In 2022, Graphex Technologies LLC (Royal Oak, MI), a subsidiary of Graphex Group Ltd. (Hong Kong, China), announced a joint venture with Emerald Energy Solutions LLC (Royal Oak, MI) to construct a 15,000-t/yr spherical graphite processing facility in Warren, MI. Graphex had been operating a similar facility in China for more than 9 years, producing about 10,000 t/yr of spherical graphite (Graphex Group Ltd., 2022).

Synthetic Graphite Production Facilities

During 2022, two companies were expanding and developing synthetic graphite plants in the United States. NOVONIX Ltd. (Brisbane, Queensland, Australia) continued to scale production at its Riverside facility in Tennessee. In 2022, the company announced an agreement with KORE Power, Inc. (Coeur d'Alene, ID) to supply synthetic graphite anode material beginning in 2024. Under the agreement, NOVONIX would supply the material at a rate of 3,000 t/yr beginning in 2024, ramping up to 12,000 t/yr by 2028. In October 2022, the company was granted $150 million from the DOE, through funding from the Bipartisan Infrastructure Law, to expand synthetic graphite anode production. NOVONIX announced it would begin construction in 2023 on a new facility, expanding production capacity by an additional 30,000 t/yr (NOVONIX Ltd., 2022).

In March 2022, Anovion Technologies LLC (Chicago, IL) was launched when it acquired the battery materials division of Pyrotek Inc. (Spokane Valley, WA). The synthetic graphite production facility in Sanborn, NY, formerly owned by Pyrotek, had a production capacity of 5,000 t/yr. Additionally, the company announced an expansion plant that would increase capacity to 50,000 t/yr in 2025. In October, Anovion was selected to receive a $117 million grant through the Bipartisan Infrastructure Law to aid with increasing capacity. In addition to the expansion, the company planned to build an additional facility for producing synthetic graphite anode materials, with an estimated capacity of 35,000 t/yr. In November, Anovion announced an agreement with American Battery Factory Inc. (American Fork, UT) to supply graphite anode materials for its battery manufacturing facility, currently in early development (Anovion Technologies LLC, 2022a–c).

Consumption

The USGS obtained the consumption data in this chapter through a survey of 78 companies that imported and used natural graphite in the United States. Consumption data for synthetic graphite were not collected. Responses were received from 41 companies, and 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 most of the natural graphite industry in the United States.

U.S. consumption of natural graphite reported by end use increased by 7% to 55,400 t in 2022 from that in 2021 (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. Crystalline flake graphite accounted for 69% of natural graphite use in the United States in 2022. Reported consumption of natural crystalline graphite increased by 60% in 2022 to 38,200 t from 23,900 t in 2021. Amorphous graphite, which includes a small amount of mixed natural and synthetic graphite, accounted for 31% of natural graphite use. Consumption of amorphous graphite decreased by 39% in 2022 to 17,300 t from 28,100 t in 2021. The main uses of natural graphite during 2022 were batteries (28%), refractories (16%), powdered metals (7%), and lubricants (5%) (table 2). The leading application for synthetic graphite was as electrodes (33%) used in steel production (table 3). Amorphous graphite demand continued to face competition from flake powder, produced during advanced processing of flake graphite. Lump graphite was used in several areas, such as steelmaking, depending on purity and particle size.

U.S. apparent consumption of natural graphite increased by 80% to 79,700 t in 2022 from 44,300 t in 2021, whereas U.S. apparent consumption of synthetic graphite increased by 26% to 431,000 t in 2022 from 343,000 t in 2021. Total U.S. graphite consumption, combined natural and synthetic, increased by 32% to 511,000 t in 2022 from 387,000 t in 2021 (table 1).

Other important uses of natural and synthetic graphite were in the manufacture of catalyst supports, porosity-enhancing inert fillers, solid carbon shapes, and static and dynamic seals. 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, and semiconductive cable compounds. 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 tide, wave, and wind turbines. In energy storage applications, graphite was used in anodes for lithium-ion batteries, bipolar plates for fuel cells and flow 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 spherical graphite, expanded graphite, and graphene.

A recent and increasing source of graphite consumption was that of lithium-ion batteries, owing to increased demand for electric vehicles, energy storage, and portable electronic devices. Graphite is an essential component of many types of batteries, making up most of the material contained in the anode. In recent years, small amounts of silicon had been added to the anode to increase energy density. The addition of silicon was limited because of its high cost and tendency to swell during charging, leading to increased degradation of the cell. Until recent years, most graphite demand traditionally came from the refractory and foundry market. In 2022, the main end uses for natural graphite, globally, were batteries (42%) and refractories (32%). The main end uses for synthetic graphite, globally, were electrodes (49%) and batteries (16%). In 2022, total graphite consumption, natural and synthetic, increased by an estimated 8% from 2021. The increase in total consumption was attributed to the battery sector, which increased by an estimated 42% in 2022 from 2021 (Project Blue Group Ltd., 2023). The use of graphite in low-current batteries was being substituted by carbon black, which was more economical.

Anode material can be made with natural or synthetic graphite. Some companies combined natural and synthetic to utilize the strengths of each, especially in the electric vehicle (EV) market. Lithium-ion batteries for EVs, energy storage systems, and portable electronics were manufactured at giant battery-manufacturing facilities, measured in gigawatthours per year (GWh/yr). Most of these factories were in China, though in recent years more countries have begun to develop additional facilities. In 2022, there were nine battery-manufacturing facilities in operation domestically, located in California, Florida, Georgia, Michigan, Nevada, New York, Ohio, Tennessee, and Texas. These facilities accounted for an estimated 47 GWh/yr, with 20 more facilities in the planning stages. Worldwide, there were an additional 228 battery-manufacturing facilities, with another 169 facilities in the planning stages. China accounted for 179 of those facilities currently in operation and 126 of those in development (Benchmark Mineral Intelligence Ltd., undated b).

