GRAPHITE

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Graphite is one of three forms of crystalline carbon; the other two are diamond and fullerenes. Graphite occurs naturally in metamorphic rocks such as marble, schist, and gneiss. It is a soft mineral, also known by the names of black lead, plumbago, and mineral carbon. The word graphite is derived from the Greek word "graphein," to write. It has a Mohs hardness of 1 to 2 and exhibits perfect basal cleavage. Depending upon the purity, the specific gravity is 2.20 to 2.30. The theoretical density is 2.26 grams per cubic centimeter. It is gray to black in color, opaque, and has a metallic luster. It is flexible but not elastic. It has high thermal and electrical conductivities, is highly refractory, and is chemically inert.

Two general types of graphite, natural and synthetic, are encountered. Worldwide, natural graphite deposits occur as lenses or layers of disseminated or massive flakes. Graphitization of naturally occurring organic carbon may occur at temperatures as low as 300º C to 500º C or as high as 800º C to 1,200º C, such as when an igneous intrusion contacts a carbonaceous body.

The three principal types of natural graphite—lump, crystalline flake, and amorphous—are distinguished by physical characteristics that are the result of major differences in geologic origin and occurrence. Lump graphite occurs in veins and is believed to be hydrothermal in origin. It is typically massive, ranging in particle size from extremely fine to coarse, platy intergrowths of fibrous or acicular crystalline aggregates with the long axis parallel to the enclosing wall rock (Kenan, 1984). Crystalline flake graphite consists of isolated, flat, plate-like particles with angular, rounded, or irregular edges. It is usually found in layers or pockets in metamorphic rocks. In some deposits, the flake graphite occurs as massive accumulations in veins, lenses, or pods. Amorphous graphite is formed by the thermal metamorphism of coal. The designation amorphous is a misnomer. Its relatively low degree of crystalline order and very fine particle size make it appear amorphous. It is usually of lower purity than the crystalline flake graphite and, therefore, commands a lower price than its more ordered counterpart.

Beneficiation processes for graphite may vary from a complex four-stage flotation at the European and U.S. mills to simple hand sorting and screening of high-grade ore at the Sri Lanka 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 clay fractions 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 screened to a variety of products marketed as flake graphite containing 75% to 90% carbon.

Legislation and Government Programs

Total national defense stockpile graphite inventories, including nonstockpile-grade, were 8,730 metric tons (t) with a value of about $1.65 million. Madagascar natural graphite inventories in the United States were 3,870 t with a value of

Graphite in the 20th Century

In 1900, 555 metric tons of graphite valued at $198,000 was produced in the United States. Michigan, New York, Pennsylvania, Rhode Island, and Wisconsin were the only graphite producing States in 1900. In contrast to production, 14,000 tons of graphite valued at $1.4 million were imported. Imports were mostly from Ceylon. In the early 1900s, natural graphite found uses in the manufacture of lead pencils, lubricants, and few electrical applications. Such uses continued throughout the mid-1950s.

There has been no graphite mined in the United States since 1990, when United Minerals Co. suspended its graphite mining operations at its Montana mine, but 60,800 tons of natural graphite was imported, mainly, in decreasing order, from China, Canada, Brazil, Mexico, and Madagascar. In 2000, the United States produced 290,000 tons of synthetic graphite valued at $771 million, and exported 94,000 tons of graphite products at a value of $97 million. Today, with the development of techniques to synthesize graphite from organic materials and advanced purification methods for natural graphite, there are myriad applications for both natural and synthetic graphite. Natural graphite of 99.8% purity can compete with synthetic graphite in a number of applications such as fiber composites. Developments in the area of materials engineering and the ability to process fibers and synthesize graphite from organic precursors have made graphite truly a high technology material that has uses such as high-strength graphite fiber composites for space age applications. The next important development in the use of graphite will come in the energy field: advanced automotive batteries and fuel cells. Fuel cells alone, once fully developed and marketed, will account for more than half the graphite consumption in the United States.

$600,000. There were 4,810 t of Sri Lanka amorphous lump with a value of $1.10 million (table 2). No acquisition of graphite for the strategic and critical materials stockpile occurred in 2000. Graphite no longer has a Government stockpile goal and all graphite in the Government stockpile has been authorized for sale.

