science for a changing world

2012 Minerals Yearbook

GRAPHITE

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Graphite

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In 2012, no domestic production of natural graphite was reported, but U.S. production of synthetic graphite was estimated to be 141,000 metric tons (t) valued at about $946 billion. U.S. exports and imports of natural graphite were estimated to be 6,310 t and 56,700 t, respectively. U.S. exports and imports of synthetic graphite were estimated to be 48,600 t and 122,000 t, respectively. U.S. apparent consumption of natural and synthetic graphite was estimated to be 50,400 t and 214,000 t, respectively (table 1). World production of natural graphite was estimated to be 1.17 million metric tons (Mt).

This report includes information on U.S. trade and use of natural graphite and U.S. production, trade, and use of synthetic graphite. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using the unrounded data.

Graphite is one of four forms of crystalline carbon; the others 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 (Topf, 2012). 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 °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 these properties combined make graphite desirable for many industrial applications, and both natural and synthetic graphite have industrial uses.

There are three types of natural graphite—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 is used for lower value graphite products and is the lowest priced graphite. Large amorphous graphite deposits are found in China, Europe, Mexico, and the United States. The flake or crystalline form of graphite consists of many graphene sheets stacked together. Flake or crystalline flake graphite is less common and higher quality than amorphous. Flake graphite occurs as separate flakes that crystallized in metamorphic rock and can be four times the price of amorphous. 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, and Madagascar. 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 is only commercially mined in Sri Lanka (Moores, 2007).

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

Beneficiation processes for graphite may vary from a complex four-stage flotation at European and United States mills to simple hand sorting and screening of high-grade ore at Sri Lankan operations. 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. It is then screened to produce a variety of products marketed as flake graphite that contain 75% to 90% carbon.

Exploration and Development

Three companies were exploring for flake graphite in the United States. Graphite One Resources Inc. was developing the Graphite Creek project in Alaska, Alabama Graphite Corp. was developing the Coosa graphite project in Alabama, and National Graphite Corp. was developing the Chedic graphite project in Nevada (Moores and others, 2012, p. 219–20).

Production

The U.S. Geological Survey (USGS) obtained the production data in this report through a voluntary survey of U.S. synthetic graphite producers. The survey of U.S. synthetic graphite producers collected data from 10 of 17 canvassed producers. Data were estimated for the producers that did not respond to the survey 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 reported mined in the United States in 2012, but 141,000 t of synthetic graphite with an estimated value of $946 million was produced and shipped (tables 1, 3).

The first process to produce synthetic graphite was invented in the mid-1890s by Edward Goodrich Acheson. He discovered that by heating carborundum to high temperatures, at about 4,150 °C (7,500 °F), the silicon vaporizes leaves behind almost pure graphitic carbon. Synthetic graphite electrodes that carry the electricity that melts 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, 2012).

Consumption

The USGS obtained the consumption data in this report through a survey of natural graphite companies in the United States. The survey of natural graphite companies collected data from 33 of 84 canvassed companies and plants. Data were estimated for the companies that did not respond to the survey 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 23% to 50,400 t in 2012 from 65,500 t in 2011 (table 1). Simultaneously, U.S. consumption of synthetic graphite increased by 23% to 214,000 t in 2012 from 173,000 t in 2011 (table 1). U.S. total graphite consumption, combined natural and synthetic, increased by 11% to 265,000 t in 2012 from 239,000 t in 2011.