Prices

Prices for natural amorphous graphite ranged from $435 to $500 per metric ton, a decrease of 32% from those in 2021 (table 4). During 2022, prices for all mesh sizes of 90%-carbon natural crystalline flake graphite were not available, but prices were available for the higher quality 94%-carbon natural crystalline flake graphite. Of the 94%-carbon crystalline flake, the median yearend prices for fine mesh size increased by 10%, the median yearend prices for medium mesh size decreased by 22%, and the median yearend prices for large mesh size decreased by 14% from those in 2021. Average median yearend prices for all crystalline sizes combined decreased by 11% to $830 to $1,200 per metric ton. Uncoated spherical graphite prices ranged from $2,800 to $3,000, a decrease of 9% from those in 2021. Prices for synthetic graphite could not be compared because data were not available.

The average unit value of all U.S. natural graphite exports increased by 3% to $2,850 per metric ton in 2022 from $2,770 per metric ton in 2021 (tables 1, 5). The average unit value of all U.S. natural graphite imports increased by 57% to $2,090 per metric ton in 2022 from $1,340 per metric ton in 2021 (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 increased slightly to $4,550 per metric ton in 2022 from $4,480 per metric ton in 2021 (tables 1, 3). The average unit value of U.S. synthetic graphite exports increased by 4% to $5,820 per metric ton in 2022 from $5,600 per metric ton in 2021 (tables 1, 5). The average unit value of all U.S. synthetic graphite imports increased by 30% to $4,210 per metric ton in 2022 from $3,240 per metric ton in 2021 (tables 1, 8).

Foreign Trade

Total U.S. graphite exports increased by 17% in tonnage to 48,200 t valued at $252 million in 2022 from 41,200 t valued at $206 million in 2021 (table 5). Total graphite export tonnage was 20% natural graphite and 80% synthetic graphite. Total U.S. natural graphite imports increased by 68% in tonnage to 89,200 t in 2022 from 53,000 t in 2021, and the value increased by 164% to $187 million in 2022 from $70.7 million in 2021. The increase in natural graphite imports resulted largely from increased demand from the battery sector during 2022. Principal import sources of natural graphite were, in descending order of tonnage, China, Mexico, Madagascar, Canada, and Mozambique, which combined accounted for 95% of both the tonnage and the value of total natural graphite imports. China and Mexico were the leading suppliers of amorphous graphite. Sri Lanka provided all of the lump and chippy graphite. China was the leading supplier, accounting for 51% of the tonnage and 75% of the value of all natural graphite imports. Imports of natural graphite from China increased by 134% in tonnage and 332% in value. China was the main source of high-purity graphite varieties, such as battery anode material. China, Madagascar, Canada, and Mozambique were, in descending order of tonnage, the leading suppliers of crystalline flake and flake dust graphite (table 6).

Total synthetic graphite imports increased by 30% to 151,000 t in 2022 from 116,000 t in 2021, and the value increased by 69% to $635 million in 2022 from $376 million in 2021 (table 8). Principal import sources of synthetic graphite were, in descending order of tonnage, China, Mexico, Spain, Japan, Brazil, France, and Canada, which combined accounted for 91% of the tonnage and 86% of the value of total synthetic graphite imports. Imports of graphite electrodes increased by 45% in tonnage to 101,000 t in 2022 from 69,800 t in 2021, and the value increased by 74% to $363 million in 2022 from $209 million in 2021. Principal import sources of graphite electrodes, by tonnage, were India, 34%; Mexico, 20%; China, 11%; and Russia, 10% (table 7).

In 2022, SPG continued to be produced mainly in China. Imports of natural SPG from China increased by 525% to 14,400 t in 2022 from 2,300 t in 2021, and the unit value increased by 14% to $4,480 per metric ton in 2022 from $3,930 per metric ton in 2021. Imports of synthetic graphite battery material increased by 65% to 36,800 t in 2022 from 22,200 t in 2021, and the unit value decreased by 7% to

$5,130 per metric ton in 2022 from $5,520 per metric ton in 2021 (Zen Innovations AG, 2023).

World Review

World production of natural graphite increased by 10% in 2022 to an estimated 1,680,000 t from 1,520,000 t (revised) in 2021. Of the natural graphite production, an estimated 12.4% was amorphous, 87.4% was crystalline flake, and 0.2% was vein or lump graphite. China maintained its position as the world's leading natural graphite producer, with 1,212,000 t, or 72% of total global production. Mozambique ranked second with 165,932 t, or 10% of the total, followed by Madagascar, Brazil, and the Republic of Korea, in descending order of tonnage. These five countries accounted for 96% of world production (table 9).

Australia.—Australia had no natural graphite production, but eight companies were evaluating and developing projects. In 2022, Renascor Resources Ltd. (Kent Town, South Australia) continued to develop the Siviour project. In 2022, Renascor updated the measured mineral resource estimate to 16.8 Mt of 8.6% Cg for 1.4 Mt of graphite content, and the indicated resource estimate to 46 Mt of 7.1% Cg for 3.3 Mt of graphite content. The company had nonbinding offtake agreements for up to 60,000 t/yr of SPG. In 2022, Renascor secured a site for its SPG facility in Bolivar, South Australia, in addition to commencing a study to potentially increase the production capacity beyond 28,000 t/yr. In November 2022, Renascor received Government approval to move forward with the development of the Siviour Mine. Renascor planned to produce up to 150,000 t/yr of graphite concentrate (Renascor Resources Ltd., 2022a, p. 8–9, 60; 2022b).

In 2022, Quantum Graphite Ltd. (Melbourne, Victoria) continued to develop the Uley 2 project. The company completed a definitive feasibility study in 2019. The project was fully approved and was projected to produce 55,000 t/yr of coarse flake during a 12-year mine life. In 2022, Quantum signed a binding offtake agreement with MRI Trading AG (Zug, Switzerland) for 100% of production from Uley 2 (Quantum Graphite Ltd., 2022, undated).

