ABRASIVE MATERIALS.

By W. C. Phalen.

INTRODUCTION.

The abrasive materials included in this report are millstones and buhrstones, grindstones and pulpstones, oilstones and scythestones, corundum and emery, abrasive quartz and abrasive feldspar, garnet, infusorial earth and tripoli, pumice, and the artificial abrasives which include carborundum, alundum, and crushed steel. Of some of these materials only a small part of the entire product is actually used for abrasive purposes. In this report, so far as it has been possible, there is included, with the exception of tripoli and possibly infusorial earth, only that part of the product that is actually used for abrasive purposes. Thus under grindstones and pulpstones, which are obtained from sandstone, only a small percentage of the stone that is quarried is used in the manufacture of abrasives, the remainder being used chiefly in the building industry; also, as stated on another page, only a small proportion of the crystalline quartz and feldspar produced is used in the abrasive industry. A large part of the tripoli mined in Missouri is used in the filter stone industry. Practically all the raw material mined or quarried for millstones, pumice, corundum, emery, and garnet (except the gem garnet) is used for abrasive purposes.

Fairly detailed descriptions of the occurrence and mode of preparation of the different abrasive materials have appeared in preceding reports of the United States Geological Survey. Thus oilstones and whetstones were described in the report for 1901, and grindstones, buhrstones, millstones, infusorial earth and tripoli in the reports for 1900 and 1901. In the report for 1902 the deposits of infusorial earth of Pinal County, Ariz., were described by W. P. Blake.[a] Pumice was treated in the report for 1901, and artificial abrasives in the same report. In the report for 1903 an article on carborundum by F. A. J. Fitzgerald was quoted from the Iron Age,[b] and also an abstract on crushed steel, from the Proceedings of the American Association for the Advancement of Science.[c]

In the present report a detailed description is given of the method of preparing millstones from the Esopus conglomerate in Ulster County, N. Y., the center of the millstone industry in that State, and also of the mode of preparing Missouri tripoli for use in filter stones. The garnet deposits in New York are treated at considerable length, as well as the occurrence of pumice in the central Western States. A detailed description of the manufacture and technology of alundum, among the artificial abrasives, is also given. It is planned to treat the other abrasive materials in similar manner in the next report.

[a] Am. Inst. Min. Eng., February meeting, 1902.
[b] Iron Age, October 15, 1903.
[c] Proc. Am. Assoc. Adv. Sci., Pittsburg meeting, 1903.

The following table gives the value of all the natural abrasive materials produced in the United States during the years 1903 to 1907, inclusive. The value of the production in 1907 showed a substantial increase as compared with that of 1906. There was a decrease in the value of millstones, oilstones and scythestones, and emery, but an increase in the value of grindstones and pulpstones, abrasive quartz and feldspar, garnet, infusorial earth and tripoli, and pumice. The most apparent reasons for the decrease in the value of millstones are competition and the introduction of modern machinery in grinding. In the case of emery care has been taken that the values assigned have been those of the crude material on board cars at the point of shipment, for only in this way is it possible to assign a uniform value per ton. This, moreover, explains in part why the value of the material is so much less than it has been in preceding years, another reason being the nonproduction of corundum, which in previous years has been combined with emery.

Value of natural abrasives produced in the United States, 1903–1907.

Kind of abrasive.	1903.	1904.	1905.	1906.	1907.
Oilstones and scythestones	$366,857	$188,985	$244,546	$268,070	$264,188
Grindstones and pulpstones	721,446	881,527	777,606	744,894	896,022
Buhrstones and millstones	52,552	37,338	37,974	48,590	31,741
Pumice	2,665	5,421	5,540	16,750	33,818
Infusorial earth and tripoli	76,273	44,164	64,637	72,108	104,406
Abrasive quartz	76,908	[a]74,850	[a]88,118	[a]121,671	[a]126,582
Garnet	132,500	117,581	148,095	157,000	211,686
Corundum and emery	64,102	57,235	61,464	44,310	12,294
Total	1,493,303	1,407,101	1,427,980	1,473,393	1,680,737

[a] Including feldspar used for abrasive purposes.

Natural abrasives were produced in 23 States in 1907, as compared with 25 States in 1906. The list of States follows, together with the material produced by each:

List of States producing abrasives in 1907.

ARKANSAS: Oilstones.
CALIFORNIA: Infusorial earth.
CONNECTICUT: Quartz, feldspar, and infusorial earth.
ILLINOIS: Tripoli.
INDIANA: Oilstones.
KENTUCKY: Infusorial earth.
MARYLAND: Quartz and infusorial earth.
MASSACHUSETTS: Quartz, infusorial earth, and emery.
MICHIGAN: Grindstones and scythestones.
MINNESOTA: Feldspar.
MISSOURI: Tripoli and grindstones.
MONTANA: Grindstones.
NEBRASKA: Pumice.
NEVADA: Infusorial earth.
NEW HAMPSHIRE: Scythestones.
NEW YORK: Garnet, infusorial earth, millstones, and emery.
NORTH CAROLINA: Garnet and millstones.
OHIO: Grindstones, pulpstones, oilstones, and scythestones.
PENNSYLVANIA: Quartz, garnet, and millstones.
VERMONT: Scythestones.
VIRGINIA: Millstones.
WEST VIRGINIA: Grindstones.
WISCONSIN: Quartz.

Under the head of artificial abrasives are included alundum, carborundum, and crushed steel. The production of these substances in the last four years is given in the following table:

Production and value of artificial abrasives in the United States, 1904–1907.

Year.	Quantity, in pounds.	Value.	Year.	Quantity, in pounds.	Value.
1904	11,870,380	$830,926	1906	11,774,300	$777,081
1905	9,820,000	701,400	1907	14,632,000	1,027,246

The production of artificial abrasives in 1907 was greater than that of any previous year of which the Survey has record, exceeding that of 1906 by 2,857,700 pounds in quantity and by $250,165 in value.

The total estimated value of all abrasive materials consumed in the United States for the years 1903 to 1907, inclusive, is given in the following table. There was an increase in 1907 in the value of natural abrasives of $207,344 and in the artificial abrasives of $250,165, a total of nearly a half million dollars. There was a decrease in the value of the imports of natural abrasives of $155,824, making a net increase in the domestic consumption of abrasives of all kinds for the year of $301,685, as compared with an increase of $376,437 in 1906. The condition of the domestic industry, however, as appears from the preceding table was much better in 1907 than in any previous year.