U.S. consumption of natural graphite reported by end use decreased by 22% to 50,900 t in 2012 from 65,300 t in 2011 (table 2), owing to decreases of 22% and 47% from the previous year in the amounts of natural graphite used in brake lining and the "Other" end-use category, respectively. The "Other" end-use category includes antiknock gasoline additives and other chemical compounds, batteries, crucibles, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, nozzles, paints and polishes, pencils, retorts, sleeves, small packages, soldering/welding, steelmaking, stoppers, and other end uses. The natural graphite consumption data in table 2 include mixtures of natural and synthetic graphite in the amorphous graphite category, and this consumption data reported by end use may include company stocks from previous years. Consequently, the table 2 reported consumption numbers are different from the computed apparent consumption numbers given in table 1. Consumption of crystalline graphite decreased slightly in 2012 to 33,800 t from 34,900 t in 2011. Consumption of amorphous graphite decreased by 44% to 17,000 t in 2012 from 30,400 t in 2011. Brake linings, refractories, and steelmaking were the three industries that dominated U.S. natural graphite use. Brake linings and refractories combined accounted for 60% of natural graphite consumption. Foundries and lubricants accounted for another 5% of natural graphite consumption. The refractories industry was the leading consumer of crystalline flake graphite in 2012.

About 80% of U.S. consumption of natural graphite was used in industrial applications. The leading market sector was refractories, foundries, and crucibles, accounting for 39% of consumption in 2012. This market sector was 70% dependent on steelmaking. Automobile manufacturing and construction drove steelmaking, which, in turn, drove refractories, foundries, and crucibles demand. Metallurgical uses accounted for 28% of demand; parts and components, 10%; lubricants, 9%; batteries, 9%; and other uses, 5% (Moores, 2012, p. 2). An important and increasing portion of graphite use was related to high-technology applications through their use of graphite as an anode material in batteries. The batteries end-use category was the fastest increasing market with growth of 15% to 25% during the year, driven by the consumption of portable electronic devices, such as mobile telephones, smartphones, and tablets (Moores and others, 2012, p. 11).

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 in 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 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. Lithium ions can be inserted to create graphite anodes for lithium ion batteries. 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 has applications in high-temperature corrosive environments, such as iron blast furnaces, ladles, and steel furnaces. Carbon-alumina linings are principally used in continuous steel-casting 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 about 66% of natural graphite usage in the United States. It was consumed mainly in batteries and refractories. Amorphous graphite was mainly used in brake linings, foundries, refractories, steelmaking, and other applications where additions of graphite improve the process or the end product. Lump graphite finds use in a number of areas, such as steelmaking, depending on purity and particle size.

Synthetic graphite is used in more applications in North America than natural graphite and accounts for a major share of the graphite market. The main market for high-purity synthetic graphite is as a carbon raiser additive in iron and steel. This market consumes a substantial portion of the synthetic graphite. Other important uses of all types of graphite are in the manufacture of catalyst supports; low-current, long-life batteries; porosity-enhancing inert fillers; powder metallurgy; rubber; solid carbon shapes; static and dynamic seals; steel; and valve and stem packing. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical. High purity natural and synthetic graphite are used to manufacture antistatic plastics, conductive plastics and rubbers, electromagnetic interference shielding, electrostatic paint and powder coatings, high-voltage power cable conductive shields, membrane switches and resistors, semiconductive cable compounds, and electrostatic paint and powder coatings.

High purity natural and synthetic graphite have played an important role in the emerging noncarbon energy sector and have been used in several new energy applications. In energy production applications, graphite is used in pebbles for modular nuclear reactors and in high-strength composites for wind, tide, and wave turbines. In energy storage applications, graphite is used in bipolar plates for fuel cells and flow batteries, in anodes for lithium-ion batteries, in electrodes for supercapacitors, in high-strength composites for fly wheels, in phase change heat storage, and in solar boilers. In energy management applications, graphite is used in high-performance polystyrene thermal insulation and in silicon chip heat dissipation. These new energy applications use value-added graphite products, such as high purity, small particle size, potato shape, expanded graphite, and graphene. Current graphite capacity may not be adequate for the increasing demands of these new energy applications, which may require doubling the current graphite supply when fully implemented (O'Driscoll, 2010).

Graphene has been referred to as "the world's next wonder material." This material is composed of a tightly packed single layer of carbon atoms that can be used to make inexpensive solar panels, very powerful transistors, and wafer-thin tablets that could be the next-generation tablet computers (Topf, 2012).