Brazil.—In 2022, Brazil produced an estimated 72,000 t of marketable natural graphite (table 9). Nacional de Grafite Ltda. (Sao Paulo) 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 Ltda. (Sao Tiago) also produced natural flake graphite from its mine and plant located in Bahia.

In 2022, South Star Battery Metals began construction on the Santa Cruz graphite mine. Upon completion, Santa Cruz would be the first new graphite mine in the Americas since 1996. South Star expected to begin commercial production by the end of 2023. Phase one production was expected to be 5,000 t/yr of graphite concentrate, with plans to reach 50,000 t/yr during phase three (South Star Battery Metals Corp., 2023).

Canada.—In 2022, Canada produced about 13,000 t of natural flake graphite (table 9). Production came from the Lac des Iles (LDI) flake graphite mine in Quebec Province, owned by Northern Graphite Corp. (Ottawa, Ontario). In 2022, the company completed its acquisition of the Mousseau West graphite project, located about 80 kilometers from the LDI Mine. Northern Graphite intended to transport mined material from Mousseau West to the processing facility at LDI. The acquisition would act to extend the life at LDI because the mine was expected to be depleted in the next couple of years. In December 2022, Northern Graphite announced that it had a nonbinding letter of intent (LOI) with Graphex Technologies to negotiate a joint venture for the production of SPG. Northern Graphite also continued to progress the Bissett Creek graphite project, located between North Bay and Ottawa in Ontario Province (Northern Graphite Corp., 2022a, b).

In 2022, Nouveau Monde Graphite Inc. (Saint-Michel-des-Saints, Quebec) continued to develop the Matawinie graphite mine in Quebec Province, with access road construction and initial tree clearing having begun in 2021. Construction continued in 2022 and focused on building environmental infrastructure. When complete, Nouveau Monde was expected to produce 103,000 t/yr of graphite concentrate during a mine life of 25 years. The company also continued to develop a battery material plant, to be located in Becancour, that was expected to produce about 43,000 t/yr of graphite anode material and 3,000 t/yr of purified jumbo flake graphite. In 2022, Nouveau Monde and Panasonic Energy Co., Ltd. (Osaka, Japan) [a subsidiary of Panasonic Holdings Corp. (Osaka, Japan)] signed an MOU for a multiyear offtake agreement for anode material from the Becancour facility (Nouveau Monde Graphite Inc., 2023, p. 4, 17, 22).

In 2022, Mason Graphite Inc. (Laval, Quebec) and Nouveau Monde entered into a joint agreement to develop the Lac Guéret project in northeastern Quebec Province. The project was subsequently renamed the Uatnan mining project. Using a cutoff grade of 5.75% Cg, combined measured and indicated resources were estimated to be 65.6 Mt of 17.2% Cg for 11.3 Mt of graphite content. In 2022, the companies initiated a PEA with a planned capacity of 250,000 t/yr. During phase three, production would potentially be expanded to approximately 500,000 t/yr, with 100% of the material intended for the anode market (Nouveau Monde Graphite Inc., 2023, p. 23–24).

China.—In 2022, China was the world's leading producer, exporter, and consumer of natural and synthetic graphite. China's production was 1,212,000 t of natural graphite, of which an estimated 1,030,000 t was flake graphite and the remaining 182,000 t was amorphous graphite; this was about 72% of the total global production (table 9). Most of China's flake graphite was produced in Heilongjiang Province, and most of the country's amorphous graphite was produced in Hunan Province.

Continued 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 of the world's spherical graphite processed from natural flake), anode materials, and the anodes and batteries themselves. In 2022, China also led global synthetic graphite production, accounting for an estimated 66% (Benchmark Mineral Intelligence Ltd., undated c).

Spherical purified graphite, for use in lithium-ion batteries, was produced mainly in China. In 2022, China increased production of SPG by an estimated 28% from that in 2021, accounting for nearly 100% of the global supply (Benchmark

Mineral Intelligence Ltd., undated a). China exported 62,300 t of SPG in 2022, an increase of 10% from 56,800 t in 2021. Top destinations in 2022 were the Republic of Korea (58%), the United States (23%), and Japan (16%) (Zen Innovations AG, 2023). Most SPG produced in China was uncoated. Traditionally, Japan and the Republic of Korea have added coatings to the imported SPG and exported the material back to China (Roskill Information Services Ltd., 2020, p. 227). In recent years, China also produced and exported synthetic graphite anode material. In 2022, China exported 84,600 t of synthetic anode material, an increase of 47% from 57,600 t in 2021. Top destinations in 2022 were the United States (43%), Japan (20%), and Hungary (18%) (Zen Innovations AG, 2023).

Finland.—In 2022, Grafintec Oy (Vaasa) [a subsidiary of Beowulf Mining plc (London, United Kingdom)] signed an MOU with Qingdao Hensen Graphite Co., Ltd. (Laixi, China) to establish a graphite anode materials production facility in Vaasa. Graphite feedstock would come from the Aitolampi project, currently under development by Grafintec. The company had two additional graphite projects in Finland, Raapysjarvi and Karhunmaki, both in the exploration phase (Grafintec Oy, 2022).

Guinea.—SRG Mining Inc. (Montreal, Quebec, Canada) continued to develop the Lola Graphite project in 2022. SRG completed a feasibility study for the project in 2019 and began an updated one in 2022. Using an average cutoff grade of 1.2% Cg, the company updated its measured resource estimate to 8.26 Mt at 4.04% Cg for 334,000 t of graphite content. SRG also updated the project's production capacity to 94,000 t/yr of graphite concentrate during a 17-year mine life (SRG Mining Inc., 2023).

Madagascar.—In 2022, Madagascar had estimated production of 130,000 t of natural flake graphite (table 9). Production of natural flake graphite increased steadily in recent years from both existing and new capacity. Tirupati Graphite plc (London, United Kingdom) continued to develop the Sahamamy and Vatomina projects. Commercial production began at Vatomina in December 2021, with a capacity of 9,000 t/yr of flake graphite concentrate. Vatomina development plans included an additional 54,000 t/yr of capacity. In 2022, Tirupati continued to construct an additional 18,000-t/yr module at Sahamamy, which had existing capacity of 3,000 t/yr of flake graphite concentrate. In September 2022, the company announced that it would be acquiring three additional mining permits located near the Sahamamy and Vatomina projects (Tirupati Graphite plc, 2021, 2022).