Total value of all abrasive materials consumed in the United States, 1903–1907.

Year.	Natural abrasives.	Artificial abrasives.	Imports.	Total value.
1903	$1,493,303	$493,815	$621,575	$2,608,693
1904	1,407,101	830,926	547,804	2,785,831
1905	1,427,980	701,400	654,821	2,784,001
1906	1,473,393	777,081	909,964	3,160,438
1907	1,680,737	1,027,246	754,140	3,462,123

BUHRSTONES AND MILLSTONES.

PRODUCTION.

The production of buhrstones and millstones in the United States during 1907 was valued at $31,741. This is a considerable falling off from the values reported to the Survey during the last few years, and the present condition of the industry approximates that of about eight years ago.

The market for millstones has been greatly curtailed of late years. The table given on a subsequent page shows that recently the industry has dwindled very much and that the value for 1907 is less than one-third of the value for 1887. The explanation of this falling off in the millstone industry is due to the introduction of superior forms of grinding machinery, chiefly rolls, ball mills, etc. The roller-mill process of grinding is now used almost exclusively in grinding wheat. Some corn and mustard mills in the Southern States still use hand-made millstones. A part of the product is sold to the cement and talc manufacturers and grinders of mineral paint.

The production of millstones, as usual, came from but four States, namely, New York, North Carolina, Pennsylvania, and Virginia. Though stone suitable for buhrstones and millstones is found in other States, there was no production from them reported to this office.

Millstone industry in New York.—New York has led for many years in the production of millstones and chasers, the latter term being applied to stones which run on edge. The raw material is obtained in Ulster County, southeastern New York, and is known as Esopus stone, Esopus being an early name for Kingston, which was formerly the main point of shipment. The material suitable for millstones is quarried from the Shawangunk grit, a quartz conglomerate found near the western base of Shawangunk Mountain in the valley of Rondout River. The material suitable for millstones is exceedingly limited, being confined in linear extent to a strip extending from High Falls on the north to Kerhonkson on the south, a distance of approximately 10 miles. Beyond these limits the texture and other properties of the rock have been found unsuitable for the highest grade of stones.

The methods employed in quarrying the rock are simple. The rock is pried or split out, advantage being taken of the joint planes, especially the concentric surface joints. The tools used are the ordinary hand drill, together with plugs and feathers. Blasting is often resorted to, but the charges of powder are usually light. The rough stones thus obtained are quarry dressed and finished, these operations being performed entirely by hand, the chief tools employed being the bull point and hammer. The operation of drilling the "eye" is performed by centering the stone and then drilling from the center of both faces inward. In many stones the eye is square. To fashion a square eye, a round eye is first drilled out and then squared up. A few of the men engaged in the industry make a modification of the regular millstone for use in the grinding of paint. In this modification the ordinary millstone is cut in halves and an iron casting is placed between the halves, which are then banded together by an iron band.

Chasers are larger than the regular millstones. They are used for heavier work, as in grinding quartz, feldspar, barytes, etc., and, as already mentioned, they run on edge. Though they are made with a diameter as short as 24 inches, they are usually turned out with diameters ranging from 50 to 84 inches and with thicknesses as great as 22 inches. These chasers are run on pans paved with blocks of Esopus grit, which are usually roughly cubical with edges about a foot in length. In grinding quartz in such pans the chasers are used in the preliminary crushing; then rough blocks, usually three in number, are either attached to or carried along by lateral arms, which in turn are joined to a vertical revolving shaft. By the circular movement of these blocks the material placed in the pan is ground to powder.

In the following table are given the values by States of buhrstones and millstones produced in the United States from 1903 to 1907:

Value of buhrstones produced in the United States, 1903–1907, by States.

State.	1903.	1904.	1905.	1906.	1907.
New York	$35,441	$24,585	$25,915	$28,848	$23,072
Virginia	9,812	4,759	8,186	15,611	4,684
North Carolina and Vermont	5,902	[a]6,500	[a]2,522	[a]1,507	[a]1,969
Pennsylvania	1,397	1,494	1,351	2,624	2,016
Total	52,552	37,338	37,974	48,590	31,741

[a] No production of buhrstones from Vermont in 1904, 1905, 1906, and 1907.

The following table gives the value of millstones and buhrstones produced in the United States since 1880:

Value of buhrstones and millstones produced in the United States, 1880–1907.

1880	$200,000	1894	$13,887
1881	150,000	1895	22,542
1882	200,000	1896	22,567
1883	150,000	1897	25,932
1884	150,000	1898	25,934
1885	100,000	1899	28,115
1886	140,000	1900	32,858
1887	100,000	1901	57,179
1888	81,000	1902	59,808
1889	35,155	1903	52,552
1890	23,720	1904	37,338
1891	16,587	1905	37,974
1892	23,417	1906	48,590
1893	16,639	1907	31,741

IMPORTS.

The value of the imports of buhrstones and millstones into the United States during 1907 was the lowest recorded in five years. This marked diminution was in the value of the rough material, as the value of the imports made up into millstones showed a gain. This latter value, however, is still insignificant. The table showing the value of imports from 1903 to 1907 follows:

Value of buhrstones and millstones imported into the United States, 1903–1907.

Year.	Rough.	Made into millstones.	Total.	Year.	Rough.	Made into millstones.	Total.
1903	$21,160	$8,481	$29,641	1906	$32,921	$277	$33,198
1904	30,117	2,269	32,386	1907	26,431	877	27,308
1905	30,478	938	31,416				

GRINDSTONES AND PULPSTONES.

PRODUCTION.

The value of the production of grindstones and pulpstones during 1907 amounted to $896,022—an increase in value of $151,128 over that of 1906. This is the highest value recorded by the Survey for grindstones and pulpstones, exceeding by $14,495 the valuation of the year 1904, hitherto the maximum. The production came from the following States named in the order of their relative importance: Ohio, Michigan, West Virginia, Montana, and Missouri, the exact order of importance for 1906. Wyoming reported no production for 1907. In the following table is given the value of the production of grindstones and pulpstones during the last five years:

Value of the production of grindstones and pulpstones, 1903–1907.