Prices

During 2012, graphite prices for all forms of natural crystalline graphite decreased for the first time since 2009, with median yearend prices decreasing between 39% and 52%. Prices for amorphous powder graphite remained the same as during 2011 (table 4).

Prices for crystalline and crystalline flake graphite concentrates ranged from $850 to $1,800 per metric ton; prices for amorphous powder ranged from $600 to $800 per ton (table 4). The average unit value of all U.S. natural graphite exports increased by 17% to $2,760 per ton in 2012 from $2,360 per ton in 2011. Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The European port price of synthetic graphite in 2012 ranged from $7,000 to $20,000 per ton. The average unit value of synthetic graphite exports increased by 7% to $3,510 per ton in 2012 from $3, 270 per ton in 2011 (table 5).

Foreign Trade

Total graphite exports decreased by 9% in tonnage to 54,900 t valued at $188 million in 2012 from 60,200 t valued at $191 million in 2011. Total graphite export tonnage was 11% natural graphite and 89% synthetic graphite (table 5). Total natural graphite imports decreased by 21% in tonnage to 56,700 t in 2012 from 71,800 t in 2011, and the value decreased by 16% to $68.4 million in 2012 from $81.3 million in 2011 (table 6). This large decrease in quantity and value was owing to a decrease of 9,590 t in quantity and a decrease of $11.2 million in the value of the "other natural crude" graphite category during 2012. Principal import sources of natural graphite were, in descending order of tonnage, Mexico, China, Canada, Brazil, and Madagascar, which combined, accounted for 97% of the tonnage and 90% of the value of total imports. Mexico provided all the amorphous graphite, and Sri Lanka provided all the lump and chippy dust variety. China, Canada, and Madagascar were, in descending order of tonnage, the leading suppliers of crystalline flake and flake dust graphite. A number of other producing nations supplied several other natural types and grades of graphite to the United States; among the most notable were Brazil and China.

World Review

World production of natural graphite increased slightly in 2012 to an estimated 1.17 Mt compared with 1.16 Mt in 2011. China maintained its position as the world's leading graphite producer, with an estimated 800,000 t or 67% of the total global production. India was the second ranked graphite producer, with 160,000 t or 13% of the total, followed by Brazil, North Korea, Canada, and Russia, in decreasing order of tonnage produced. These six countries accounted for 96% of world production (table 8).

In 2012, Canada was the leading country for natural graphite development with a favorable outlook for new mines. Eight companies were exploring for graphite in Canada. This exploration was focused on properties in Ontario and Quebec (Topf, 2012). Brazil was the second leading country providing new natural graphite supply with a new 40,000 metric tons per year mine being considered by Magnesita Refratarios SA (Moores and others, 2012, p. 12).

Outlook

Worldwide demand for combined natural and synthetic graphite is expected to continue increasing as global economic conditions improve. Demand is also expected to continue increasing as more noncarbon energy applications that use graphite are developed.

The trend of collaboration between Far Eastern and Western graphite producers is expected to continue. These collaborations have been combining superior management, processing, and packaging techniques of Western companies with China's production capabilities located in and adjacent to the largest markets. China offers the optimum cost-location balance. China had made progress in eliminating logistics challenges, such as freight issues, shipping problems, and rising container rates (Moores, 2007; Feytis, 2010). However, during 2011, the Chinese Government ordered the majority of graphite mines under its control in Hunan Province to be closed for environmental and resource protection. This action is expected to cause future production decreases for the world's leading natural graphite producer. Amorphous graphite availability will most likely decline, while flake graphite production will probably remain stable (Moores, 2011). The Chinese Government also began restricting natural graphite exports in order to protect its own domestic industries (Topf, 2012). China will have some capacity to increase graphite flake production even with its recent production cap on amorphous graphite and its discouraging raw graphite material exports in favor of exports of value added products like spherical graphite for batteries (Moores and others, 2012, p. 12).