Production

No graphite was mined in the United States in 2000. The reported U.S. production of synthetic graphite reached 290,000 t with a value of $771 million (table 4).

Graphite is mined from open pit and underground mine operations. Open pit operations are more economical and, thus, are preferred where the overburden can be removed economically. Mines in Madagascar are mostly of this type. In the Republic of Korea, Mexico, and Sri Lanka, where the deposits are deep, underground mining techniques are required.

Consumption

The use of graphite has changed dramatically. Graphite exhibits the properties of a metal and a nonmetal, which makes it suitable for many industrial applications. The metallic properties include thermal and electrical conductivity. The nonmetallic properties include inertness, high thermal resistance, and lubricity. The combination of conductivity and high thermal stability allows graphite to be used in many applications such as refractories, batteries, and fuel cells. Lubricity and thermal conductivity make it an excellent material for high-temperature applications, because it results in a material that provides effective lubrication at a friction interface while furnishing a thermally conductive matrix to remove heat from the same interface. Lubricity and electrical conductivity 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. Today's high technology products, such as friction materials and battery and fuel cells, demand higher purity graphite.

U.S. consumption of natural graphite increased by more than 20% in 2000 to 41,800 t from 34,600 t in 1999 (table 3). The crystalline grade increased in 2000 by only 3.5% to 17,900 t from 17,300 t in 1999, whereas amorphous grade increased by an impressive 38% in 2000 to 23,900 t from 17,300 t in 1999. This increased use translated into a more than 50% increase in value in 2000.

The four major industries—refractories, brake linings, lubricants, and foundries—for which natural graphite is used continued their dominance in graphite usage, accounting for one-half of the graphite consumed by U.S. industry in 2000 (table 3). The refractories industry was again the major consumer of crystalline flake graphite followed by the manufacture of brake linings and metal powders. Refractory applications of graphite included castable ramming, gunning mixtures, and carbon-bonded brick. Carbon-magnesite brick has applications in high-temperature corrosive environments such as steel furnaces, ladles, and iron blast furnaces. Carbon-alumina linings are principally used in continuous steel-casting operations. Magnesite- and alumina-carbon brick requires a particle size of 100 mesh and a purity of 95% to 99% graphite.

Crystalline flake graphite accounted for nearly 45% of graphite usage in the United States. It was used mainly in refractories, batteries, and other thermal and electrical conductivity applications. Amorphous graphite is mainly used as a lubricant additive, as a pigment in paints; in plastic refractories, and in other applications where additions of graphite improve the process or the end product. Lump graphite finds appropriate uses in a number of areas, such as steelmaking, depending on the purity and particle size.

Synthetic graphites remain the choice in North America, accounting more than half of the market. The main market for high purity synthetic graphites is iron and steel as a carbon-raiser additive. This market consumes more than 50% of the synthetic graphite.

Other significant uses of all types of graphites are in the manufacture of low-current, long-life batteries, steelmaking, solid carbon shapes, static and dynamic seals, valve and stem packing, catalyst supports, porosity enhancing inert fillers, manufacture of rubber, and powder metallurgy. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical.

Prices

Graphite prices remained unchanged during 2000. Prices for crystalline flake graphite concentrates ranged from $480 to $550 per metric ton and commanded higher prices than the amorphous, which was priced at $220 to $235 per ton (table 5). Carbon content, flake and crystal size, size distribution, and ash content affect the price of graphite. The price of synthetic graphite, however, declined to $1.94 per kilogram in 2000 from $2.29 per kilogram in 1999. Customary negotiations between the buyer and the seller lead to wide price fluctuations.

Foreign Trade

Total imports of natural graphite increased in tonnage to 60,800 t in 2000 from 55,800 t in 1999, but the value declined to $32.5 million in 2000 compared with $34.7 million in 1999 (table 7). Principal import sources of natural graphite were China, Canada, Mexico, Japan, Madagascar, and Brazil, in order of tonnages, which accounted for 89% of the value of total imports. Mexico continued to be the major supplier of amorphous graphite and Sri Lanka provided the lump variety. A number of other producers supplied various types and grades of graphite to the United States, among the more notable being Japan and Germany.