In 2022, Greenwing Resources Ltd. (Brisbane, Queensland, Australia) continued to develop the Graphmada Complex, that was on care-and-maintenance status pending stage two expansion. The expansion would aim to increase production to 40,000 t/yr of graphite concentrate. In 2022, the company expanded its measured mineral resource to 18.7 Mt at 4.9% Cg for 911,000 t of graphite content, and the indicated resources estimate to 12.3 Mt of 4.7% Cg for 582,000 t of graphite content (Greenwing Resources Ltd., 2022a; 2022b, p. 54).

NextSource Materials Inc. (Toronto, Ontario, Canada) continued to progress the Molo graphite project, which started construction in early 2022. Using an average cutoff grade of 3% Cg, measured resources were estimated to be 23.6 Mt of 6.3% Cg for 1.49 Mt of graphite content. The company planned to produce 17,000 t/yr of concentrate during phase one. In February, the company announced the results of a PEA for phase two of the project. The study considered a processing plant capable of producing 150,000 t/yr of graphite concentrate during a 26-year life of mine. In October, NextSource started construction of the graphite processing plant, followed by site acceptance testing and mine commissioning. NextSource also planned to build several battery anode facilities to produce SPG. In October 2022, the company selected a site for the first facility (NextSource Materials Inc., 2022a, p. 23, 28–29; 2022b).

In 2022, Evion Group NL (Perth, Western Australia, Australia), formerly BlackEarth Minerals NL, continued to develop the Maniry project. In November 2022, the company completed a definitive feasibility study. During stage one, Evion planned to produce 39,000 t/yr of graphite concentrate, expanding to 56,000 t/yr during stage two. The estimated project life was 21 years. In December, the company signed a nonbinding offtake agreement for providing 15,000 t/yr of Maniry graphite to Urbix Resources LLC (Mesa, AZ). Urbix would use the graphite in the production of coated SPG for the electric vehicle battery industry (BlackEarth Minerals NL, 2022, p. 2; Evion Group NL, 2022).

Mexico.—In 2022, Mexico produced 2,000 t of natural amorphous graphite (table 9). Mexico produced both natural and synthetic graphite. The United States has had a long tradition of investing in the Mexican graphite industry. United States companies owned shares in natural graphite mines and operated synthetic production capacity in Mexico. Almost all Mexican production of natural graphite was exported to the United States. In September, inspectors from the State Attorney's Office for the Environment of the State of Nuevo Leon issued a temporary suspension of operations at a graphite electrode manufacturing facility in Monterrey, owned by GrafTech Mexico, S.A. de C.V. (Nuevo Leon), a subsidiary of GrafTech International Ltd. (Brooklyn Heights, OH). Although the company operated multiple facilities globally, the Monterrey location was the sole producer of connecting pins, which were used to connect graphite electrodes together in an EAF. The suspension was conditionally lifted in November, subject to the completion of an environmental impact study and other required environmental activities (GrafTech International Ltd., 2023, p. 11).

Mozambique.—In 2022, Mozambique produced 165,932 t of natural flake graphite (República de Moçambique, 2023, p. 37) (table 9). Production at the Balama Mine, owned by Syrah, located in Cabo Delgado Province, increased by about 130% to 163,000 t in 2022 from 72,000 t in 2021. As of 2022, the Balama ore reserve estimate was 110 Mt at 16.4% Cg for 18.0 Mt of graphite content. In September, operations at Balama were halted because of a strike but were restarted 41 days later (Syrah Resources Ltd., 2023a, p. 6, 28–29; 2023b).

In recent years, Mozambique experienced an ongoing insurgency in the northern part of the country, where Balama and other graphite projects are located. The insurgency led to travel disruptions and security incidents, which negatively affected operations (Syrah Resources Ltd., 2022a, b; Triton Minerals Ltd., 2022).

Namibia.—In 2022, Northern Graphite acquired the Okanjande graphite project and the Okorusu processing plant in Namibia. In 2022, Northern Graphite completed a PEA for the restart of operations at Okanjande. The company planned to restart production during 2023 at an average rate of 31,000 t/yr (Northern Graphite Corp., 2022c, d).

Gratomic Inc. (Toronto, Ontario, Canada) continued to progress the Aukam vein graphite project to operational status. Aukum was the site of historical mining from 1940 to 1974. In April 2022, the company announced that it had processed the first graphite ore from the Aukum plant. In August, Gratomic began a bench-mining program, which involved cutting berms along the mountain edge. The company planned to begin commercial operations in 2023 (Gratomic Inc., 2023, p. 5, 20, 22–23).

Sweden.—In 2022, Talga Group Ltd. (Perth, Western Australia, Australia) commissioned a battery anode qualification plant in Lulea. The feedstock would come from the Vittangi graphite project. The company also was evaluating two additional projects in Sweden, the Jalkunen and Raitajarvi. In September 2022, Talga announced a nonbinding offtake agreement with Automotive Cells Company SE (Levallois-Perret, France) to supply 60,000 t of anode material over 5 years. Automotive Cells Company was a battery maker co-owned by Mercedes-Benz Group AG (Stuttgart, Germany), Stellantis N.V. (Hoofddorp, Netherlands), and Saft (Levallois-Perret, France) [a subsidiary of TotalEnergies (Courbevoie, France)] (Talga Group Ltd., 2022a, b).