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 improved graphite in electronics, foils, friction materials, and lubrication applications. Products produced by advanced refining technology in the next few years could increase profitability in the U.S. graphite industry.

Graphene likely will not be a volume driver for graphite markets. It is expected to remain as a niche research and development product for the next 5 years unless important innovations are realized. Refractory end uses will remain the leading end market for natural graphite accounting for a steady 38% of consumption through 2016 (Moores and others, 2012, p. 12).

The expected increase in manufacture and sales of hybrid and electric vehicles is likely to increase demand for high-purity graphite in fuel-cell and battery applications. Fuel cells are a potential high-growth, large-volume graphite (natural and synthetic) end use but are currently a very small part of consumption. High volumes of graphite are not expected to be consumed in fuel cells for many years but may be used in the longer term. In general, the forecasted need to double present graphite supplies to produce value-added graphite products for new energy applications has triggered reopening of shutdown graphite mines and development of graphite resources globally (O'Driscoll, 2010).

Batteries are expected to be fastest increasing end-use sector owing to growth in portable electronics that require larger, more powerful and more graphite-intensive batteries. The increasing use of electric vehicle batteries will have an important effect on the graphite markets from 2014 onward, and then, only fully electric vehicles will have a major volume impact. The battery end-use sector will increase its market share of graphite consumption from 8% to 10% by 2017. Production of spherical graphite feedstock material will need to increase to meet the battery demand. Graphite is not dependent on the success of the lithium-ion battery, because natural graphite anodes are preferred in all battery technologies currently (Moores and others, 2012, p. 12–13).

Increased global demand for graphite used in batteries will be divided between two main consuming sectors—alkaline batteries and lithium-ion batteries. Synthetic and natural graphite are used in these batteries. In alkaline batteries, graphite is the conductive material in the cathode. Until recently, synthetic graphite was predominantly used in these batteries. With the advent of new purification techniques and more efficient processing methods, it has become possible to improve the conductivity of most natural graphite to the point where it can be used in batteries. The decision of whether to use synthetic or natural graphite will be based on performance and price. The growth of the lithium-ion battery market could have a more dramatic effect on the graphite market as the demand for mobile energy storage systems rises.

Brake linings and other friction materials are expected to steadily use more natural graphite as new automobile production continues to increase and more replacement parts are required for the increasing number of vehicles. Natural graphite (amorphous and fine flake) is used as a substitute for asbestos in brake linings for vehicles heavier than cars and light trucks. Flexible graphite products, such as grafoil (a thin graphite cloth), are expected to be the fastest growing market but are expected to use small quantities of natural graphite compared to major end-use markets, such as brake linings and refractories.

Specialized and high-tech applications require higher purity and more consistent products. Higher-purity graphite is being increasingly produced as thermal processing and acid leaching techniques continues. High-purity graphite has applications in advanced carbon graphite composites.

The markets for graphite used in rubber and plastics (including Styrofoam coatings) are increasing, and continued growth is expected. The U.S. market for graphite in pencils has almost disappeared; pencil "leads" now are imported directly from China. These markets, however, use little graphite and are not expected to have a significant impact on future consumption.

A California-based company was developing a technology that turns carbon dioxide emissions into high-purity synthetic graphite. With the world's industrialized nations pledging to reduce their carbon dioxide emissions by 50% by 2050, this technology could become a promising new synthetic graphite source while helping industrialized nations reach their target emissions goals (Industrial Minerals, 2009).