	1903.	1904.	1905.	1906.	1907.
Grindstones	$687,476	$820,207	$726,536	$694,894	$846,522
Pulpstones	33,970	61,320	51,070	50,000	49,500
Total	721,446	881,527	777,606	744,894	896,022

In the following table are given the values of the grindstones and pulpstones produced in the United States from 1903 to 1907, by States:

Value of grindstones and pulpstones produced in the United States, 1903-1907, by States.

State.	1903.	1904.	1905.	1906.	1907.
Ohio	$646,776	$767,552	$644,315	$644,720	$764,276
Michigan	70,550	112,500	111,500	78,500	(a)
West Virginia, Missouri, and Montana	4,120	b 1,475	b 21,791	b 21,674	131,746
Total	721,446	881,527	777,606	744,894	896,022

a Included with West Virginia, etc.
b Including a small production from Wyoming in 1904, 1905, and 1906.

The value of the production of grindstones and pulpstones from 1880 to 1907 is shown in the following table:

Value of grindstones and pulpstones produced in the United States, 1880-1907.

1880	$500,000	1894	$223,214
1881	500,000	1895	205,768
1882	700,000	1896	326,826
1883	600,000	1897	368,058
1884	570,000	1898	489,769
1885	500,000	1899	675,586
1886	250,000	1900	710,026
1887	224,400	1901	580,703
1888	281,800	1902	667,431
1889	439,587	1903	721,446
1890	450,000	1904	881,527
1891	476,113	1905	777,606
1892	272,244	1906	744,894
1893	338,787	1907	896,022

IMPORTS.

The imports consist principally of pulpstones and a few grindstones for use in the glass and optical trades. This material is obtained chiefly from Newcastle-upon-Tyne and from Wales and Scotland. The value of imports in 1907 was $111,495, as compared with $134,136 in 1906. No distinction has been made between finished and unfinished products since 1883. The value of the imports of pulpstones and grindstones has shown a steady increase up to 1907, when there was a decided falling off. The figures for the last five years are given in the following table:

Value of grindstones imported and entered for consumption in the United States, 1903-1907.

1903	$85,705	1906	$134,136
1904	93,152	1907	111,495
1905	113,752		

CANADIAN PRODUCTION.

The value of the production of grindstones in Canada during 1907 amounted to $46,876, as compared with $61,624 in 1906. In the table following is given the value of the Canadian production of grindstones during the last five years.

Value of production of grindstones in Canada, 1903–1907.

1903	$48,302	1906	$61,624
1904	42,782	1907	46,876
1905	57,200		

OILSTONES AND SCYTHESTONES.

PRODUCTION.

The production of oilstones and scythestones in the United States during 1907 amounted to $264,188, as compared with a production of $268,070 in 1906. This is a decrease of $3,882, or but little more than 1.5 per cent; in other words, the condition of the industry for the year is about the same as that for 1906. The production of oilstones and whetstones is from Arkansas, Indiana, and Ohio, and the first State mentioned produces about two-thirds of the output. Scythestones are manufactured from material found in New Hampshire, Vermont, Ohio, and Michigan, named in the order of their relative importance.

In the following table is given the value of the oilstones and scythestones from 1891 to 1907:

Value of oilstones and scythestones produced in the United States, 1891–1907.

1891	$150,000	1900	$174,087
1892	146,730	1901	158,300
1893	135,173	1902	221,762
1894	136,873	1903	366,857
1895	155,881	1904	188,985
1896	127,098	1905	244,546
1897	149,970	1906	268,070
1898	180,486	1907	264,188
1899	208,283		

IMPORTS AND EXPORTS.

The value of the imports of hones, oilstones, and whetstones in 1907 amounted to $89,939, as compared with $83,863 in 1906. The imports are a trifle larger in proportion to the domestic production than they were in 1906. In that year they amounted to less than one-third of the home production, but in 1907, owing to the slight increase in imports and the slight decrease in domestic production, the imports are a little more than 33 per cent of the domestic production. The imports are in part offset by the exportation of Arkansas oilstones and New Hampshire scythestones, the value of which, however, can not be given since no separate record is kept of them. The following table shows the total value of all kinds of hones, oilstones, and whetstones imported into the United States in the last five years:

Value of imports of hones, oilstones, and whetstones, 1903–1907.

1903	$65,763	1906	$83,863
1904	61,609	1907	89,939
1905	65,753		

CORUNDUM AND EMERY.

With the exception of the diamond, emery and corundum are the best natural abrasives known. Corundum is pure aluminum oxide with a hardness of 9 in Moh's scale, namely, next to that of the diamond. So far as composition goes, emery may be considered a mixture of corundum with more or less magnetite or hematite. The material feels and looks much like a black, fine-grained iron ore, which it was long considered to be. There is almost every gradation from the evenly fine-grained emery to the kind in which corundum is present in distinct crystals, as is frequently the case with the Peekskill emery ore.

Peekskill emery ore.—The deposits of emery near Peekskill, Westchester County, N. Y., are located about 4 miles southeast of the town and a few miles east of the Hudson River. It is reported that the deposits were first exploited for iron ore. The emery occurs in a series of igneous rocks intruded into metamorphic sedimentary rocks. To these intrusions the name Cortlandt series has been applied. This series includes rocks belonging mainly to the norite, diorite, and peridotite classes. The emery deposits, according to G. H. Williams,[a] are simply segregations of the basic oxides in the norite, the components of the latter rock occurring in even the purest emery ore. A study of the thin section of the material from these deposits has revealed the presence of hercynite (iron spinel), magnetite, garnet, and corundum, some of the latter being pale blue and perfectly transparent. Of these minerals, H. C. Magnus[b] states that hercynite forms, in some cases, nearly 100 per cent of the material, and in others corundum makes up more than 50 per cent of it. Hercynite is inferior in hardness to corundum, being 8 in the scale of hardness, while corundum is 9. This softness, however, is in part compensated by a readier cleavage, which causes hercynite to present fresh, sharp cutting edges.

The deposits of emery vary considerably in size. They are all worked by open cuts which vary in width and depth with the size of the ore body. The ore is blasted out by light charges of explosives, and is broken up and roughly cobbed before shipment to the mill. The subsequent mill treatment consists in cleansing and grading the rough cobbed material for use in the form of emery powder, emery paper and cloth, and emery wheels. It has been claimed that the Westchester material is very serviceable when made into wheels with a vitreous bond, but in general the selection of a bond depends upon the work to be accomplished, and the work to be accomplished should always be stated when ordering the wheel.

