

# ABRASIVE MATERIALS.

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## INTRODUCTION.

The abrasive materials are as a whole but little understood, although they are in one sense among the most important of the mineral products. The principal abrasives can readily be divided into three general groups:

1. Those which occur as rock formations and are cut and manufactured directly into the form desired, while retaining their original rock structure and appearance, as grindstones, whetstones, etc.
2. Those which occur as a constituent of either a rock or a vein, and have to be mechanically separated from the associated gangue and cleaned, as corundum, emery, and garnet.
3. Artificial abrasives, as carborundum, crushed steel, and artificial corundum.

The abrasives included in the above groups are treated under the following heads: Oilstones and whetstones, grindstones and pulpstones, buhrstones and millstones, pumice, infusorial earth and tripoli, crystalline quartz, garnet, corundum and emery, carborundum, crushed steel, and artificial corundum.

While the production of certain of these abrasives is on the decline, that of others is increasing, and the aggregate amount of abrasive materials used is greater than ever before. This is due to the increase in our manufacturing industries. Their use, of course, is limited, and there could readily be an overproduction of most of them; but there will be an increasing demand for them from year to year, which will depend principally upon the growth of manufacturing industries, and with an increase or a decrease in these industries there will be a corresponding change in the production of the abrasives. There will be noticeable changes in the amount of the different kinds of abrasives used from year to year, some increasing rapidly and some steadily decreasing, these variations being due to the introduction of new natural or artificial products. To what extent the artificial abrasives will replace the natural ones can not now be stated, for no appreciable change that

is due to the introduction of the artificial can now be noticed in the production of these natural abrasives, and no change may be observed for some years to come.

The total value of all the natural abrasives produced in the United States during 1901 was \$1,194,772, as compared with \$1,208,073 for 1900. In the following table is given a list of the values of production of the different abrasives in the United States for the years 1900 and 1901:

*Value of abrasives produced in United States during 1900 and 1901.*

Kind of abrasive.	Value.		Kind of abrasive.	Value.	
	1900.	1901.		1900.	1901.
Oilstones and scythestones..	\$174,087	\$158,300	Crystalline quartz .....	\$40,705	\$41,500
Grindstones .....	710,026	580,703	Garnet .....	123,475	158,100
Buhrstones and millstones..	32,858	57,179	Corundum and emery .....	102,715	146,040
Infusorial earth and tripoli.	24,207	52,950	Total.....	1,208,073	1,194,772

*Artificial abrasives produced in United States during 1900 and 1901.*

Kind of abrasive.			Kind of abrasive.		
	1900.	1901.		1900.	1901.
	<i>Pounds.</i>	<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>
Carborundum .....	2,401,000	3,838,175	Crushed steel .....	700,000	690,000

#### OILSTONES, WHETSTONES, ETC.

The term oilstone is a little ambiguous in meaning and is a word that has come to be applied to all stones used for sharpening mechanics' tools, for the reason that it is necessary to use oil on most of them to prevent the stone from becoming hot and thus heating the tool and also to prevent the small particles of steel that are ground off from the tool from entering into the pores of the stone. Thus it is that the same stone when used for one purpose will be called an oilstone and when used for another will be called a whetstone, or perhaps a scythestone.

#### SOURCES AND KINDS OF WHETSTONE-PRODUCING ROCKS.

The materials from which these stones are made are very variable, but are of sedimentary origin, and include quartz-mica-schist, sandstone, novaculite, and the intermediate stones. These are found abundantly in various localities, so that there is probably no country, or at any rate but few countries, which have not within their borders a supply of some kind of stone suitable for making whetstones. Although the material for manufacturing whetstones is so common, only those quarries which produce stones of superior quality and have the greatest advantages for manufacture and for shipment can survive competition in the trade. This is the reason the supply of whetstones

is confined to a few localities. Where, however, the stone is of exceptional quality, as the novaculites of Arkansas, there is a large demand for them both at home and abroad, although their price may be higher than that of other whetstones.