In spite of showing a noticeable decrease in tonnage, total exports recorded an impressive 16% increase in total revenue to $96.5 million in 2000 compared with $82.8 million in 1999 because of the increase in value of the finished goods exported (table 6).

World Review

World production of graphite in 2000 was estimated to be 602,000 t compared with 600,000 t in 1999. China maintained its position as the world's leading graphite producer with 220,000 t, with India in second place with 140,000 t, followed by Brazil, Mexico, and the Czech Republic, in order of importance. These five countries accounted for over three-quarters of the world production (table 9).

Sri Lanka continued to account for nearly all the high-purity lump graphite produced. Sri Lankan deposits were estimated to average 95% graphite in situ. China accounted for 37% of world production.

Current Research and Technology

In recent years, new technology in processing and treatment has expanded the use of natural graphites in battery applications. Graphite for these applications is purified to 99.9% carbon. Most new uses for graphite products are being developed through advances in graphite thermal technology. The ability to refine and modify graphite and carbon products will be the key to future growth in the graphite industry. Innovative refining techniques have enabled the use of improved graphite in friction materials, electronics, foil, and lubrication applications (Hand, l997). Some of the new application areas include electrically conductive asphalt for heated runways at airports and roadway bridges.

With its low specific gravity, refractoriness, and corrosion resistance, graphite is critical for many industrial applications, such as dies for continuous casting, rocket nozzles, and heat exchangers for the chemical industry. Relatively poor wear and oxidation resistance of graphite, however, limit its use. A class of high-performance materials based on titanium carbide-coated graphite makes the material suitable for some of the most demanding applications (Webb, 2000). Because titanium carbide is one of the hardest and most durable materials, the resulting components are extremely resistant to wear, corrosion, and elevated temperatures. These composites can be engineered to fit many industrial uses through control of the coating composition, thickness, microstructure, and surface finish. In metal melting applications titanium carbide coatings have been shown to improve the service life of the graphite components by as much as fivefold.

Advanced refining technology in the next few years, despite a weak refractory market and pricing pressure from Chinese material, could bring a reversal of fortune to the graphite industry.

Enigmatic clusters of carbon atoms, called fullerenes, which are found as large carbon-cage molecules, have been puzzling scientists since 1985 when they were first discovered among the byproducts of laser-vaporized graphite (Pierson, 1993). Their hollow spherical structure, reminiscent of geodesic domes of architect Buckminster Fuller, earned them the names "buckyballs" and "fullerenes." Mistakenly called a new form of carbon, fullerenes have been found to exist in interstellar dust as well as in geological formations on Earth. Fullerenes are fascinating because they exhibit unusual properties for carbon materials. For example, adding 3 alkali atoms per fullerene unit (C_{60}) results in a material that exhibits superconductivity at quite high temperatures (10º K to 40º K). These materials also exhibit lubricity superior to that of graphite. To date, no product based on fullerenes has been offered in the market. The full potential of fullerenes in practical applications remains to be explored.

Outlook

The main areas of natural graphite consumption in the near future will be in high temperature applications for the iron and steel industry as the industry modernizes its production facilities. Brake linings and other friction materials will steadily consume more natural graphite as new automobile production continues to increase and more replacement parts are required for the growing number of vehicles. Flexible graphite product lines, such as grafoil (a thin graphite cloth), will probably be the fastest growing market but will consume small amounts of natural graphite compared with major end-use markets.

The advent of hybrid and electric vehicles is expected to bring increased demand for high-purity graphite in fuel cell and battery applications. One optimistic prediction is that the demand for high quality, high carbon graphite could increase to more than 100,000 metric tons per year (t/yr) for fuel cell and battery applications alone (Crossley, 2000). The global demand for graphite used in batteries may double to more than 25,000 t/yr in the next 5 years. This demand is expected to be spread between the two main consuming sectors-alkaline batteries and lithium-ion batteries. Synthetic and natural graphite are both used in these batteries.

In alkaline batteries, graphite is the conductive material in the cathode. Until recently, synthetic graphite was dominantly used in these batteries. But 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 whether to use synthetic or natural graphite will be a balancing act between price and performance. The growth of the lithium-ion battery market could have a more dramatic effect on the graphite market as the demand rises for mobile energy storage systems.