In 1907 the output of emery in the United States came from but two localities, Chester, Mass., and near Peekskill, N. Y. At Chester but one firm has been active, the Ashland Emery and Corundum Company; in New York four firms have either mined or shipped emery. The only change noted in the industry at Peekskill has been the taking over by the Keystone Emery Mills, of Frankford, Pa., of the properties of the late H. M. Quinn.

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[a] Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 33 *et seq.*
[b] Twenty-third Rept. State Geologist, N. Y. State Mus., 1903, pp. 163–172.

PRODUCTION.

There was no production of corundum reported to the United States Geological Survey for the year 1907. The production of emery in the United States in 1907 amounted to 1,069 short tons, valued at $12,294. As compared with the production of 1906, the quantity of material is slightly less, and the value shows a great decrease. The valuation for 1907 is based on the rough material as it comes from the quarries at the point of shipment. All the emery mined at Peekskill is shipped to other points for grinding and for manufacture into finished forms, after which, of course, its value is greatly increased. The following table gives the total quantity and value of the corundum and emery produced in the United States since 1881, the figures for the year 1907, however, representing the value of emery alone:

Annual production of corundum and emery, 1881–1907, in short tons.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1881	500	$80,000	1895	2,102	$106,256
1882	500	80,000	1896	2,120	113,246
1883	550	100,000	1897	2,165	106,574
1884	600	108,000	1898	4,064	275,064
1885	600	108,000	1899	4,900	150,600
1886	645	116,190	1900	4,305	102,715
1887	600	108,000	1901	4,305	146,040
1888	589	91,620	1902	4,251	104,605
1889	2,245	105,567	1903	2,542	64,102
1890	1,970	89,395	1904	1,916	56,985
1891	2,247	90,230	1905	2,126	61,464
1892	1,771	181,300	1906	1,160	44,310
1893	1,713	142,325	1907	1,069	12,294
1894	1,495	95,936			

IMPORTS.

Imported emery comes from Asia Minor, Turkey, and the island of Naxos, Greece. According to Mr. E. L. Harris, U. S. consul at Smyrna, Asia Minor, Turkey,[a] all the mines in Asia Minor which are now worked are located from 50 to 200 miles southeast of the city of Smyrna. At the mining operations near the city all of the visible emery has been removed, and the cost of extraction is almost doubled from the fact that the workings are so far below the surface. Mining operations are conducted in the most primitive fashion. In the case of the deposits remote from Smyrna, the ore is brought by camels and less frequently by mules and donkeys. The value of emery varies from $17 to $19 per ton at the point of shipment. The yearly shipments average 20,000 tons from Turkey and 7,000 tons from Naxos. Sixty per cent of this goes to the United States. The table following gives the quantity and value of emery and corundum imported into the United States from all foreign sources in the last five years.

[a] Mining World, December 28, 1907.

Emery and corundum imported into the United States, 1903–1907.

Year.	Grains.		Ore and rock.		Other manufactures.	Total value.
	Quantity.	Value.	Quantity.	Value.	Value.	
	Pounds.		*Long tons.*			
1903	3,595,239	$109,272	10,884	[a]$194,468	$17,829	$321,569
1904	2,281,193	109,772	7,054	[b]138,931	11,721	260,424
1905	3,209,915	143,729	11,073	185,689	18,007	347,425
1906	4,655,668	215,357	13,841	286,386	19,339	521,082
1907	4,282,228	186,156	11,235	211,192	15,282	412,630

[a] Including emery rock valued at $5,488. [b] Including emery rock valued at $7,338.

CANADIAN CORUNDUM.

Canadian corundum is mined chiefly by two companies, the Ontario Corundum Company and the Canadian Corundum Company (Limited). The deposits of corundum occur in pinkish syenite and nepheline syenite, and are located in the province of Ontario. The Canadian Corundum Company (Limited) during a part of 1907 treated only corundum from its Craig mine at Craigmont, Ragland Township, Renfrew County, Ontario, where mining operations were begun in 1900.[a] In the following table are given the quantity and value of Canadian corundum during the last five years:

Production of Canadian corundum, 1903–1907.

1903	short tons	916	$92,940
1904	do	919	101,050
1905	do	1,644	149,153
1906	short tons	2,274	$204,973
1907	do	1,892	177,922

ABRASIVE QUARTZ AND FELDSPAR.

PRODUCTION.

The production of crystalline quartz and feldspar used for abrasive purposes in the United States in 1907 amounted to 17,435 short tons, valued at $126,582, as compared with a production of 24,082 short tons, valued at $121,671, in 1906. This increase in value, coupled with the decrease in production, is notable, but is explained by the greater values per ton reported by producers, due largely to the fact that the material is put on the market chiefly in the ground or partially prepared form. The quartz reported comes from Connecticut, Maryland, Massachusetts, Pennsylvania, and Wisconsin.

A large part of the output given above, namely, 47 per cent, is feldspar, which is being used in an increasingly large quantity as an abrasive. The feldspar quarried for abrasive purposes comes from Minnesota and Connecticut, and is used in the manufacture of scouring soaps, for which purpose it is especially well adapted.

In the table following is given the production of abrasive quartz from 1895 to 1903, and that of abrasive quartz and feldspar since that period.

[a] Haultain, E. T., Canadian Mining Journal, August 1, 1907, pp. 291–296.

Production of crystalline quartz, 1895–1907.

1895.....short tons..	9,000	$27,000	1902.....short tons..	15,104	$84,335
1896..........do....	6,000	18,000	1903..........do....	8,938	76,908
1897..........do....	7,500	22,500	1904..........do....	[a]31,940	[a]74,850
1898..........do....	8,312	23,990	1905..........do....	[a]19,039	[a]88,118
1899..........do....	13,600	39,000	1906..........do....	[a]24,082	[a]121,671
1900..........do....	14,461	40,705	1907..........do....	[a]17,435	[a]126,582
1901..........do....	14,050	41,500			

From the figures of the total production of quartz and feldspar, given on another page of this volume, it will be observed that only a small part of the production of these commodities is used solely for abrasive purposes. For a discussion of these substances and their uses the reader is referred to the report on quartz and feldspar.