In the United States rocks suitable for making whetstones are found in nearly all the States east of the Mississippi and in a number of those to the west of that river; but the supply is obtained from a few of them, namely, Arkansas, Indiana, Ohio, New York, Vermont, and New Hampshire. As there are a number of different rocks from which whetstones are manufactured, it is a natural consequence that the stones themselves should be varied and should be used for many different kinds of grinding, as in the case of grindstones. Not only the variation in the kind of rock used, but also the variation in the size and character of the grit in the rock, causes a change in the character and quality of the whetstone. In order better to understand the variations in the whetstones, some idea must be had of the kind of rocks from which they are made, and for this reason the rocks are described below.

*Sandstones.*—Under this head are included a number of rocks, as pure sandstone, micaceous sandstone, and the peculiar sandstone known as novaculite. Of these three varieties the novaculite is by far the most important, as from it are made the most celebrated oilstones.

The pure sandstones from which whetstones are made are the same rock formations that occur in Ohio, known as the Berea grit, from which grindstones are made, as described fully under "Grindstones." As a rule, whetstones made from this sandstone can be used only for coarse grinding, on account of the size of the grains of quartz. The main exceptions to the above are the sandstone found at Euclid, Ohio, and known as Euclid grit, which furnishes a very fine-grained oilstone, and another sandstone at Chagrin Falls. When there is any earthy or mineral matter present in these rocks it will, if in small amount, add solidity to the stone and assist in producing a finer edge than the grit alone would give. On the other hand, if there is very much of the earthy material present it will interfere with the abrasive efficiency of the grains of quartz and be injurious to the stone.

Sometimes there is present in the sandstone a considerable percentage of mica; and these might well be called mica-sandstones. Rocks of this character have been utilized for the manufacture of whetstones, but at the present time none of these are used.

Novaculite is the name given to an exceptional sandstone rock that is extensively developed in Arkansas.<sup>a</sup> While at first this rock was supposed to be allied to the cherts, which are cryptocrystalline siliceous rocks formed by chemical action and containing a large percentage

<sup>a</sup>Novaculites, by L. S. Griswold: Ann. Rept. Geol. Survey Arkansas, Vol. III, 1890.

of silica principally in the form of chalcedony, chemical analyses and microscopic examination have shown that it is a pure siliceous rock made up of finely fragmental quartz grains. Novaculite does not contain any silica in the form of chalcedony, and has a fine gritty feeling, while the chert is more glassy, although both are tough rocks and break with a conchoidal fracture. The quartz in the novaculite is in minute irregular grains having an average diameter of less than .01 millimeter, which are closely crowded together, forming a dense groundmass. Here and there are little cavities which appear on first sight to be irregular in outline but are really rhombic, indicating that calcite (carbonate of lime) was formerly present in the rock but has been leached out. The cavities are small, averaging about .05 millimeter in diameter, and are occasionally observed to be filled with secondary silica. The novaculite deposits occur in Arkansas as a stratified formation, whose common thickness is 500 to 600 feet, including some flinty shales and sandstones. The novaculites proper, which are the prominent members of this formation, occur in beds from a few inches to 12 or 15 feet in thickness. The strata are found commonly in a nearly vertical rather than in a horizontal position. The movements that have caused this change in the strata have, in some cases, had a tendency to crush certain portions of the brittle novaculite into fragments, and in others to form only planes of cleavage. These joint planes form systems of parallel planes dipping at all angles, and they are apt to be found at almost any point in the novaculite formation, as many as six systems having been observed in a single quarry. They are apt to prevent the obtaining of large blocks of good novaculite. Sometimes they are only a fraction of an inch apart, thus completely breaking up the blocks into small pieces by the intersection of several sets of planes. Conchoidal planes of fracture sometimes exist, which have apparently been developed by the same pressure that produced the other planes, and although they are not evident when the stone is first taken out, they render it liable to fracture. Thus stones containing them can not be considered sound, although the grit in them may be of the first quality. Another obstacle in quarrying novaculite is the cracking and breaking of the stone, due to the freezing of the water that it has absorbed. The stone has been known to break in cold weather while being manufactured, from the freezing of the water absorbed by the novaculite during the sawing process. There are often hard spots and cracks that have to be avoided in obtaining good stone, and also fine quartz veins which intersect the rock in great numbers. Many of these veins of quartz are so thin that they can hardly be distinguished by the eye, yet they would render a finished stone worthless, as they would nick a tool while grinding. As a rule these veins lie along joint planes, so that their extent can often be determined. As they do not show at the surface, frequently they are not found until

the stone has been sawed, which usually means a large loss of stone. Still again, the novaculite may be injured by the presence of small cavities called "sand hills," which vary in size from that of a pin head or smaller to over an inch in diameter. These "sand hills" should not be confounded with the microscopic rhombohedral cavities to which reference has previously been made.

