GRAPHITE.

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INTRODUCTION.

Natural graphite may be either crystalline or amorphous. Crystalline or flake graphite is commonly understood to mean graphite in crystals of sufficient size to be visible to the naked eye; much of the so-called amorphous graphite shows a crystalline structure under the microscope. Crystalline graphite occurs either in veins, as in the Ceylon deposits, or as flakes disseminated through the country rock, as in many of the deposits in the United States.

Most deposits of amorphous graphite are the result of the alteration of coal beds by the intrusion of igneous rocks. Amorphous graphite s also made artificially by means of the electric furnace.

The peculiar physical properties of graphite—infusibility, chemical inertness, high conductivity, extreme softness, and low specific gravity—fit it for a large number of uses, such as the manufacture of crucibles and other refractory products, lubricants, "lead" pencils, paint, oundry f acings, as a preparation to loosen boiler scale, as a polish for gunpowder, and in various types of electrical work. Of these uses the manufacture of crucibles takes by far the greatest share of the total output.

CRYSTALLINE GRAPHITE.

GENERAL CONDITIONS.

For most purposes amorphous graphite, either natural or artificial, may be used with as good effect as the crystalline variety, but for the manufacture of crucibles it is essential that the flakes be of sufficient size to add to the binding power of the clay with which the graphite is mixed. Graphite for crucibles should carry a considerable proportion of flakes 1 millimeter or more in diameter. The great increase in the manufacture of brass and crucible steel since the outbreak of the

NOTE.—Much of the material in this article is derived from the Geological Survey reports on graphite by Edson S. Bastin, particularly the report for 1913 (Mineral Resources, 1913, pt. 2, pp. 181-251, 1914) and "Geology of the graphite deposits of the United States" (Bull. 679, in preparation).

war has resulted in a tremendous increase in the demand for crystalline graphite. This demand has been met for the most part by largely increased imports, particularly from Ceylon, and only in minor part by expansion of the domestic graphite industry. The following table shows the imports and domestic output of crystalline graphite for the last six years:

Crystalline graphite imported and produced in the United States, 1911–1916.

Quantity (short tons).

	1911	1912	1913	1914	1915	1916
Imports:[a]						
Ceylon	13,119	16,791	16,996	8,755	14,491	24,984
Other countries	2,384	2,819	2,382	2,328	4,504	7,122
	15,503	19,610	19,378	11,083	18,995	32,106
Domestic production	2,395	1,772	2,532	2,610	3,537	5,468
Total available supply	17,898	21,382	21,910	13,693	22,532	37,627
Per cent represented by domestic production	13.4	8.3	11.6	19.1	15.7	14.68

Value.

Imports:[a]						
Ceylon	$1,132,678	$1,379,587	$1,674,764	$962,593	$1,746,153	$6,013,366
Other countries	83,124	127,347	160,766	144,599	303,639	920,369
	1,215,002	1,506,934	1,735,530	1,006,292	2,049,792	6,933,731
Domestic production	256,050	187,689	254,328	285,368	417,273	914,748
	1,471,852	1,694,623	1,989,858	1,291,660	2,467,065	7,848,479
Per cent represented by domestic production	17.5	11.1	12.8	22.1	16.9	11.7

[a] From records of the Department of Commerce.

During 1914 and 1915 the imports from Ceylon were less than normal, owing chiefly to the high freight rates and scarcity of ships. The sharp increase in the value of the Ceylon graphite imported in 1916 is due largely to the fact that because of the conditions menioned only the higher-grade material was imported.

Domestic flake graphite of a grade suitable for crucible use has increased greatly in price during the last two years. The prices paid at the mines for the highest-grade product, in cents a pound, have been as follows: 1911 and 1912, 6 to 7; 1913, 6 to 8; 1914, 6½ to 8; 1915, 7 to 10; 1916, 10 to 16.

Average prices of crystalline graphite of all grades, including dust as well as flake, have been as follows:

Prices of crystalline graphite, 1911–1916, in cents a pound.

	Ceylon.	Domestic.		Ceylon.	Domestic.
1911	4.3	5.3	1914	4.5	5.5
1912	4.1	5.3	1915	6.4	5.9
1913	4.9	5.0	1916	12.0	8.4

DOMESTIC SUPPLIES.

In the United States crystalline graphite is mined in Alabama, California, Montana, New York, Pennsylvania, and Texas, and deposits are known in Alaska, Maine, Massachusetts, New Hampshire, New Jersey, North Carolina, Vermont, Virginia, and Washington.

Alabama.—The Alabama mines contribute about half the total domestic output. The graphite is found in lenses of graphitic schist, which occur in a broad belt stretching southwestward across Clay, Coosa, and Chilton counties. Where mined the schist contains an average of about 3 or 4 per cent of graphitic carbon. The deposits are weathered to depths of 50 to 65 feet, and mining is confined to the weathered material. Weathering has lessened the coherence between the graphite and other minerals, and consequently the material is more easily mined and milled than unweathered material. The unweathered graphite schist, the "blue rock" of the miners, may eventually be worked, but its treatment will probably involve added expense and some modifications of the present methods of milling. Should conditions arise that would compel the United States to depend on its own supplies of graphite, this "blue rock" may become a valuable resource.