ABRASIVE GARNET.

PRODUCTION.

The production of garnet reported for abrasive purposes in 1907 was 7,058 short tons, valued at $211,686. This is the highest production ever recorded by the Survey, exceeding that of 1906 by 2,408 tons, or 52 per cent, in quantity, and by $54,686, or 35 per cent, in value. The average price per ton of the garnet was $30.34, which is about the mean of the minimum and maximum quotations (depending on quality) on ordinary wholesale lots in New York during the year. The garnet mined came from New York, Pennsylvania, and North Carolina.

The following table gives the quantity and value of abrasive garnet produced in the United States for the years 1895 to 1907:

Production of abrasive garnet, 1895–1907.

1895.....short tons..	3,325	$95,050	1902.....short tons..	3,926	$132,820
1896..........do....	2,686	68,877	1903..........do....	3,950	132,500
1897..........do....	2,554	80,853	1904..........do....	3,854	117,581
1898..........do....	2,967	86,850	1905..........do....	5,050	148,095
1899..........do....	2,765	98,325	1906..........do....	4,650	157,000
1900..........do....	3,185	123,475	1907..........do....	7,058	211,686
1901..........do....	4,444	158,100			

NOTES ON THE GARNET INDUSTRY.

New York.[b]—The production of garnet for abrasive purposes is a well-established industry in the Adirondack region of New York. The seat of the industry is in Warren and Essex counties near the upper Hudson Valley, and North Creek, the terminus of the Adirondack branch of the Delaware and Hudson Railroad, is the principal point of shipment.

The garnet produced is almandite, the iron aluminum variety, with the symbol $3FeO.Al_2O_3.3SiO_2$. Ordinarily garnet has a hardness of 6.5 to 7.5, but it is claimed that the Adirondack garnet is harder than this, occurring from 7.5 to 8 in the scale, thus lying intermediate between quartz (7) and corundum (9). According to

[a] Includes feldspar used for abrasive purposes.

[b] The notes on the garnet industry in New York have been largely compiled from the reports of D. H. Newland, contained in bulletins of the New York State Museum devoted to the mining and quarry industry.

Newland,[a] the garnet is usually associated with amphibolite, which occurs in lens-shaped bodies in a country rock of acid gneiss. The amphibolite has been metamorphosed, as is usual with garnet-bearing rocks. The mineral occurs in crystals ranging from an inch upward in diameter, and the larger crystals have been so strained and shattered by compression that they readily crumble into small fragments.

In working the deposits the country rock is broken down by the ordinary quarry methods of picking or blasting. The rock is then crushed sufficiently fine to release the garnets, and the product is washed. The garnet is recovered either by hand sorting or by mechanical means. Some difficulty has in the past been encountered in separating the garnet from the accompanying hornblende, but the North River Garnet Company has solved the difficulty by employing crushers and then concentrating on a special type of jigs.

The output is used in the shoe and wood-working industries, and sold in the form of garnet paper. The mineral does not possess any distinct mineral cleavage, but there is a rather distinct parting parallel to the dodecahedral faces which is usually well developed in the Adirondack mineral. This insures a smooth surface for attachment to the cloth or paper and at the same time leaves a sharp cutting edge. The resultant efficiency is said to be much greater than that of ordinary sandpaper.

The output of the region, as already mentioned, comes from Essex and Warren counties. The North River Garnet Company has a mine at Thirteenth Lake, Warren County, so situated that it is practicable to work it throughout the year; but at other points, as at Gore Mountain and Garnet Peak, where the garnet is obtained by open-cut work and hand sorting, winter work is not practicable.

In 1905 exploratory work was done on a type of deposits somewhat different from those described. The locality is on the east slope of Mount Bigelow 5½ miles south of Keeseville, near Lake Champlain. Newland has described the country rock as follows:[b]

The country rock is anorthosite, a part of the great mass of that rock which is exposed in the central Adirondacks. It is made up of granular feldspar with a little pyroxene, biotite, and garnet, and has a more or less laminated appearance. In the vicinity of the garnet deposit the rock shows considerable variation due to included bands of amphibolite and pegmatite. The garnet does not form crystals, but occurs in irregular lens-shaped bodies of massive character that are apparently in direct contact with the anorthosite. Except for admixture with small greenish crystals of pyroxene, the garnet is quite pure. At one locality there is an almost continuous series of outcrops extending north and south for a distance of 400 feet. The greatest thickness shown is about 40 feet. The garnet usually has a finely granular texture and readily crumbles under slight pressure, but occasionally it is platy and breaks with a smooth surface. Its origin is probably to be explained by alteration similar to that which has given rise to the amphibolite bands which have been caught up during the intrusion of the anorthosite or have been folded into the latter and metamorphosed. Impure limestone would afford the necessary constituents for its formation.

During 1906 the property was under development, and the first reports of production from this area were received from Messrs. E. Schaaf-Regelman and George W. Smith, and are contained in the figures for 1907. The garnet from this locality is known to the trade as "massive garnet," and the product is of exceptional purity.

North Carolina-Pennsylvania.—The production of garnet from North Carolina in 1907, reported to the Survey, came from Marshall,

[a] The mining and quarry industry of New York State: N. Y. State Mus. Bull. 102, 1906, p. 71.
[b] The mining and quarry industry of New York State: N. Y. State Mus. Bull. 102, 1906, p. 72.

Madison County. The deposits were operated by the Highland Development Company of Boston. There was no production in 1906, but the industry was on a substantial basis in 1907.

The production from Pennsylvania was reported from Chelsea, a small town situated in the extreme southeastern part of the State in Delaware County and near the State line between Pennsylvania and Delaware. The garnet is the ruby or rose-colored variety and is found in gneiss.

INFUSORIAL EARTH AND TRIPOLI.

PRODUCTION.

In previous reports on the production of abrasives in the United States it has been the custom to combine the statistics of infusorial earth and tripoli. So far as our present information goes, the two substances are quite different in origin and to a certain extent in their uses.