*Mica-schists.*—The rocks of this class that are of value for the manufacture of whetstones are those that contain a considerable percentage of grit, usually in the form of grains of quartz. The mica-schists are finely laminated metamorphic rocks that are the result of the thorough metamorphism or recrystallization of sandstones, shales, and clays. They are also formed by the crushing and excessive shearing of igneous rocks. In many localities a quartz-schist is found in which the grains of quartz are evenly arranged, giving to the rock a uniformity of structure which adapts it to the manufacture of a whetstone. These schists vary in color and in hardness with the percentage of quartz. They are often of an argillitic or slaty structure, and some of them may have been derived from slates. The grit of the schist is not so sharp as that of the sandstones, because in the schist there is a great deal of soft material besides the grains of quartz, which would prevent them from abrading freely, and the grains of quartz are also apt to be more lenticular than those in the sandstones. These schists make a strong stone that wears away rapidly and is used very largely in the production of scythestones. While quartz is the material that usually gives the abrasive power to the schist, occasionally this is due to microscopic garnets, as in the Belgian stones.

#### WHETSTONE LOCALITIES.

*Arkansas.*—The Arkansas whetstone quarries are located in Garland and Saline counties, the principal ones being on Quarry or Whetstone Mountain, near Hot Springs, Garland County. Griswold, in his report on the novaculite areas of Arkansas,<sup>a</sup> shows that the novaculite deposits are extensive, but only one new quarry of any importance has been opened since that report was published. This quarry is located in Saline County, near Brazils post-office. The reasons for this scarcity of quarries are perhaps indicated by what has been said above regarding the difficulties encountered in quarrying and manufacturing the stone. The quality of the rock varies greatly in different parts of the same quarry, but two distinct types of stone, known as the Arkansas and Washita (formerly spelled Ouachita), are obtained. The Arkansas stone is a true novaculite, and an average analysis shows it to contain 99.5 per cent of silica. There are two grades of the stone, known as hard and soft Arkansas, which are described in

<sup>a</sup>Ann. Rept. Geol. Survey Arkansas, Vol. III, 1890, p. 224.

detail in the report for 1899.<sup>a</sup> The difference between the two is that the soft Arkansas stone is more porous, and hence does not impart quite so fine an edge as the other. It is used principally in the form of small wheels, oilstones of different shapes, and points such as are used by engravers, surgeons, carvers, dentists, jewelers, watchmakers, die sinkers, etc. It is the best stone manufactured for all who use small-pointed or very fine-edged tools.

The Washita stone is in all its physical characteristics very similar to the Arkansas, but is less dense and much more porous, this porosity being due to the abundance of the rhombic cavities in the stone. It does not have so waxy a luster as the Arkansas stone, but has more of the appearance of glazed china ware. There are two grades of the Washita stone, known as hard and soft.<sup>b</sup>

*Indiana.*—The sandstones of Orange County, Ind., furnish a whetstone known as the Hindostan or Orange stone, which is quarried in Frenchlick and Northwest townships. The stone is fine grained and is used for an oilstone. It is considered the best low-priced sharpening stone for mechanics' tools. A considerable quantity of this stone is now being exported.

*Kentucky.*—The Caron Stone Company is quarrying to a limited extent a water hone from Hardin County, Ky. It is claimed that when heated this stone makes a good oilstone.

