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 United States mills to simple hand sorting and screening of high-grade ore at the 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 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 non-stockpile-grade, were 8,761 metric tons (t) with a value of about $1.66 million. Madagascar natural graphite inventories in the United States were 3,850 t with a value of $600,000. There was 4,910 t of Sri Lanka amorphous lump with a value of $1.12 million (table 2). No acquisition of graphite from the strategic and critical materials stockpile took place in 2001. 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 2001. The reported U.S. production of synthetic graphite reached 298,000 t with a value of $906 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 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, require higher purity graphite.

U.S. consumption of natural graphite decreased by more than 22% in 2001 to 32,900 t from 42,200 t in 2000 (table 3). The crystalline grade decreased in 2001 by 23% to 14,100 t from 18,200 t in 2000, whereas amorphous grade decreased by 22% in 2001 to 18,800 t from 24,000 t in 2000. This decreased use translated into a 21% decrease in value in 2001. The four major industries—refractories, brake linings, foundries, and lubricants—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 2001 (table 3). The refractories industry was again the major consumer of crystalline flake graphite. However, the refractory uses of crystalline flake graphite decreased by a staggering 41% compared with 2000. The existence of the refractories industry depends, in large part, on the success of the steel industry. The decline in the steel industry during 2000 accounts for most of the decrease in the use of graphite in refractory brick production. This decline in refractory applications that was forthcoming could be predicted from the closure of several domestic chrome-magnesite brick plants in 2000. Use for brake linings followed refractories as a close second, with lubricants in a distant third place.

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 43% 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 primary choice in North America, accounting for a significant share of the graphite market. The main market for high-purity synthetic graphites is as a carbon-raiser additive in iron and steel. This market consumes a significant portion of the total 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

Natural graphite prices remained unchanged during 2001. 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, increased to $2,070 per ton in 2001 from $1,940 per ton in 2000. Customary negotiations between the buyer and the seller lead to wide price fluctuations.

Foreign Trade

Total imports of natural graphite decreased in tonnage to 52,100 t in 2001 from 60,800 t in 2000, a more than 14% decline, and the value declined to $23.3 million in 2001 compared with $32.5 million in 2000 (table 1). Principal import sources of natural graphite, in descending order of tonnage, were China, Mexico, Canada, and Japan, which accounted for more than 80% 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 Brazil (high purity), China, Germany, and Japan. In spite of showing a noticeable decrease in tonnage, for the second year in a row, total exports recorded a modest 3.5% increase in total revenue to $100 million in 2001 compared with $96.5 million in 2000 owing to the increase in value of the finished goods exported (table 6).

World Review

World production of graphite in 2001 was estimated to be 873,000 t compared with 857,000 t in 2000. China maintained its position as the world's leading graphite producer with 450,000 t, with India in second place with 140,000 t, followed by Brazil, Madagascar, Mexico, the Czech Republic, the Republic of Korea, and Canada in order of tonnage produced. These five countries accounted for 87% 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 52% of world production.

Current Research and Technology

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 dyes 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, p. 356-357). Their hollow spherical structure, reminiscent of the 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 three alkali atoms per fullerene unit (C_{60}) results in a material that exhibits superconductivity at quite high temperatures (10 K to 40 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

Refractory use trends of graphite will closely follow the events in the steel industry because it is mostly used in the manufacture of refractory brick used in iron and steel furnace linings. If the U.S. steel industry benefits from the recent tariff levy on steel imports, then the share of graphite use in refractories may reach the levels of 2000. 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 two main consuming sectors—alkaline batteries and lithium-metal 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 for mobile energy storage systems rises.

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, p. 122).

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/

		1997	1998	1999	2000	2001
United States:						
Apparent consumption 2/	metric tons	18,400	33,600	26,400	39,000	28,200
Exports	do.	39,700	28,000	29,400	21,800	23,900
Value	thousands	$20,500	$14,100	$15,200	$12,500	$16,900
Imports for consumption	metric tons	58,100	61,600	55,800	60,800	52,100
Value	thousands	$32,400	$34,800	$34,700	$32,500	$23,300
World, production	metric tons	685,000	651,000 r/	692,000 r/	857,000 r/	873,000 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 GOALS AND YEAREND
STOCKS OF NATURAL GRAPHITE IN 2001, BY TYPE 1/ 2/

(Metric tons)

Type	Stock
Madagascar crystalline flake	3,850
Sri Lanka amorphous lump	4,910
Nonstockpile-grade, all types	1

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, 2001.