Some of the Missouri tripoli is and always has been used for abrasive purposes, but much of it is used in the manufacture of filter stones. The Illinois product [a] is employed in the paint industry, as a wood filler, for enameling purposes, etc. No attempt has heretofore been made to procure from producers of tripoli a definite statement of the exact proportion used for abrasive purposes, nor has any attempt been made to get at the tonnage of rough tripoli blocks worked up into filter stones. Even if this tonnage had been found it would be impossible to value the resultant product on a uniform basis and thus to obtain a reliable ratio between quantity and value, for the reason that the price of filter stones varies and is dependent not only on the size of the stones but also on the amount of work done on each. For this reason it has been decided in this report to give simply the value of the production of infusorial earth and tripoli and to omit the tonnage.

In the following table are given the quantity and value of infusorial earth and tripoli produced in the United States from 1880 to 1906 and the value of these products in 1907:

Production of infusorial earth and tripoli, 1880–1907.

1880......short tons..	1,833	$45,660	1894......short tons..	2,584	$11,718
1881..........do....	1,000	10,000	1895..........do....	4,954	20,514
1882..........do....	1,000	8,000	1896..........do....	3,846	26,792
1883..........do....	1,000	5,000	1897..........do....	3,833	22,835
1884..........do....	1,000	5,000	1898..........do....	2,733	16,691
1885..........do....	1,000	5,000	1899..........do....	4,334	37,032
1886..........do....	1,200	6,000	1900..........do....	3,615	24,207
1887..........do....	3,000	15,000	1901..........do....	4,020	52,950
1888..........do....	1,500	7,500	1902..........do....	5,665	53,244
1889..........do....	3,466	23,372	1903..........do....	9,219	76,273
1890..........do....	2,532	50,240	1904..........do....	6,274	44,164
1891..........do..........		21,988	1905..........do....	10,977	64,037
1892..........do..........		43,655	1906..........do....	8,099	72,108
1893..........do..........		22,582	1907..........do..........		104,406

[a] The Illinois product is called tripoli, for the reason that its origin is regarded as essentially the same as that usually assigned to the Missouri product.

NOTES ON DEPOSITS OF INFUSORIAL EARTH.

Infusorial earth in 1907 was mined for market in the following States: California, Connecticut, Kentucky, Maryland, Massachusetts, Nevada, and New York. California led in production, that of the other States combined being a relatively small part of the whole.

Diatomaceous or infusorial earth resembles chalk or clay in its physical properties, but can be distinguished at once from the former substance by the fact that it does not effervesce when treated with acids. It is generally white or gray in color, but may be brown or even black when mixed with much organic matter. Owing to its porosity it has great absorptive powers. Chemically, it is a variety of opal.

Heretofore the principal uses of infusorial earth have been largely for abrasive purposes, in the form of polishing powders, scouring soaps, etc., but of late its uses have been considerably extended. Owing to its porous nature it has been used in the manufacture of dynamite, as a holder of nitroglycerine. This same porous structure renders it a nonconductor of heat, which property, in connection with its lightness in weight, has extended its use as a packing material in safes, steam pipes, and boilers, and as a fireproof building material in general. The California product, according to Arnold and Anderson,[a] may be cut into any shape desired, and, like the Missouri tripoli, may be used as a filter stone. The material is quarried for building stone in southern California, for which purpose it seems to be well adapted, especially in that region of earth tremors, owing to its elasticity and because the minimum amount of damage is likely to result from the falling of so light a material.

California.—In California important deposits of infusorial earth are found in Los Angeles, Monterey, Orange, San Luis Obispo, Shasta, and Santa Barbara counties, and deposits are reported from San Benito, San Bernardino, and Tehama counties. The material occurring at Lompoc, in northern Santa Barbara County, is considered by Aubury[b] the best yet found in the State. The greater part of the diatomaceous earth in this region occurs in the Monterey (middle Miocene) and in the lower part of the Fernando (upper Miocene) formations, and deposits are described by Arnold and Anderson[c] in the hill south of Santa Ynez River, in the Burton mesa, in the hills between Santa Ynez and Los Alamos valleys, in the vicinity of Santa Ynez and Casmalia, in the Santa Maria oil district, in the Canada del Gata and Sisquoc areas, in the mountains northeast of the Santa Maria Valley, and in the San Luis quadrangle.

Maryland.—Infusorial earth is found at the base of the Calvert formation, and comprises beds which in Anne Arundel, Calvert, and Charles counties attain a thickness of 30 to 40 feet. The only deposits worked on a commercial scale during 1907 are located near Dunkirk, Calvert County.

New York.—Infusorial earth occurs at several places in New York, but of late years the only deposits worked are those located near Hinckley, Herkimer County. According to Newland,[d] a bed from 2 to 30 feet thick forms the bottom of White Lead Lake.

[a] Bull. U. S. Geol. Survey No. 315, 1907, p. 446.
[b] Bull. Cal. State Min. Bur. No. 38, 1906. p. 293.
[c] Bull. U. S. Geol. Survey No. 315 1907, pp. 440–445.
[d] The mining and quarry industry of New York State: N. Y. State Mus. Bull. No. 102, 1906, p. 68

The deposit is under 4 feet of water. The material is excavated and purified by washing and settling in vats, after which it is compressed into cakes, and is used mainly as a polishing powder. It runs 86.5 per cent silica.

NOTES ON THE TRIPOLI INDUSTRY.

The tripoli mined in the United States during 1907 came from Missouri and Illinois. The material produced in Union County, Ill., is called silica by the Illinois State Geological Survey,[a] but the suggestion has been made that it has essentially the same origin as the well-known tripoli deposits of Newton County, Mo. In this report, therefore, it has been regarded as tripoli, and its production is combined with that of the tripoli of Missouri.