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TABLE 1
SALIENT NATURAL AND SYNTHETIC GRAPHITE STATISTICS[1]

		2008	2009	2010	2011	2012
United States:						
Natural:						
Exports:						
Quantity	metric tons	7,950	11,400	5,600	6,280	6,310
Value	thousands	$15,600	$21,600	$15,200	$14,800	$17,400
Imports for consumption:						
Quantity	metric tons	58,300	33,100	65,400	71,800	56,700
Value	thousands	$48,100	$29,700	$52,100	$81,300	$68,400
Apparent Consumption:[2]						
Quantity	metric tons	50,300	21,700	59,800	65,500	50,400
Value	thousands	$32,500	$8,050	$36,900	$66,500	$51,000
Synthetic:						
Production:						
Quantity	metric tons	196,000	118,000	134,000	149,000 r	141,000
Value	thousands	$1,050,000	$998,000	$1,070,000	$1,090,000 r	$946,000
Exports:						
Quantity	metric tons	54,900	35,000	40,000	53,900	48,600
Value	thousands	$166,000	$109,000	$136,000	$177,000	$170,000
Imports for consumption:						
Quantity	metric tons	66,600	33,800	44,000	79,700	122,000
Value	thousands	$131,000	$79,400	$119,000	$176,000	$191,000
Apparent Consumption:[2]						
Quantity	metric tons	208,000	116,000	138,000	173,000	214,000
Value	thousands	$1,010,000	$969,000	$1,050,000	$1,050,000	$967,000
World production, Natural[e]	metric tons	1,050,000 r	794,000 r	1,070,000 r	1,160,000 r	1,170,000

[e]Estimated. [r]Revised.

[1]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)	Total Quantity (metric tons)	Total Value (thousands)
2011:						
Brake lining	442	$1,680 r	2,970	W	3,420	W
Carbon products[3]	308 r	880 r	W	W	622	$2,750
Foundries[4]	W	W	W	W	1,810 r	W
Lubricants[5]	596 r	2,220 r	169 r	W	765 r	3,070 r
Powdered metals	309	1,300	--	--	309	1,300
Refractories	22,600	25,300 r	W	W	27,500	34,500
Rubber	W	W	W	W	396	W
Other[6]	10,400 r	19,700 r	20,100 r	$112,000 r	30,400 r	132,000 r
Total	34,900 r	51,600 r	30,400	142,000	65,300 r	194,000 r
2012:						
Brake lining	396	1,540	2,280	W	2,680	W
Carbon products[3]	286	905	424	W	710	2,670
Foundries[4]	W	W	1,130	W	1,350	W
Lubricants[5]	693	2,730	W	W	1,350	W
Powdered metals	340	W	--	--	340	W
Refractories	22,400	25,700	W	9,920	28,000	35,600
Rubber	W	154	W	W	337	W
Other[6]	9,440	16,400	W	W	16,100	59,000
Total	33,800	49,300	17,000	70,200	50,900	119,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
[1]Data are rounded to no more than three significant digits.
[2]Includedes 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/electronic devices, industrial diamonds, magnetic tape, mechanical products, nozzles, paints and polishes, pencils, retorts, sleeves, small packages, soldering/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)
2011:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,300	$532,000
Unmachined graphite shapes	8,860	122,000
Other[2]	46,500 r	432,000 r
Total	149,000 r	1,090,000 r
2012:		
Cloth and fibers (low modulus)	W	W
Electrodes	90,900	511,000
Unmachined graphite shapes	8,060	83,600
Other[2]	41,900	352,000
Total	141,000	946,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Data are rounded to no more than three significant digits.
[2]Includes anodes, crucibles and vessels, electric motor brushes and machined shapes, graphite articles, high-modulus fibers, lubricants (alone/in greases), refractories, steelmaking carbon raisers, additives in metallurgy, and other powder data.