TABLE 3
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE 1/

	Crystalline		Amorphous 2/		Total	
End use	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2000:						
Batteries	W	W	--	--	W	W
Brake linings	1,100	$1,340	5,480	$4,010	6,580	$5,350
Crabon products 3/	471	1,390	W	210	W	1,600
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	821	633
Foundries 4/	W	584	W	W	W	W
Lubricants 5/	389	649	1,180	883	1,570	1,530
Pencils	W	W	W	W	520	W
Powdered metals	428 r/	993 r/	W	W	W	W
Refractories	5,670 r/	W	5,360	3,590	11,000 r/	W
Rubber	W	W	W	W	W	W
Steelmaking	28	18	W	W	W	W
Other 6/	W	W	812	541	W	W
Total	18,200 r/	19,500 r/	24,000 r/	18,600 r/	42,200 r/	38,100 r/
2001:						
Batteries	W	W	--	--	W	W
Brake linings	886	1,610	5,540	4,400	6,420	6,010
Crabon products 3/	357	1,060	212	181	569	1,240
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries 4/	W	576	W	1,460	2,640	2,030
Lubricants 5/	328	489	284	444	612	933
Pencils	334	W	82	W	416	W
Powdered metals	492	991	W	W	W	W
Refractories	3,360	2,050	3,860	2,780	7,220	4,840
Rubber	52	79	W	319	W	397
Steelmaking	W	W	W	4,200	W	W
Other 6/	W	W	W	690	7,230	W
Total	14,100	15,600	18,800	14,600	32,900	30,200

See footnotes at end of table.

TABLE 3--Continued
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE 1/

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)
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
2001:		
Anodes	W	W
Cloth and fibers (low modulus)	W	W
Electric motor brushes and machined shapes	W	22,000
Electrodes	185,000	484,000
High-modulus fibers	2,680	52,300
Unmachined graphite shapes	6,030	69,000
Synthetic graphite powder and scrap 2/	95,000	W
Other	W	W
Total	298,000	906,000

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	2000	2001
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	1,940	2,070

1/ Prices are normally cost, insurance, and freight main European port.

Source: Industrial Minerals, no. 399, December 2000, p. 74; no. 411, December 2001, p. 82.

TABLE 6
U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY 1/ 2/

	Natural 3/		Artificial 4/		Total	
Country	Quantity (metric tons)	Value 5/ (thousands)	Quantity (metric tons)	Value 5/ (thousands)	Quantity (metric tons)	Value 5/ (thousands)
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
2001:						
Australia	528	869	1,110	3,150	1,630	4,020
Brazil	67	56	1,110	3,280	1,170	3,340
Canada	7,270	3,500	6,260	11,800	13,500	15,300
France	589	238	2,820	15,300	3,410	15,600
Germany	189	304	862	2,830	1,050	3,130
Italy	698	1,330	383	858	1,080	2,180
Japan	368	370	20,000	17,000	20,400	17,400
Korea, Republic of	355	485	5,460	4,730	5,810	5,210
Malaysia	935	970	264	366	1,200	1,340
Mexico	1,950	1,100	2,910	3,420	4,870	4,520
Netherlands	3,280	1,170	18,900	7,450	22,100	8,620
Singapore	171	229	1,210	731	1,380	960
Switzerland	2,840	1,120	81	170	2,920	1,290
United Kingdom	682	474	1,380	4,200	2,060	4,680
Other 6/	3,980	4,680	5,290	8,040	9,280	12,700
Total	23,900	16,900	68,000	83,400	91,900	100,000