During 1916 seven companies mined graphite in Alabama, three of which were new producers; several more companies have begun operations since January 1, 1917, and others are planning to start in the near future. Mining and milling methods have been much improved in recent years, and costs have been so far reduced that it will be possible for the more efficiently managed companies to continue in operation even under peace conditions. Recent articles by Prouty [1] give interesting descriptions of the Alabama deposits.

New York.—Nearly all the New York deposits of graphite that have been worked are in the eastern and southeastern Adirondack region, in Essex, Warren, and Saratoga counties and the northern part of Washington County. West of the Adirondacks some prospecting and development work has been done in St. Lawrence County. The graphite occurs as disseminated flakes in metamorphic rocks, crystalline limestone, schist, and gneiss, and the graphite content of the material mined averages rather higher than in the Alabama deposits. The deep zone of soft weathered rock which favors cheap mining of the Alabama deposits is, however, lacking in this northern region. Near Ticonderoga graphite also occurs in small veins.

Pennsylvania.—Chester County has for many years been the center of the graphite industry of Pennsylvania and within the last 10 years

[1] Prouty, W. F., Flake graphite in Alabama; its location, its history, and its value to the State: Birmingham Age-Herald, Jan. 28, 1917; Extent and development of flake graphiter esources of Alabama: Manufacturers' Record, Apr. 19, 1917, pp. 66-67.

has been the sole productive district in the State. The rocks mined for graphite are graphitic quartz-mica schists and minor amounts of graphitic limestone. The graphite deposits of Pennsylvania have been described in a special report by Miller.[1] This report may be procured by addressing Richard R. Hice, State geologist, Beaver, Pa., and to it the reader is referred for fuller details.

Texas.—The graphite deposits of Texas are similar to those of Alabama and occur in the vicinity of Burnet and Llano, in the central part of the State. The year 1916 marks the beginning of the Texas production.

California.—Deposits of graphitic schist have been mined in southern California, in Los Angeles and San Diego counties. These deposits resemble the characteristic deposits of New York, Pennsylvania, and Alabama in that the graphite occurs as flakes disseminated through a schist. The flakes in the California schists, however, are much smaller than those in the eastern deposits, most of them not exceeding 0.25 millimeter in diameter, and therefore the material is not adapted for use in the manufacture of crucibles. On the other hand, the percentage of graphite in the California deposits appears to be nearly twice that of most of the eastern deposits of similar type.[2]

Montana.—A deposit of crystalline graphite is being mined near Dillon, Mont., and is of particular interest because the graphite occurs in veins, like that of the Ceylon deposits. One mine has reached the producing stage and has made shipments to the eastern markets.

Nonproductive areas.—Extensive deposits of graphite-bearing schists occur in Alaska on both the northern and southern slopes of the Kigluaik Mountains, in the southern part of Seward Peninsula. Two companies are developing these deposits but have not yet produced commercial quantities.

Some development work has been done recently on graphite properties on the eastern slope of the Cascade Range in Chelan County, Wash.

Graphite occurs in many places in the crystalline rocks of the Atlantic States but except in New York, Pennsylvania, and Alabama has not been mined successfully. It is present at several localities in Maine,[3] and in 1905 an unsuccessful attempt was made to mine it near Madrid, in Franklin County. Graphite also occurs in the crystalline rocks at many places in Vermont and New Hampshire but has never been successfully mined. In Massachusetts a graphite deposit near Sturbridge, not far from the Connecticut boundary, was worked as early as 1658, and the mine is therefore one of the oldest

[1] Miller, B. L., Graphite deposits of Pennsylvania: Pennsylvania Top. and Geol. Survey Comm. Rept. 6, 1912.

[2] U. S. Geol. Survey Mineral Resources 1915, pt. 2, p. 87, 1916.

[3] Smith, G. O., Graphite in Maine: U. S. Geol. Survey Bull. 285, pp. 480–483, 1906.

in the United States. Little work has been done here in recent years, however.

Graphite is found in disseminated flakes in the crystalline rocks of the highlands of northern New Jersey at a number of localities. Several attempts to mine and concentrate the material have been made in the past but have not proved successful, and the State is not now a graphite producer.

Although graphite is not now produced in Virginia it occurs at a number of localities in the Piedmont region, east of the Blue Ridge. Some development work was done in 1915 in the northern part of Albemarle County.

Graphite has been found at many places within the area of crystalline rocks in the central and western parts of North Carolina. The principal graphite deposits of this State have been briefly described by Pratt,[1] and copies of his report may be obtained from the State geologist, Chapel Hill, N. C.

PROSPECTS OF INCREASING THE DOMESTIC OUTPUT.

From the short descriptions given above it will be seen that the United States possesses a considerable reserve of crystalline graphite, for the most part suitable for crucible manufacture. At the ordinary price of graphite, however, it is possible to mine only the most favorably situated deposits. Cheap labor and large and easily mined deposits make mining costs in Ceylon much lower than in America and offset the freight charges.