TABLE 4

REPRESENTATIVE YEAREND GRAPHITE PRICES[1]

(Dollars per metric ton)

Type	2011	2012
Crystalline large, 94% to 97% carbon, +80 mesh	2,500–3,000	1,400–1,800
Crystalline large, 90% carbon, +80 mesh	2,000–2,500	1,200–1,600
Crystalline medium, 94% to 97% carbon, +100–80 mesh	2,200–2,500	1,050–1,400
Crystalline medium, 90% carbon, +100–80 mesh	1,500–2,000	950–1,200
Crystalline medium, 85% to 87% carbon, +100–80 mesh	1,500–1,900	900–1,150
Crystalline fine, 94% to 97% carbon, +100 mesh	2,000–2,400	900–1,200
Crystalline fine, 90% carbon, -100 mesh	1,400–1,800	850–1,050
Amorphous powder, 80% to 85% carbon	600–800	600–800
Synthetic 99.95% carbon[2]	7,000–20,000	7,000–20,000

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

[2]Swiss border.

Source: Industrial Minerals, no. 531, December 2011, p. 62; no. 543, December 2012, p. 78.

TABLE 5

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

	Natural[3]		Synthetic[4]		Total	
Country	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)
2011:						
Canada	1,590	$1,980	6,170	$15,200	7,760	$17,100
China	277	565	5,120	25,500	5,390	26,100
France	24	92	3,460	26,300	3,480	26,400
Germany	425	831	2,740	7,800	3,170	8,630
Hong Kong	11	62	262	818	273	879
Italy	253	450	1,230	6,770	1,480	7,220
Japan	722	1,930	2,070	10,500	2,790	12,500
Korea, Republic of	62	287	3,390	14,300	3,450	14,600
Mexico	1,360	1,620	7,720	9,730	9,080	11,300
Netherlands	123	138	162	672	285	810
Taiwan	91	463	3,950	6,280	4,040	6,740
United Kingdom	227	3,430	981	2,540	1,210	5,970
Other	1,110	3,000	16,700	50,100	17,800	53,100
Total	6,280	14,800	53,900	177,000	60,200	191,000
2012:						
Canada	1,690	2,610	4,830	13,800	6,520	16,400
China	376	986	4,530	15,900	4,900	16,800
France	7	25	2,110	15,400	2,110	15,400
Germany	128	299	1,770	7,570	1,900	7,870
Hong Kong	13	67	354	1,050	368	1,110
Italy	87	285	542	1,360	629	1,650
Japan	886	2,490	1,880	11,200	2,760	13,700
Korea, Republic of	89	536	6,510	32,700	6,600	33,200
Mexico	1,340	2,680	9,180	11,100	10,500	13,800
Netherlands	2	30	398	1,390	400	1,420
Taiwan	127	478	1,050	4,850	1,180	5,330
United Kingdom	90	857	1,390	2,890	1,480	3,740
Other	1,470	6,030	14,000	51,300	15,500	57,400
Total	6,310	17,400	48,600	170,000	54,900	188,000

[1]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” and “Colloidal or semicolloidal graphite,” codes 3801.10.0000 and 3801.20.0000.

[5]Values are free alongside ship.

Source: U.S. Census Bureau.

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

Country	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude; high-purity; expandable		Amorphous		Total	
	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)
2011:										
Austria	--	--	--	--	15	$27	--	--	15	$27
Brazil	--	--	--	--	3,940	7,290	--	--	3,940	7,290
Canada	12,300	$16,600	--	--	--	--	--	--	12,300	16,600
China	20,700	22,600	--	--	13,900	21,800	--	--	34,500	44,400
Germany	--	--	--	--	167	702	--	--	167	702
India	--	--	--	--	26	118	--	--	26	118
Japan	--	--	--	--	186	3,760	--	--	186	3,760
Madagascar	831	873	--	--	--	--	--	--	831	873
Mexico	--	--	--	--	--	--	19,000	$5,700	19,000	5,700
Sri Lanka	--	--	616	$1,120	--	--	--	--	616	1,120
United Kingdom	--	--	--	--	114	584	--	--	114	584
Other	24	27	--	--	27	163	--	--	52	163
Total	33,900	40,100	616	1,120	18,300	34,400	19,000	5,700	71,800	81,300
2012:										
Austria	--	--	--	--	15	25	--	--	15	25
Brazil	--	--	--	--	3,380	7,690	--	--	3,380	7,690
Canada	12,000	17,800	--	--	--	--	--	--	12,000	17,800
China	13,800	17,800	--	--	4,830	9,960	--	--	18,600	27,700
Germany	--	--	--	--	178	912	--	--	178	912
India	--	--	--	--	(3)	3	--	--	(3)	3
Japan	--	--	--	--	235	4,100	439	25	674	4,120
Madagascar	1,450	1,750	--	--	--	--	--	--	1,450	1,750
Mexico	--	--	--	--	--	--	19,700	6,820	19,700	6,820
Sri Lanka	--	--	526	1,030	--	--	--	--	526	1,030
United Kingdom	--	--	--	--	92	438	--	--	92	438
Other	6	12	--	--	25	96	--	--	31	108
Total	27,300	37,300	526	1,030	8,750	23,200	20,200	6,840	56,700	68,400