Missouri.[b]—The tripoli deposits worked at the present time in Missouri are located near Seneca and Racine, Newton County. They occur in the Boone formation in bodies from 4 to 12 feet in thickness. The material is a light, even-textured rock, fairly tenacious after drying, but more or less friable when mined. It is extremely porous and light; hence the term "cotton rock," which is sometimes applied to it. No trace of fossils of any kind has been found in the deposits. The material runs over 98 per cent in silica. It is thought to have been derived from a fine, granular, and nonfossiliferous limestone from which the calcareous material has been leached, leaving the silica in a thoroughly porous condition. The tripoli is usually massive, with scarcely a trace of stratification, but is divided by various systems of joints into blocks of varying sizes. Chert in lenses or balls is commonly associated. After removing a thin mantle of clay, gravel, and residual chert from the tripoli, the material is quarried by the methods described below:

Vertical channels 12 inches wide are cut to the bottom of the deposit, or to such depth as is desired. These channels are easily made with a light pick of ordinary shape. Where the rock is much cut up by fissures and clay seams the channels are cut along the most prominent of these joints, to lose as little as possible of the dimension stone. A 2-inch hole is then drilled between the ends of the channels, filled with unslacked lime, and tamped. By absorption of quarry sap the lime is slacked, swells, and lifts the stone, the steadily increasing pressure having a tendency to loosen up the blocks along the already existing joints, rather than to make new fractures. The shape and size of the blocks thus obtained depend on the number and attitude of the joints. The larger blocks of good quality are sent directly to the filter shop. Spalls and pieces not suitable for filters are sent to the dry sheds, to be later ground into tripoli flour. When rock for grinding only is desired, that is to say, when it is too much jointed or for some other reason is unsuitable for filter stones, powder is used instead of lime in raising the rock, as it gives blocks of smaller size and saves some hand breaking before crushing.

Where the rock is not so closely beset with joints and fractures, narrow 2-inch cross channels are cut the length of the handle with a narrow-eyed pick, the eye being no wider than the cutting edge of the pick. In this way pieces of regular dimensions are obtained. Blocks 2 by 2 by 5 feet are as large as are ordinarily desired.

The rough blocks from the quarry are taken directly to the mill and are there ultimately turned into filter stones of various sizes and shapes. These are made on regular turning lathes. Defective blocks, trimmings, and the dust go to the tripoli flour mill. After

[a] Bain, H. F., Bull. Ill. State Geol. Survey, No. 4, 1907, p. 185.

[b] The notes on the tripoli deposits of Missouri have been compiled from the report of C. E. Siebenthal and R. D. Mesler: The tripoli deposits near Seneca, Missouri, Bull U. S. Geol. Survey No. 340, 1907.

thorough drying the material is crushed, ground, and bolted. Two grades are marketed, depending on the degree of fineness; the grade known as O. G. (once ground) will pass through a 60-mesh sieve, and that known as D. G. (double ground) will pass through a 140-mesh sieve. Three colors of the tripoli flour are made—white, cream, and rose. The material is sacked or barreled and shipped like ordinary flour. This fine material is used almost entirely as an abrasive.

IMPORTS.

There is an importation of infusorial earth and tripoli into the United States each year which is not separately recorded by the Department of Commerce and Labor, but which is included with rotten stone used for similar purposes. The value of the imports of rotten stone and tripoli for the past five years has been as follows: 1903, $34,977; 1904, $23,022; 1905, $18,986; 1906, $25,990; 1907, $27,121. No record is kept of the number of tons of this material imported.

CANADIAN PRODUCTION.

The Canadian production during 1907 was 30 short tons of tripoli, valued at $225.

PUMICE.

PRODUCTION.

The pumice produced in the United States in 1907 amounted to 8,112 short tons, valued at $33,818. This was a decrease of 4,088 tons from the production of 1906, but there was a large increase in value, due in part to increased cost of handling the material at the mines and of getting it into cars. The production of pumice in the United States during the last five years is given in the following table:

Production of pumice in the United States, 1903–1907, in short tons.

Year.	Quantity.	Value.	Price per ton.
1903	885	$2,665	$3.01
1904	1,530	5,421	3.54
1905	1,832	5,540	3.02
1906	12,200	16,750	1.37
1907	8,112	33,818	4.17

IMPORTS.

The value of imports of pumice into the United States in 1907 amounted to $85,647. This is $26,048 less than the value of the imports into the country in 1906. The figures for the last five years are given in the following table:

Value of pumice imported into the United States, 1903–1907.

1903	$83,920	1906	$111,695
1904	77,211	1907	85,647
1905	77,489		

NOTES ON DEPOSITS OF PUMICE.

The pumice produced in the United States comes from Harlan and Lincoln counties in Nebraska. Deposits are also known in South Dakota and Wyoming to the north and northwest, and in Kansas and Oklahoma on the south. Scattered deposits are also known in other of the Western States.

The term "pumice" is applied to a form of acid volcanic rock which may be either massive or in a finely comminuted state. The former variety of pumice is largely imported from the Lipari Islands, a group of volcanic islands north of Sicily in the Mediterranean Sea. It owes its peculiar porous, vesicular, or pumiceous condition to the rapid expansion of included moisture or gases due to sudden release of pressure at the time of its ejection from the volcano. This expansion may be carried to such an extent that the rock is completely shattered and the resultant finely powdered material may be carried to unknown distances by wind and air currents and then deposited in beds often several feet in thickness. The latter explanation is that usually assigned to the material composing the deposits in Harlan and Lincoln counties, Nebr.

Nebraska.—The Nebraska deposits have been described by Barbour.[a] According to the report of this writer practically the entire State is overlain by deposits of natural pumice, which extend as far east as Omaha. The extent and thickness of the beds are evidence of extraordinary former volcanic activity. To the north of the State in the heart of the Big Bad Lands of South Dakota beds were noted 10 to 15 feet thick. In Scotts Bluff and Banner counties, in the western part of the State, beds 100 feet thick were measured which, though not consisting wholly of volcanic ash, still were rendered white by it. The material in individual beds differs greatly in purity, texture, and physical condition. Some of the material is pure and white; in some places it is adulterated with silt, sand, clay, and particles of limestone, etc. In texture it exhibits great variety, the coarser material being found in almost every stage of consolidation from incoherent dust to fairly compact rock. Nearly all of the material is used for abrasive purposes, either in the form of polishing powders or soaps.

Colorado.—Woolsey[b] has recently described material of a nature similar to pumice from near Durango, La Plata County, Colo. The substance occurs in three isolated beds lying within a radius of 4 miles of the place. One is located at the east end of the dry valley north of Animas City Mountain, on the shoulder of the southward-facing spur. Opposite the west end of the same valley, on the crest of the ridge between Dry Gulch and Junction Creek, another bed occurs. Both of these deposits have the same elevation—about 400 feet above Junction Creek at this point. The third bed lies nearly east of Durango, on the east slope of Frorida Mesa, 250 feet above Florida River. All these beds lie at nearly the same elevation and have a somewhat similar mode of occurrence. The material from the three localities is very similar in appearance, resembling a dust-like powder of white opaque flakes, glistening in the sunlight. The material is gritty and entirely unconsolidated. Under the micro-

[a] Barbour, E. H., Mineral Industry, vol. 4, pp. 22-25.
[b] Bull. U. S. Geol. Survey, No. 285, 1906, pp. 476-479.

scope the particles of the material are decidedly angular and fairly uniform in size. The material is very similar to the volcanic ash described by Merrill [a] from Montana and Idaho. The bed north of Animas City Mountain has been prospected, as has also the bed on Florida Mesa.