Fuel cells convert hydrogen into electricity by an electrochemical reaction. The hydrogen molecules break down into protons and electrons at the cell's anode. Protons are then conducted through the electrode and the electrons travel through an external circuit and generate electricity. Graphite, as cathode material, forms a crucial part of fuel cell technology. Some predictions show that consumption of graphite in fuel cell electrodes could reach 80,000 t/yr in just 2 to 3 years. Canada, Germany, Japan, and the United States are aggressively promoting fuel cell development. The cost of fuel cells, however, is still too high for commercial vehicles. The price per unit needs to drop to about $1,500 before they will be viable. Daimler-Chrysler Corporation has pledged to have a commercially viable fuel cell vehicle by 2004, and trials for fuel cell buses, taxis, and bicycles have already begun.

In the event of any price increases, China may increase its production to take advantage of potentially increased profits, leading to a sharp price decline in certain grades and possibly to a production stoppage in other countries. If the Chinese iron and steel industry, however, expands its consumption of natural graphite, Chinese exports may eventually decline, encouraging new producers to enter the market (Roskill Information

Services Ltd., 1998).

Industry trends that appear to be common to advances in graphite technology and markets include higher purity and consistency in specifications for some specialized and high-tech applications. Production of higher purity graphite using thermal processing and acid leaching techniques continues to be the trend. This material has applications as advanced carbon-graphite composites.

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TABLE 1
SALIENT NATURAL GRAPHITE STATISTICS 1/

		1996	1997	1998	1999	2000
United States:						
Apparent consumption 2/	metric tons	27,400	18,400	33,600	26,400	39,000
Exports	do.	26,000	39,700	28,000	29,400	21,800
Value	thousands	$14,600	$20,500	$14,100	$15,200	$12,500
Imports for consumption	metric tons	53,400	58,100	61,600	55,800	60,800
Value	thousands	$28,600	$32,400	$34,800	$34,700	$32,500
World production	metric tons	555,000 r/	685,000 r/	646,000 r/	600,000 r/	602,000 e/

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. GOVERNMENT STOCKPILE YEAREND STOCKS OF
NATURAL GRAPHITE IN 2000, BY TYPE 1/ 2/

(Metric tons)

Type	Stock
Madagascar crystalline flake	3,870
Sri Lanka amorphous lump	4,810
Nonstockpile-grade, all types	49

1/ Graphite no longer has a goal.
2/ Data are rounded to no more than three significant digits.

Source: Defense National Stockpile Center, Inventory of Stockpile Material as of December 31, 2000.

TABLE 3
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)
1999:						
Batteries	W	W	--	--	W	W
Brake linings r/	1,090	$1,290	5,280	$4,540	6,380	$5,830
Carbon products 3/	425	1,310	318	268	743	1,570
Crucibles, retorts, stoppers, sleeves, nozzles	W	711	W	W	W	W
Foundries 4/	W	494	1,780	825	W	1,320
Lubricants 5/	328	580	1,190 r/	911 r/	1,510	1,490
Pencils	W	W	W	W	W	W
Powdered metals	435 r/	1,000 r/	W	W	W	W
Refractories	W	W	5,580	3,670	W	W
Rubber	W	844	W	367	W	1,210
Steelmaking	W	W	W	W	W	W
Other 6/	W	W	788	510	W	W
Total	17,300	18,800	17,300	12,200 r/	34,600	31,000
2000:						
Batteries	W	W	--	--	W	W
Brake linings	1,100	1,340	5,480	4,010	6,580	5,350
Carbon products 3/	471	1,390	W	210	W	1,600
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries 4/	W	584	W	W	W	W
Lubricants 5/	389	649	1,180	883	1,570	1,530
Pencils	W	W	W	W	W	W
Powdered metals	437	1,010	W	W	W	W
Refractories	5,310	W	5,360	3,590	10,700	W
Rubber	W	W	W	W	W	W
Steelmaking	28	18	W	W	W	W
Other 6/	W	W	812	541	W	W
Total	17,900	19,400	23,900	18,500	41,800	38,000

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/ Includes mixtures of natural and manufactured graphite.
3/ Includes bearings and carbon brushes.
4/ Includes foundries (other) and foundry facings.
5/ Includes ammunition and packings.
6/ Includes antiknock and other compounds, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, paints and polishes, small packages, soldering/welding, and other end-use categories.