Tanzania.—In 2022, Tanzania produced an estimated 6,120 t of natural flake graphite (table 9). Tanzania had been a recent target for exploration, with many companies developing potential projects. In 2022, Walkabout Resources Ltd. (Perth, Western Australia, Australia) continued construction at the Lindi Jumbo graphite mine. In 2022, Walkabout signed a binding offtake agreement with Wogen Pacific Ltd (Wan Chai, China) for the entirety of production, expected to be 40,000 t/yr. Wogen, a metal and mineral trading company, would distribute the graphite into the global market (Walkabout Resources Ltd., 2022).

In 2022, EcoGraf Ltd. (Perth, Western Australia, Australia) completed a bankable feasibility study for the Epanko graphite project. The company planned to produce 60,000 t/yr of flake graphite concentrate from Epanko. EcoGraf also continued to develop a battery anode material facility with a 25,000-t/yr capacity. In 2021, EcoGraf signed a nonbinding MOU with POSCO International [a subsidiary of POSCO Holdings Inc. (Pohang, Republic of Korea)] to supply battery material from the planned facility. In February 2022, the company was conditionally approved for a $40 million loan by the Australian Government for the battery anode facility. Additionally, EcoGraf continued to develop a battery anode material recycling program, with the initial focus on production scrap. The company also continued to develop the Merelani-Arusha graphite project (EcoGraf Ltd., 2022a, p. 9, 12, 15; 2022b).

Volt Resources Ltd. (Perth, Western Australia, Australia) continued to advance the Bunyu graphite project. In February 2022, Volt signed a letter of intent to supply battery anode materials for a battery manufacturing facility in the United States being developed by Energy Supply Developers, LLC (Lambertville, NJ). In April, Volt entered a joint development agreement with Urban Electric Power Inc. (Pearl River, NY) and AETC. The joint project would test nonspherical graphite for improving alkaline battery performance. The nonspherical purified graphite is a byproduct of the spheroidization process when making graphite anode material for lithium-ion batteries. In June, Volt signed an LOI with Graphex Technologies for 5,000 t/yr, expandable to 10,000 t/yr, of Bunyu fine flake graphite over 10 years. In August, Volt began an updated feasibility study for stage one of the Bunyu graphite project. During stage one, the company planned to produce 23,700 t/yr of graphite concentrate, expanding to 170,000 t/yr in stage two. In October, Volt entered into an MOU with 24M Technologies, Inc. (Cambridge, MA) to collaborate and qualify graphite from Volt's anode material and cathode conductivity additive (Volt Resources Ltd., 2022a; 2022b, p. 2, 7, 9; 2022e).

Magnis Energy Technologies Ltd. (Sydney, New South Wales, Australia) completed a bankable feasibility study in 2016 for the Nachu project and an updated study in 2022. Using a cutoff grade of 3% Cg, measured resources were estimated to be 63 Mt of 4.7% Cg for 3.0 Mt of graphite content, and indicated resources were estimated to be 61 Mt of 5.7% Cg for 3.5 Mt of graphite content. Magnis expected to produce an average of 236,000 t/yr of flake graphite concentrate during a 15-year mine life. In December 2021, the company announced an offtake agreement with Traxys S.à.r.l. (Strassen, Luxembourg) to supply 600,000 t of high-purity graphite during a 6-year period. In October 2022, Magnis announced plans to establish an anode material processing plant in the United States. The anode material would be produced using graphite feedstock from the Nachu graphite project (Magnis Energy Technologies Ltd., 2022a, p. 15–16, 34; 2022b).

In 2022, Black Rock Mining Ltd. (Perth, Western Australia, Australia), through its Tanzanian subsidiary Faru Graphite Corp., continued to develop the Mahenge project. Black Rock completed a definitive feasibility study in 2018, an updated study in 2019, and updated the measured mineral resource estimate in 2022. Measured resources were estimated to be 31.8 Mt of 8.6% Cg for 2.7 Mt of graphite content, and indicated resources were estimated to be 84.6 Mt of 7.8% Cg for 6.6 Mt of graphite content. In 2022, Faru signed a conditional framework agreement with Urbix for phase two graphite supply. Under the agreement, Faru would supply 7,500 t/yr of fine flake graphite, increasing to 15,000 t/yr following production rampup. The company had offtake agreements for 70% (60,000 t/yr) of phase one production. Stage one production was expected to be 89,000 t/yr, expanding to 347,000 t/yr during stage four (Black Rock Mining Ltd., 2022a, p. 12, 19, 41, 53; 2022b).

In 2022, Evolution Energy Minerals Ltd. (Perth, Western Australia, Australia) continued to develop the Chilalo graphite project. In 2022, the company signed a binding offtake agreement with Yichang Xincheng Graphite Co., Ltd. (Dangyang, China) for 30,000 t/yr of coarse flake graphite for a minimum of 3 years. Yichang Xincheng Graphite manufactured a range of graphite products, such as expandable graphite and graphite foils. Additionally, the two companies announced a joint venture for a 25,000-t/yr processing facility for graphite products including graphite foil, bipolar plates, and seals for

electric vehicles. In 2022, Evolution announced that Chilalo graphite had been successfully spheroidized, purified, and coated for use as battery anode material (Evolution Energy Minerals Ltd., 2022a–c).

Ukraine.—In February 2022, Volt halted graphite production in Ukraine, citing Russian military action. Operations recommenced in August but were halted again in November owing to energy supply disruptions. Because of ongoing disruptions related to the conflict, mine production was not restarted prior to the winter season mine closure (Volt Resources Ltd., 2022c, d, 2023).

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, energy storage, fuel cells, graphene, lithium-ion batteries, pebble-bed nuclear reactors, and solar power.

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. Powder flake graphite, produced during the advanced processing of fine and medium flake graphite, will likely continue to displace demand for natural amorphous graphite.

The battery end-use sector is expected to continue to grow, owing to increased consumption from electric vehicles, energy storage, and portable electronics. These applications require larger, more-powerful, and more-graphite-intensive lithium-ion batteries. With 20 additional battery production factories planned domestically, demand for flake graphite is expected to increase significantly in the near future. Global flake graphite consumption has increased by 80% since 2018, owing largely to consumption in the battery end-use market, which increased by an estimated 370% during the same period. Since 2018, global synthetic graphite consumption has increased by 23%, also owing largely to consumption in the battery end-use market, which increased by approximately 280% during the same period (Benchmark Mineral Intelligence Ltd., undated a, c).