-- Zero.
[1]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[1, 2]

Country	Quantity (metric tons)	Value[3] (thousands)
2011:		
Canada	11,700	$59,900
China	26,200	52,500
Germany	3,010	21,400
India	16,300	37,800
Japan	19,800	99,800
Mexico	16,100	46,800
Poland	1,120	4,930
Russia	10,000	27,900
South Africa	2,050	8,410
Ukraine	1,890	5,200
United Kingdom	242	1,070
Other	1,230	6,150
Total	110,000	372,000
2012:		
Austria	2,000	10,200
Canada	13,800	72,600
China	18,100	63,400
Germany	2,860	21,600
India	13,200	32,500
Japan	24,300	141,000
Mexico	10,100	33,100
Poland	956	4,570
Russia	10,400	31,600
South Africa	233	860
Ukraine	1,420	4,190
United Kingdom	262	1,130
Other	858	5,860
Total	98,600	423,000

[1]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 “Electric furnace electrodes,” code 8545.11.0000.

[3]Customs values.

Source: U.S. Census Bureau.

TABLE 8
NATURAL GRAPHITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2008	2009	2010	2011	2012
Austria	250 r, 3	750 3	420 3	925 r, 3	1,000
Brazil, marketable	74,831 3	59,425 3	92,364 r, 3	105,188 r, 3	110,000 p
Canada	27,000	15,000	20,000	25,000	25,000
China	650,000	450,000	700,000 r	800,000	800,000
Czech Republic	3,000	--	--	--	--
India, run-of-mine[4]	140,000	130,000	140,000	150,000	160,000
Korea, North	30,000	30,000	30,000	30,000	30,000
Korea, Republic of	73,000 r, 3	48,000 r	34,000 r	-- r	--
Madagascar	4,922 r, 3, 5	3,437 3, 5	3,783 3, 5	3,573 r, 3, 5	4,100
Mexico, amorphous[3]	7,229	5,105 r	6,628 r	7,348 r	8,192
Norway	4,100 r	4,562 r	6,270 r	6,000 r	1,500
Romania	--	20,000	7,000 r	-- r	--
Russia	14,000	14,000	14,000	14,000	14,000
Sri Lanka	6,615 3	3,171 3	3,437 3	3,500	3,600
Sweden	-- r	-- r	-- r	-- r	--
Turkey, run-of-mine[6]	3,236 3	2,400 3	-- r, 3	5,250 r, 3	5,200
Ukraine	5,800	5,500	6,000 r	6,000 r	6,000
Uzbekistan	60	60	60	60	60
Zimbabwe	5,134 3	2,463 3	5,000	5,000	6,000
Total	1,050,000 r	794,000 r	1,070,000 r	1,160,000 r	1,170,000

pPreliminary. rRevised. -- Zero.
[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through September 18, 2013.
[3]Reported figure.
[4]Indian marketable production is 10% to 20% of run-of-mine production.
[5]Reported exports.
[6]Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.