TABLE 4
U.S. PRODUCTION OF SYNTHETIC GRAPHITE, BY END USE 1/

End use	Quantity (metric tons)	Value (thousands)
1999:		
Anodes	W	W
Cloth and fibers (low modulus)	W	$82,500 r/
Electric motor brushes and machined shapes	5,380	32,400
Electrodes	172,000	535,000
High-modulus fibers	2,450	54,400
Unmachined graphite shapes	4,870 r/	44,600 r/
Synthetic graphite powder and scrap 2/	W	W
Other	W	W
Total	267,000	823,000 r/
2000:		
Anodes	W	W
Cloth and fibers (low modulus)	W	90,700
Electric motor brushes and machined shapes	W	22,300
Electrodes	188,000	471,000
High-modulus fibers	W	W
Unmachined graphite shapes	5,980	57,300
Synthetic graphite powder and scrap 2/	84,500	46,700
Other	W	W
Total	290,000	771,000

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 lubricants (alone/in greases), steelmaking carbon raisers, additives in metallurgy, and other powder data.

TABLE 5
REPRESENTATIVE YEAREND GRAPHITE PRICES 1/

(Per metric ton)

Type	1999	2000
Crystalline large flake, 94% carbon	$570-$750	$570-$750
Crystalline large flake, 90% carbon	480-550	480-550
Crystalline medium flake, 90% carbon	370-410	370-410
Crystalline small flake, 80% to 95% carbon	270-500	270-500
Amorphous powder, 80% to 85% carbon	220-235	220-235
Synthetic, 99.95% carbon, Swiss border	2,290	1,940

1/ Prices are normally cost, insurance, and freight (c.i.f.) main European port.

Source: Industrial Minerals, no. 387, December 1999, p. 70; no. 399, December 2000, p. 74.

TABLE 6

U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY 1/ 2/

Country	Natural 3/		Artificial 4/		Total	
	Quantity (metric tons)	Value 5/ (thousands)	Quantity (metric tons)	Value 5/ (thousands)	Quantity (metric tons)	Value 5/ (thousands)
1999:						
Australia	267	$342	1,670	$1,620	1,940	$1,960
Bangladesh	6,240	2,160	--	--	6,240	2,160
Belgium	60	23	1,270	962	1,330	985
Brazil	38	13	1,580	2,110	1,620	2,120
Canada	5,410	3,570	8,290	12,800	13,700	16,300
France	4	16	3,740	5,590	3,750	5,600
Germany	207	128	1,110	1,410	1,320	1,540
Hong Kong	1,200	557	236	274	1,430	831
Italy	68	69	3,920	3,790	3,990	3,860
Japan	328	240	15,600	8,190	16,000	8,430
Korea, Republic of	238	202	8,470	4,870	8,710	5,080
Malaysia	231	135	908	2,140	1,140	2,270
Mexico	8,090	3,130	3,220	2,310	11,300	5,440
Netherlands	2,270	889	10,400	4,070	12,700	4,960
Sweden	54	39	1,390	1,900	1,440	1,940
Switzerland	1,200	521	47	146	1,250	667
Taiwan	674	414	1,080	1,390	1,760	1,800
United Kingdom	299	227	3,070	2,750	3,370	2,980
Venezuela	1,490	1,750	711	983	2,200	2,730
Other r/ 6/	1,010	794	5,770	10,400	6,780	11,200
Total	29,400	15,200	72,600 r/	67,600	102,000	82,800
2000:						
Aruba	1,020	347	--	--	1,020	347
Australia	187	207	1,340	2,300	1,530	2,510
Belgium	144	72	1,140	1,390	1,280	1,460
Brazil	40	20	1,310	2,900	1,350	2,920
Canada	4,750	4,550	7,940	13,600	12,700	18,100
France	19	62	2,450	10,400	2,470	10,500
Germany	78	129	1,620	2,260	1,690	2,390
Hong Kong	1,270	658	567	448	1,840	1,110
Israel	710	252	874	1,250	1,580	1,500
Italy	180	256	1,510	3,310	1,690	3,560
Japan	64	113	17,100	9,710	17,200	9,830
Korea, Republic of	360	226	5,370	5,130	5,740	5,350
Mexico	2,370	1,200	4,370	5,520	6,740	6,720
Netherlands	4,170	1,430	17,000	7,500	21,100	8,930
Spain	247	202	779	998	1,030	1,200
Switzerland	2,920	614	100	205	3,020	819
Taiwan	1,130	777	336	470	1,470	1,250
United Kingdom	482	400	3,270	4,720	3,750	5,120
Other 6/	1,710	1,020	5,250	11,900	6,950	12,900
Total	21,800	12,500	72,300	84,000	94,100	96,500