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TABLE 1
SALIENT NATURAL AND SYNTHETIC GRAPHITE STATISTICS[1]

(Metric tons and thousand dollars)

	2018	2019	2020	2021	2022
United States:					
Natural:					
Exports:					
Quantity	9,950	5,880	5,920	8,660 r	9,500
Value	23,600	18,900	20,400	24,000	27,100
Imports for consumption:					
Quantity	70,700	50,100	36,000	53,000 r	89,200
Value	64,500	56,100	44,600	70,700 r	187,000
Apparent consumption:[2]					
Quantity	60,700	44,200	30,000	44,300 r	79,700
Value	40,900	37,200	24,200	46,700 r	159,000
Synthetic:					
Production:					
Quantity	219,000	286,000	225,000	259,000	319,000
Value	1,170,000	1,240,000	1,140,000	1,160,000	1,450,000
Exports:					
Quantity	50,400	40,700	26,900	32,500	38,700
Value	279,000	230,000	159,000	182,000	225,000
Imports for consumption:					
Quantity	129,000 r	92,200 r	62,400	116,000	151,000
Value	428,000 r	532,000 r	314,000	376,000 r	635,000
Apparent consumption:[2]					
Quantity	298,000 r	338,000 r	261,000	343,000 r	431,000
Value	1,320,000 r	1,540,000 r	1,300,000	1,360,000	1,860,000
World production, natural[3]	1,490,000 r	1,520,000 r	1,300,000 r	1,520,000 r	1,680,000

rRevised.
[1]Table includes data available through August 21, 2023. Data are rounded to no more than three significant digits.
[2]Defined as domestic production plus imports minus exports.
[3]May include estimated data.

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

End use	Crystalline		Amorphous[2]		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2021:						
Batteries	W	W	W	W	3,750	$30,900
Brake linings	1,050	$3,220	2,080	$1,800	3,120	5,020
Carbon products[3]	226	1,210	W	W	226	1,210
Foundries[4]	W	W	1,920	2,100	1,920	2,100
Lubricants[5]	W	W	W	W	W	W
Powdered metals	W	W	W	W	4,740	11,200
Refractories	W	W	W	W	9,020	12,700
Rubber	W	W	406	945	406	945
Other[6]	22,600	94,300	23,700	39,200	28,800	78,700
Total	23,900	98,700	28,100	44,100	52,000	143,000
2022:						
Batteries	W	W	W	W	15,400	105,000
Brake linings	860	2,970	1,400	1,880	2,260	4,850
Carbon products[3]	W	W	W	W	758	2,360
Foundries[4]	W	W	W	W	1,580	6,020
Lubricants[5]	493	2,480	2,510	3,370	3,000	5,850
Powdered metals	W	W	W	W	3,860	9,800
Refractories	W	W	W	W	9,100	12,100
Rubber	W	W	W	W	1,630	3,690
Other[6]	36,800	170,000	13,400	40,000	17,800	71,900
Total	38,200	176,000	17,300	45,300	55,400	221,000

W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Table includes data available through August 14, 2023. 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, 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)
2021:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,100	W
Unmachined graphite shapes	9,050	W
Other[2]	157,000	$1,160,000
Total	259,000	1,160,000
2022:		
Cloth and fibers (low modulus)	W	W
Electrodes	106,000	W
Unmachined graphite shapes	9,820	W
Other[2]	203,000	1,450,000
Total	319,000	1,450,000

W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Table includes data available through August 14, 2023. 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, 2]

(Dollars per metric ton)

Type	2021	2022
Amorphous powder, 80% to 85% carbon	635–750	435–500
Crystalline fine, 94% to 97% carbon, -100 mesh	755	830
Crystalline medium, 94% to 97% carbon, +100 mesh	1,250	980
Crystalline large, 94% to 97% carbon, +80 mesh	1,395	1,200
Graphite spherical, 99.95% carbon, 15 microns	3,100–3,300	2,800–3,000

[1]Prices are cost, insurance, and freight China to main European port.
[2]Price ranges are unavailable, unless otherwise specified.

Sources: Fastmarkets IM, December 2022 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)
2021:						
Belgium	477	$1,070	263	$1,990	740	$3,060
Brazil	161	229	1,060	6,560	1,220	6,790
Canada	2,130	1,970 r	5,500	17,000	7,620 r	19,000
China	198	918	2,130	26,800	2,330	27,700
France	75	214	1,620	10,600	1,690	10,900
Germany	336	935	448	12,700	783	13,600
India	486 r	1,770	735	4,000	1,220	5,770
Italy	81	263	1,140	11,400	1,220	11,600
Japan	695	3,040	743	6,290	1,440	9,330
Korea, Republic of	1,200	7,330	1,530	19,600	2,730	26,900
Mexico	1,940	2,520	11,000	21,900	13,000	24,400
Poland	155	329	789	1,940	944	2,260
Saudi Arabia	1	19	728	2,630	730	2,650
Taiwan	63	167	618	10,800	681	11,000
United Arab Emirates	2	11	620	1,330	622	1,340
United Kingdom	106	205	1,060	2,660	1,160	2,870
Other	557	3,010	2,530	24,000	3,090	27,000
Total	8,660 r	24,000	32,500	182,000	41,200	206,000
2022:						
Belgium	432	1,000	718	2,580	1,150	3,580
Brazil	10	40	1,600	8,690	1,610	8,730
Canada	3,010	2,220	4,110	19,400	7,120	21,600
China	405	1,250	2,800	37,400	3,200	38,700
Czechia	--	--	535	957	535	957
France	(6)	3	1,740	13,100	1,740	13,100
Germany	295	983	936	17,800	1,230	18,800
India	349	1,190	556	4,480	905	5,670
Italy	66	180	1,160	13,200	1,230	13,400
Japan	459	2,010	1,160	9,610	1,610	11,600
Korea, Republic of	1,510	10,500	1,200	12,700	2,710	23,200
Mexico	2,400	4,730	12,000	29,700	14,400	34,400
Poland	6	57	1,180	3,560	1,180	3,620
Saudi Arabia	--	--	1,670	8,460	1,670	8,460
Taiwan	15	49	598	10,800	614	10,900
United Arab Emirates	1	23	3,090	4,310	3,090	4,330
United Kingdom	19	136	1,160	3,140	1,180	3,280
Other	522	2,630	2,480	25,500	3,010	28,100
Total	9,500	27,100	38,700	225,000	48,200	252,000