-- 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)
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
2001:										
Brazil	974	521	--	--	1,910	3,070	--	--	2,890	3,590
Canada	9,520	5,040	--	--	4	21	65	4	9,590	5,070
China	6,390	3,190	--	--	7,950	2,430	1,100	238	15,400	5,860
Germany	126	106	--	--	17	85	--	--	142	191
India	168	195	--	--	100	268	--	--	267	463
Japan	--	--	--	--	550	3,110	2,470	138	3,020	3,240
Madagascar	2,500	1,180	--	--	--	--	--	--	2,500	1,180
Mexico	2	2	--	--	1	10	14,100	1,980	14,100	2,000
Norway	--	--	--	--	--	--	2,550	238	2,550	238
Sri Lanka	--	--	221	301	--	--	--	--	221	301
Zimbabwe	140	65	--	--	--	--	--	--	140	65
Other 4/	205	92	--	--	316	855	784	172	1,300	1,120
Total	20,000	10,400	221	301	10,900	9,840	21,100	2,770	52,100	23,300

-- 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, Belgium, Finland (2000), France, Hong Kong, Indonesia (2000), Italy, the Marshall Islands (2000), the Republic of Korea (2001), the Netherlands, Russia (2000), Seychelles, South Africa, Sweden (2001), Switzerland, Taiwan, 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)
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

See footnotes at end of table.

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

Country	Quantity (metric tons)	Value 3/ (thousands)
2001:		
Brazil	1,610	3,310
Canada	1,960	5,140
China	3,670	6,110
France	3,290	6,210
Germany	3,580	8,970
India	1,400	2,510
Italy	2,840	4,450
Japan	9,520	24,500
Mexico	19,300	31,100
Russia	1,370	1,580
Other 4/	1,130	2,460
Total	49,700	96,300

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	1997	1998	1999	2000	2001 e/
Austria	12,000 e/	10,738 r/	12,635 r/	12,000 e/	12,000
Brazil (marketable) 3/	40,587	61,369	53,503 r/	71,208 r/	72,000
Canada e/	25,000 4/	25,000 4/	25,000 4/	25,000	25,000
China e/	310,000	224,000	300,000 r/	430,000 r/	450,000
Czech Republic	25,000	28,000	22,000	23,000 r/	25,000
Germany (marketable)	1,030	270 r/	300 r/	300 r/ e/	300
India (run-of-mine) 5/	102,143	143,333	145,000 e/	140,000 e/	140,000
Korea, North e/	40,000	35,000	33,000 r/	30,000 r/	25,000
Korea, Republic of	83	62	62	65 r/	65
Madagascar 6/	14,107 r/	20,629 r/	16,137 r/	40,328 r/	40,300
Mexico:					
Amorphous	46,707	42,893	27,781	30,330	30,000
Crystalline flake	1,275	568	--	--	--
Mozambique	5,125	5,889	4,007 r/	--	--
Norway e/	2,600	2,600	2,500	2,500	2,500
Romania	2,563	1,951	1,041	1,251 r/	1,500
Russia e/	6,000	6,000	6,000	6,000	6,000
Sri Lanka	5,400	5,910	4,592	5,902 r/	6,000
Sweden	1,470	3,011	4,500 e/	5,000 e/	5,000
Tanzania	11,000	--	--	--	--
Turkey (run-of-mine) e/ 7/	15,000	15,000	15,000	15,000	15,000
Ukraine	5,000 e/	5,104	7,461	7,431 r/	7,500
Uzbekistan e/	60	60	60	60	60
Zimbabwe	12,779	13,806	11,405 r/	11,812 r/	10,000
Total	685,000	651,000 r/	692,000 r/	857,000 r/	873,000

e/ Estimated. 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 13, 2002.
3/ Does not include the following quantities sold directly without beneficiation, in metric tons: 1997--9,397; 1998--10,747; 1999--10,700 (estimated); 2000--not available (revised); and 2001--not available.
4/ Source: World Mineral Statistics, British Geological Survey, 1995-99.
5/ Indian marketable production is 10% to 20% of run-of-mine production.
6/ Exports. Source: United Nations, Department of International Economic and Social Affairs, Statistical Office.
7/ Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.