r/ Revised. -- Zero.

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 within the "Other" category under the "Country" list.

3/ Amorphous, crystalline flake, lump and chip, and natural, not elsewhere classified. The applicable Harmonized Tariff Schedule (HTS) nomenclature titles and codes are: "Natural graphite in powder or in flakes" and "Other," HTS codes 2504.10.0000 and 2504.90.0000.

4/ Includes data from the applicable HTS nomenclatures: "Artificial graphite" and "Colloidal or semicolloidal graphite," HTS codes 3801.10.0000 and 3801.20.0000.

5/ Values are free alongside ship (f.a.s.).

6/ Includes data for countries reflecting less than 1,000 metric tons of total exports from the United States.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY 1/ 2/

Country or territory	Crystalline flake and flake dust: Quantity (metric tons)	Crystalline flake and flake dust: Value 3/ (thousands)	Lump and chippy dust: Quantity (metric tons)	Lump and chippy dust: Value 3/ (thousands)	Other natural crude, high-purity, expandable: Quantity (metric tons)	Other natural crude, high-purity, expandable: Value 3/ (thousands)	Amorphous: Quantity (metric tons)	Amorphous: Value 3/ (thousands)	Total: Quantity (metric tons)	Total: Value 3/ (thousands)
1999:										
Brazil	38	$46	--	--	4,710	$9,440	--	--	4,750	$9,490
Canada	12,600	7,510	--	--	1	26	--	--	12,600	7,540
China	8,180	3,360	--	--	9,720	5,180	741	$170	18,600	8,710
Germany	--	--	--	--	182	519	--	--	182	519
India	24	25	--	--	--	--	--	--	24	25
Japan	21	12	--	--	384	2,120	491	28	896	2,160
Madagascar	2,570	1,370	--	--	--	--	--	--	2,570	1,370
Mexico	--	--	--	--	570	264	12,500	1,820	13,100	2,080
Mozambique	1,190	1,050	--	--	--	--	--	--	1,190	1,050
Sri Lanka	--	--	418	$530	--	--	--	--	418	530
Zimbabwe	200	81	--	--	--	--	--	--	200	81
Other 4/	815	552	--	--	207	581	216	53	1,240	1,190
Total	25,600	14,000	418	530	15,800	18,100	14,000	2,070	55,800	34,700
2000:										
Brazil	675	808	--	--	1,050	2,020	324	73	2,040	2,900
Canada	14,300	8,540	--	--	18	60	--	--	14,300	8,600
China	6,570	4,440	--	--	10,100	4,330	2,250	327	19,000	9,100
Germany	7	7	--	--	83	210	--	--	90	217
India	150	137	--	--	--	--	--	--	150	137
Japan	9	12	--	--	454	4,130	4,600	358	5,060	4,500
Madagascar	3,690	1,780	--	--	--	--	349	101	4,040	1,880
Mexico	--	--	--	--	415	202	13,900	1,900	14,300	2,100
Mozambique	196	111	--	--	--	--	--	--	196	111
Sri Lanka	--	--	265	330	--	--	--	--	265	330
Zimbabwe	180	95	--	--	--	--	--	--	180	95
Other 4/	486	172	--	--	821	2,340	--	--	1,310	2,510
Total	26,200	16,100	265	330	13,000	13,300	21,400	2,760	60,800	32,500

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The information framework from which data for this material were derived originated from Harmonized Tariff Schedule (HTS) base data.

3/ Customs values.