rRevised. -- Zero.
[1]Table includes data available through August 14, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Numerous countries and (or) localities for which data were reported have been combined in "Other."
[3]Amorphous, crystalline flake, lump and chip, and natural, not elsewhere classified. The applicable Schedule B nomenclatures are "Natural graphite in powder or in flakes" and "Other," codes 2504.10.0000 and 2504.90.0000, respectively.
[4]Includes data from applicable Schedule B 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, 3801.20.0000, 3801.90.0000, and 6903.10.0000, respectively.
[5]Free alongside ship value.
[6]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY OR LOCALITY[1]

Country or locality	Crystalline flake and flake dust[2]		Lump and chippy dust[3]		Other natural crude, high-purity, expandable[4]		Amorphous[4]		Total	
	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)
2021:										
Argentina	--	--	--	--	(6)	$6	--	--	(6)	$6
Austria	157	$150	--	--	1	15	97	$63	255	228
Bahrain	--	--	--	--	3	13	--	--	3	13
Belgium	37	83	--	--	--	--	--	--	37	83
Brazil	2,990	5,410	--	--	164	550	--	--	3,150	5,960
Canada	9,980	14,100	--	--	66	415	23	6	10,100	14,500
China	6,470 r	10,800 r	--	--	4,700 r	16,000 r	8,130	5,390	19,300 r	32,200 r
France	--	--	--	--	72	292	--	--	72	292
Germany	116	225	--	--	117	669	--	--	233	894
Hong Kong	177	169	--	--	--	--	2,340	1,590	2,520	1,760
India	8	13	--	--	--	--	--	--	8	13
Ireland	--	--	--	--	(6)	25	--	--	(6)	25
Italy	--	--	--	--	10	26	--	--	10	26
Japan	40	94	--	--	71	550	--	--	111	644
Korea, Republic of	--	--	--	--	3	19	--	--	3	19
Libya	--	--	--	--	(6)	13	--	--	(6)	13
Madagascar	5,870 r	4,830 r	--	--	110	820	-- r	-- r	5,980	5,650
Mexico	1,070	1,040	--	--	--	--	6,680	3,770	7,740	4,810
Mozambique	2,770	2,450	--	--	--	--	--	--	2,770	2,450
Netherlands	20	26	--	--	14	40	--	--	34	67
Norway	70	98	--	--	6	33	--	--	76	132
Spain	--	--	--	--	(6)	3	--	--	(6)	3
Sri Lanka	--	--	340	$684	--	--	--	--	340	684
Turkey	--	--	--	--	--	--	20	7	20	7
United Arab Emirates	41	52	--	--	--	--	--	--	41	52
United Kingdom	13	30	--	--	4	50	160	124	177	203
Total	29,800 r	39,600 r	340	684	5,340 r	19,500 r	17,500 r	11,000 r	53,000 r	70,700 r
2022:										
Australia	--	--	--	--	19	70	--	--	19	70
Austria	96	132	--	--	4	96	--	--	100	229
Belgium	20	41	--	--	7	18	--	--	27	59
Brazil	1,930	3,490	--	--	402	1,100	--	--	2,330	4,590
Canada	8,090	12,600	--	--	297	872	9	3	8,400	13,500
China	16,800	21,700	--	--	26,400	116,000	1,840	917	45,100	139,000
France	--	--	--	--	120	534	--	--	120	534
Germany	22	39	--	--	145	930	--	--	167	969
Hong Kong	82	92	--	--	--	--	1,080	639	1,160	732
Ireland	--	--	--	--	(6)	49	--	--	(6)	49
Japan	--	--	--	--	143	884	--	--	143	884
Korea, Republic of	--	--	--	--	61	408	--	--	61	408
Madagascar	10,800	9,850	--	--	(6)	10	--	--	10,800	9,860
Malaysia	--	--	--	--	(6)	2	--	--	(6)	2
Martinique	20	23	--	--	--	--	--	--	20	23
Mexico	176	196	--	--	--	--	12,000	6,830	12,200	7,020
Mozambique	8,070	7,000	--	--	--	--	--	--	8,070	7,000
Norway	64	122	--	--	27	90	--	--	91	212
Poland	--	--	--	--	1	25	--	--	1	25
Sri Lanka	--	--	301	779	--	--	--	--	301	779
Sweden	--	--	--	--	(6)	28	--	--	(6)	28
Switzerland	--	--	--	--	(6)	13	--	--	(6)	13
Taiwan	--	--	--	--	(6)	16	--	--	(6)	16
United Arab Emirates	58	78	--	--	--	--	--	--	58	78
United Kingdom	--	--	--	--	44	339	--	--	44	339
Total	46,300	55,400	301	779	27,700	122,000	14,900	8,390	89,200	187,000

See footnotes at end of table.