The graphitic schists from which American flake graphite is derived require crushing and concentration. The developing of milling methods especially adapted to the treatment of graphite has not yet reached any degree of standardization, and the quantity saved is rarely over 60 per cent of the graphite content of the ore. Recenc important developments have been the adaptation of electrostatit separation to graphite concentration and the use of oil flotation. Each improvement in graphite treatment results in a larger proportion of clean concentrates of the best grades. Continued improvement in methods of treatment will probably result in a better situation for American flake graphite after the war. Many manufacturers who before the war used imported graphite exclusively have perforce turned to the American product and, finding the graphite of the better grades suitable for their purposes, have used it mixed with Ceylon graphite, and they will continue to use it unless Ceylon graphite of good grade can be put on the market at greatly reduced prices. It can not be expected, however, that the present prices of flake graphite will continue after the war, for there will be no longer the

[1] Pratt, J. H., The mining industry in North Carolina during 1901: North Carolina Geol. Survey Econ. Paper 6, pp. 69-72, 1902.

tremendous demand for graphite as an adjunct to munition manufacture, and graphite from Ceylon and other foreign countries will again enter the market under normal conditions. Those contemplating the development of graphite deposits should estimate the probable costs very carefully and be sure that the deposit is one that shows good promise of being profitably mined at normal prices.

AMORPHOUS GRAPHITE.

Amorphous graphite is suitable for all purposes for which graphite is used except the manufacture of crucibles. As it does not enter to any large degree into the manufacture of munitions, the war has not greatly affected either price or production. Moreover, artificial graphite and crystalline graphite in particles too small for crucible manufacture are adapted to practically all uses to which natural amorphous graphite can be put, and the reserves of amorphous graphite are therefore less important. The uses of amorphous graphite vary greatly with the purity of the substance mined. For paint and foundry facings a high degree of purity is not essential, but for lubricants, pencils, and electric purposes high-grade material is necessary. The better grades of amorphous graphite are imported from Mexico and Chosen, and the imports, like those of crystalline graphite, greatly exceed the domestic output. The sharp decrease in importation in 1915 shown in the following table was due chiefly to the disturbed conditions in Mexico, but also to decreased imports from Chosen owing to high freight rates and scarcity of ships.

Amorphous graphite imported and produced in the United States, 1911–1916.

Quantity (short tons).

	1911	1912	1913	1914	1915	1916
Imports	5,199	6,031	9,501	10,917	4,080	10,837
Domestic production	1,223	2,063	2,243	1,725	1,181	2,622
Total available supply	6,422	8,094	11,744	12,642	5,261	13,458
Per cent represented by domestic production	19.0	25.6	19.1	13.6	21.9	19.5

Value.

Imports	$279,927	$202,403	$270,217	$290,969	$111,286	$345,732
Domestic production	32,415	32,894	39,428	38,750	12,358	20,723
Total	312,342	235,297	309,645	329,719	123,644	366,455
Per cent represented by domestic production	10.4	14.0	12.7	11.8	10.0	5.7

ARTIFICIAL GRAPHITE.

Graphite in large quantities is manufactured at Niagara Falls, N. Y., by the International Acheson Graphite Co., which utilizes electric power generated at the Falls. The bulk graphite produced by this

company in 1915 was reported as 2,542 short tons, and in 1916 as 4,199 tons. This represents only the graphite that would come into competition with natural graphite and does not include graphitized products that do not compete with natural graphite. The material, most of which is made either from anthracite or from petroleum coke, comes from the furnace in an earthy, incoherent condition and is utilized mainly in lubricants and paints and for foundry facings, boiler-scale preventives, and battery fillers.

Besides the graphite products that enter into competition with natural graphite, there are a large number of graphite products for which artificial graphite is especially adapted. Chief among these are graphite electrodes, the demand for which has greatly increased during the last two years on account of the remarkable growth in certain electrochemical industries. The extent of this growth is indicated by the statement [1] that during 1915 the number of electric steel furnaces in operation in this country increased 78 per cent.

POSSIBLE INCREASE OF SUPPLY.

The domestic production of amorphous graphite is of minor importance both in amount and grade compared to the imports, and an expansion of the artificial graphite industry could supply any demand for this material. An increase in the production of crystalline graphite, however, is very important. This may be accomplished by bringing new areas into active production and by increasing the efficiency of milling operations. Increased efficiency would in turn make it profitable to mine deposits now considered unworkable. At present in Alabama, where the deposits are cheaply mined, material containing 3 per cent of graphite by weight is the poorest that can be successfully mined. The problem of concentrating the lightest material in an ore, rather than the heaviest, is one that demands further intensive study. Many of the graphite deposits of the present nonproductive areas might be mined if processes of treatment could be improved, and further study of these deposits would determine which district shows the best promise of future development. Prospecting is proceeding vigorously but is largely confined to areas in the neighborhood of the present productive mines.

[1] Iron Age, Jan. 6, 1916, p. 95.