4/ Includes Austria (2000), Belgium (2000), Dominican Republic (1999), Finland (2000), France, Hong Kong, Indonesia (2000), Italy, the Marshall Islands (2000), the Netherlands, Russia (2000), Seychelles (2000), South Africa, Sweden (1999), Switzerland (2000), Taiwan (2000), Ukraine (1999), and the United Kingdom.

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

TABLE 8
U.S. IMPORTS FOR CONSUMPTION
OF GRAPHITE ELECTRODES, BY COUNTRY 1/ 2/

Country	Quantity (metric tons)	Value 3/ (thousands)
1999:		
Brazil	4,890	$11,700
Canada	9,010	22,300
China	1,980	3,490
Germany	3,360	9,450
India	3,480	7,130
Italy	6,700	13,500
Japan	8,730	25,900
Mexico	17,500	28,300
Russia	3,630	4,930
Switzerland	1,680	3,860
Other 4/	1,910	4,490
Total	62,800	135,000
2000:		
Brazil	6,480	13,500
Canada	6,000	15,900
China	2,990	5,070
Germany	4,110	9,970
India	2,700	5,880
Italy	4,380	7,830
Japan	11,100	30,500
Mexico	17,300	29,200
Russia	3,350	4,620
Other 4/	2,450	5,370
Total	60,900	128,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The applicable Harmonized Tariff Schedule (HTS) code and nomenclature title are HTS 8545.11.0000, "Electric Furnace Electrodes."
3/ Customs values.
4/ Includes data for countries reflecting less than 1,000 metric tons per year for imports.

Source: U.S. Census Bureau.

TABLE 9
GRAPHITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Austria e/	12,000	12,000	12,000	12,000	12,000
Brazil (marketable)	31,254	40,587	61,369	56,200 r/	56,000
Canada e/ 3/	25,000	25,000	25,000	25,000	25,000
China e/	185,000	310,000	224,000 r/	217,000 r/	220,000
Czech Republic e/	30,000	25,000	28,000	22,000 r/	25,000
Germany (marketable)	2,603	1,030	1,000 e/	1,000 e/	1,000
India (run-of-mine) 4/	115,233	102,143	143,333	145,000 e/	140,000
Korea, North e/	40,000	40,000	35,000	25,000	25,000
Korea, Republic of	1,113	83	62	62 r/	60
Madagascar 5/	12,134	13,975	13,087 r/	13,000 r/ e/	13,000
Mexico:					
Amorphous	38,967	46,707	42,893	27,781 r/	30,330 p/
Crystalline flake	1,445	1,275	568	-- r/	--
Mozambique	3,283	5,125	5,889	2,100 r/ e/	--
Norway e/	2,600 r/	2,600	2,600 r/	2,500	2,500
Romania	2,931	2,563	1,951 r/	1,041 r/	1,500
Russia e/	6,000	6,000	6,000	6,000	6,000
Sri Lanka	5,618	5,400 r/	5,910 r/	4,592 r/	4,600
Sweden	463	1,470	3,011	4,500	5,000
Tanzania e/	6,776 6/ 7/	11,000	-- 8/	--	--
Turkey (run-of-mine) e/ 9/	20,000	15,000	15,000	15,000	15,000
Ukraine	5,000 r/ e/	5,000 r/ e/	5,104 r/	7,461 r/	7,500
Uzbekistan e/	60	60	60	60	60
Zimbabwe	7,691	12,779	13,806	12,321 r/	12,000
Total	555,000 r/	685,000 r/	646,000 r/	600,000 r/	602,000

e/ Estimated. p/ Preliminary. r/ Revised. -- 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 May 11, 2001.
3/ Source: World Mineral Statistics, British Geological Survey, 1995-99.
4/ Does not include the following quantities sold directly without beneficiation, in metric tons: 1996--4,134; 1997--9,397; 1998--10,747; 1999--10,700 (estimated); and 2000--10,500 (estimated).
5/ Indian marketable production is 10% to 20% of run-of-mine production.
6/ Reported figure.
7/ Exports. Source: United Nations, Department of International Economic and Social Affairs, Statistical Office.
8/ Graphtan Limited Mine closed. Only remaining stocks shipped in January-February 1998.
9/ Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.