TABLE 6—Continued
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY OR LOCALITY[1]

[r]Revised. -- Zero.
[1]Table includes data available through August 23, 2023. 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 "Natural Graphite Except Powder Or Flakes," code 2504.90.0000.
[3]The applicable HTS nomenclature is "Natural Graphite Crystalline Flake Exc Flake Dust," code 2504.10.1000.
[4]The applicable HTS nomenclature is "Natural Graphite In Powder Or Flakes, Nesoi," code 2504.10.5000.
[5]Customs value.
[6]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)
2021:		
Austria	2,060	$9,320
Canada	451	481
China	7,240 [r]	15,300 [r]
France	668	3,830
Germany	401	3,990
India	16,100	33,500
Italy	4,290	20,800
Japan	982	7,760
Mexico	21,900	74,400
Poland	1,330	6,080
Russia	10,300	24,500
Ukraine	2,540	4,990
United Kingdom	1,350	3,540
Other	146 [r]	792 [r]
Total	69,800 [r]	209,000
2022:		
Austria	3,610	20,900
Canada	806	421
China	11,000	32,500
France	3,820	23,200
Germany	427	14,100
India	34,400	73,600
Italy	4,700	28,600
Japan	2,530	16,400
Malaysia	2,180	14,200
Mexico	20,300	77,200
Poland	2,660	12,800
Russia	10,400	31,400
Spain	1,710	9,820
Taiwan	95	476
Ukraine	1,640	5,340
United Kingdom	561	1,960
Other	53	460
Total	101,000	363,000

[r]Revised.
[1]Table includes data available through August 14, 2023. 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, respectively.
[3]Customs value.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF SYNTHETIC GRAPHITE, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2021 Quantity (metric tons)	2021 Value[3] (thousands)	2022 Quantity (metric tons)	2022 Value[3] (thousands)
Austria	38	$327	259	$1,440
Belgium	1	83	66	441
Brazil	1,840	1,620	2,660	3,850
Canada	6,080	10,300	2,660	7,050
China	60,300 r	172,000 r	88,600	348,000
Czechia	67	110	--	--
France	2,970	20,100	2,660	17,900
Germany	941	10,300	886	13,900
India	915	4,940	1,720	9,730
Italy	150	1,400	1,070	3,920
Japan	4,550	36,100	3,270	29,200
Korea, Republic of	1,050	6,980	2,210	18,100
Malaysia	551	954	1,360	5,180
Mexico	26,300	69,400	27,600	85,500
Netherlands	544	973	268	1,270
Norway	232	203	95	90
Poland	1,400	3,980	1,400	4,650
Russia	(4)	49	11	346
Singapore	39	120	343	1,380
South Africa	--	--	43	148
Spain	3,730	17,500	9,810	55,700
Sri Lanka	38	82	31	95
Sweden	93	119	(4)	7
Switzerland	3,330 r	15,100	2,650	22,400
Taiwan	34	384	13	272
United Kingdom	772	1,990	1,090	3,930
Other	11	587 r	12	192
Total	116,000	376,000 r	151,000	635,000

rRevised. -- Zero.
[1]Table includes data available through August 14, 2023. 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 value.
[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	2018	2019	2020	2021	2022
Austria, amorphous[e]	500	500	500	500	500
Brazil, crystalline flake	78,980 [r]	81,770 [r]	67,020	78,560 [r]	72,000 [e]
Canada, crystalline flake	11,000	11,000	7,620 [r]	7,700 [r]	13,000
China:					
Amorphous	469,600 [2]	473,600 [2]	170,000 [r]	179,000 [r]	182,000
Crystalline flake	694,400	711,400	920,000 [r, 2]	1,010,000 [r]	1,030,000
Total	1,164,000	1,185,000	1,090,000 [r]	1,189,000 [r]	1,212,000
Germany, crystalline flake[e]	222	207	108	181 [r]	170
India:[e, 3]					
Amorphous	800	800	600	700	700
Crystalline flake	7,100	7,200	5,400	6,300	10,300
Total	7,900	8,000	6,000	7,000	11,000
Korea, North:[e]					
Amorphous	3,600	3,600	3,600	3,600	3,600
Crystalline flake	4,500	4,500	4,500	4,500	4,500
Total	8,100	8,100	8,100	8,100	8,100
Korea, Republic of:					
Amorphous	--	--	--	7,812	16,758
Crystalline flake	670	302	3,052	10,485	7,040
Total	670	302	3,052	18,297	23,798
Madagascar, crystalline flake	54,587 [r]	45,106 [r]	61,405 [r]	91,092 [r]	130,000 [e]
Mexico, amorphous	4,130	2,300 [e]	2,033	1,800 [r]	2,000
Mozambique, crystalline flake	106,773	113,803 [r]	18,159	77,116 [r]	165,932
Namibia, crystalline flake	3,456	-- [4]	-- [4]	-- [4]	-- [4]
Norway, crystalline flake	10,000	9,780	5,549	6,293	10,380
Russia, crystalline flake	11,900	17,500	12,900	16,200 [r]	16,000 [e]
Sri Lanka, vein	3,800 [e]	2,648	2,000 [e]	3,388 [r]	3,299
Tanzania, crystalline flake	5,950 [r]	10,900 [r]	2,490 [r]	3,230 [r]	6,120 [e]
Turkey, amorphous[5]	1,700 [r]	1,000 [r]	1,500 [r]	2,800 [r]	2,800
Ukraine, crystalline flake[e]	15,000	16,000	10,000	10,000	1,000
Vietnam, crystalline flake[e]	1,500 [r]	3,500 [r]	3,700 [r]	1,200 [r]	500
Grand total	1,490,000 [r]	1,520,000 [r]	1,300,000 [r]	1,520,000 [r]	1,680,000
Of which:					
Amorphous	480,000 [r]	482,000 [r]	178,000 [r]	196,000 [r]	208,000
Crystalline flake	1,010,000	1,030,000 [r]	1,120,000 [r]	1,320,000 [r]	1,470,000
Vein or lump	3,800	2,650	2,000	3,390 [r]	3,300

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

[1]Table includes data available through August 21, 2023. All data are reported unless otherwise noted; grand totals may include estimated data. Grand totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Source: China Nonmetallic Mining Industry Association.

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

[4]The sole producing graphite mine in this country was in care-and-maintenance status.

[5]Turkish marketable production averaged approximately 5% of run-of-mine production. Almost all was for domestic consumption.