Some of the possible uses of the material are in semifused filling brick and in fireproofing and mineral wool for packing as a non-conductor of heat and sound. In its natural condition it may also be used in refrigerating plants, in the manufacture of puzzolan cements, and in some of the cheaper varieties of glassware.

ARTIFICIAL ABRASIVES.

Under the head of artificial abrasives are included carborundum, crushed steel, and alundum. The total production of these substances, by years, since 1904 is given in the following table:

Production of artificial abrasives in the United States, in pounds, 1904–1907.

Year.	Quantity	Value.
1904	11,870,380	$830,926
1905	9,820,000	701,400
1906	11,774,300	777,081
1907	14,632,000	1,027,246

The production in the year 1907 was greater than that of any year of which the Survey has record, exceeding that of 1906 by 2,857,700 pounds in quantity and by $250,165 in value.

In previous reports it has been the custom to give, in addition to the total production and value of artificial abrasives, the quantity and value of each of the several commodities listed above. As single firms are engaged in making each class of artificial abrasives, the practice obtaining heretofore will be discontinued.

CARBORUNDUM.

Carborundum is manufactured by a single firm in the United States, the Carborundum Company of Niagara Falls, N. Y. The foreign demand for this abrasive has increased so rapidly within the last few years that the company has constructed a plant at Düsseldorf, Germany, for the manufacture of carborundum wheels and abrasive articles. The factory began operations in February, 1907.

Carborundum is manufactured by fusing in the intense heat of the electric furnace a mixture of granulated coke, very pure glass sand, and sawdust. The two materials first mentioned are the purest obtainable. The coke represents the carbonaceous residue from the distillation of petroleum; the sand used is the purest glass sand. The sawdust is added entirely for mechanical purposes, namely, to make the mixture porous and thus to avoid explosions of the carbon monoxide produced during the course of the reaction. The fundamental reaction takes place between the sand (silica) and the coke (carbon), resulting in the production of a carbide of silicon, or carborundum. The details of the furnace construction and oper-

[a] Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 199 *et seq.*

ation have been described by F. A. J. Fitzgerald,[a] and will not be considered here.

The latest developments in the industry have been summarized recently by F. J. Tone,[b] from which article the following notes are taken.

Carborundum has been used for some time in the plate glass and granite industries. The recent extension of its use to the marble industry follows as a natural course. A complete line of machinery has been developed for the various operations involved in preparing marble for market, and in this industry the use of carborundum is rapidly dispensing with the old style machine tools and with skilled labor. Carborundum is being introduced into the wood-working and paper industries, and also into the hat trade. Other applications of the material are in nonslipping stair treads, carriage treads, nonslipping horseshoes, and also in the construction of cement pavements and sidewalks.

ALUNDUM.

The abrasive known as alundum is manufactured by the Norton Company at Niagara Falls from the mineral bauxite. The crude bauxite is first calcined to drive off combined water. This is accomplished in a rotary calciner 60 feet long, heated by two gas producers. The machine at Niagara Falls is continuously acting and will calcine 40 tons of bauxite per day.

The ore after calcination is ready for the electric furnaces. These are conically shaped pots which stand on cars and are heated by vertical electrodes, which are gradually raised as the molten bauxite fills the furnace. In the furnace room 2,000 E. H. P. are used. It is said that the temperature attained in the furnaces ranges from 5,000 to 6,000 degrees Fahrenheit. The dimensions of the furnaces are calculated so that the fusion shall not extend to the water-cooled shell. During the fusion iron is reduced from the bauxite as a result of the reducing action of the electrodes. This iron, containing 5 to 12 per cent silicon, is sold to the steel makers. These masses, which are called pigs, each contain about three tons of abrasive material

After the completion of the fusion, the furnace is taken to a position under an electric crane which removes the solidified mass and places it on the cooling floor until it is cool enough to handle. The mass is then broken up and fed to a crusher, after which the alundum passes through a reel which removes all the fine dust, which is re-fused. The product which has gone over the reel is passed over a sorting belt, where the material not up to the standard is picked out. The resulting product in fragments about the size of a man's fist is then loaded on cars and sent to the company's plant at Worcester, Mass., where it is subjected to the various operations necessary for use in the alundum wheels.

One of the recent applications of alundum is as a refractory material. The substance melts at 2,300° C., and has a very low coefficient of expansion, if it has any at all. It is, moreover, very inert chemically, and tests made in the basic open-hearth furnaces show that it is not appreciably affected by slags in these processes. A lining of a Deville furnace does not show deterioration after repeated burns at

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[a] Electro-chem. and Metallurg. Industry, February, 1906.
[b] Mineral Industry for 1906, vol. 15, 1907, pp. 95-99.

1,800° C. It remains to be proved just how much better alundum is than other standard refractories, as its cost will necessarily be quite high. It is believed, however, that for many special purposes it will prove of great value.

CRUSHED STEEL.

The method of manufacturing crushed steel abrasives has been described by M. M. Kann, secretary and treasurer of the Pittsburg Crushed Steel Company,[a] and by Pratt.[b]

In the manufacture of crushed steel abrasives, high-grade crucible steel is heated to nearly white heat, and is then quenched in a bath of cold water. The fragments of steel thus produced are then crushed to particles varying from fine powder up to one-sixth of an inch, more or less, in diameter. The crushed product is then classified and tempered, being then known as "diamond crushed steel," "diamond steel emery," and "steelite."

The chief use of crushed steel is in the stove, brick, glass, and metal trades—the size of the steel used depending on the character of the stone to be cut, rubbed, ground, or polished.

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[a] Proc. Am. Assoc. Adv. Sci., Pittsburg meeting, July, 1903.
[b] Mineral Resources U. S., 1903, p. 1013.