*Ohio.*—At a number of the quarries in the Berea sandstone a grade of stone is obtained that is suitable for making whetstones, principally at Berea, in Cuyahoga County, and at Grafton, in Lorain County. This makes a scythestone that does good work, but it does not stand transportation so well as the scythestones made from schist. At Euclid, Cuyahoga County, is a fine-grained sandstone from which a considerable number of oilstones are made, and which will be described under the heading "Grindstones." The well-known Deerlick oilstone is made at Chagrin Falls, in the same county, from a fine-grained sandstone, and since the introduction of this stone, a few years ago, its production has increased considerably each year.

*New York.*—In Cortland County, near Labrador Lake, a sandstone similar to that quarried in Ohio is found. It is known as Labrador stone, and is used to a limited extent in the manufacture of whetstones.

*New Hampshire and Vermont.*—In Haverhill Township, Grafton County, N. H., and near Lamoille, Orleans County, Vt., there is a quartz-mica-schist from which are manufactured the celebrated Indian Pond, White Mountain, and Lamoille scythestones. These schists are variable in their structure, so that only portions or bands of them can be utilized. In these bands, however, which are usually homogeneous, there is little waste material except that which is lost in splitting and

<sup>a</sup> Twenty-first Ann. Rept. U. S. Geol. Survey, Part VI Cont., p. 474.

<sup>b</sup> Loc. cit., p. 475.

breaking the stone for the rubbing tables. The cutting quality of the stones varies with the compactness of the schists and the percentage of quartz or grit contained. There are two principal grades of stone found at the New Hampshire quarries, which are known as the Indian Pond and the White Mountain. The name Indian Pond was used as early as 1820 for a stone obtained from a stratum of schist about 7 miles south of Pike Station, near a pond known by the above name. Both of these stones come from the same quarry. The White Mountain is more compact and has a finer texture, and the Indian Pond includes the more laminated varieties of the schist. The main quarries from which these stones are obtained are near Pike Station, where the home office and principal manufacturing plant are located. As the flat slabs of schist are taken from the quarry they are readily split up along the planes of lamination, and are then roughly broken into pieces about a foot square. These are then marked with a steel point, on each side, indicating sections that will give the desired width for the scythestones. A heavy knife blade is then placed on one of these marks and given a quick blow with a hammer, which readily breaks the squares into the desired width. A man can cut, on an average, about 3,000 stones a day. The best record for cutting is 5,300 in one day of ten hours. These rough-cut sticks of stone are taken to the rubbing mill, where they are ground down to the desired shape and size, and are then ready to be labeled and packed for shipment. The stones from the quarries at Lamoille are sold under the name of Lamoille stones. At Lisbon, Grafton County, N. H., there occurs a fine-grained quartz-mica-schist of a bluish chocolate color, which furnishes a stone known as the Chocolate whetstone. It is a medium hard stone and is especially adapted for leather and skinning knives, and is also used extensively for sharpening cloth cutters' tools, kitchen and carving knives, etc.

While the sale of oilstones and whetstones has either increased or held its own in the United States, there has been a considerable falling off in the sale of scythestones. This is undoubtedly due to the small use at the present time of scythes, sickles, etc., which have been almost entirely replaced by improved agricultural machines and implements; and scythestones are now used in quantity only in the border States or in those countries into which the improved agricultural machines have not yet been introduced. Thus it is that scythestones have been forced to seek a market in foreign countries, and now form the larger part of our exports of this kind of stone.

#### PRODUCTION.

During the last few years there has been a general increase in the production of oilstones and whetstones in the United States, though their value has declined since 1899. This has been partly due both

to the successful introduction of the American stones into foreign markets and to the general growth in this country of the trades that use them. The year of maximum production was 1899, when the value of the output amounted to \$208,283. There was a considerable falling off in the value of the production of 1901, which was \$158,300.

In nearly all cases the producers of these abrasive materials for oilstones and whetstones are also the manufacturers, and for this reason the statistics of the production of these stones are for the finished product. There is but very little of the raw material sold. The value of the oilstones, whetstones, etc., produced from 1891 to 1901, inclusive, is given in the following table:

*Value of oilstones, whetstones, etc., produced in the United States since 1891.*

Year.	Value.	Year.	Value.
1891.....	\$150,000	1897.....	\$149,970
1892.....	146,730	1898.....	180,486
1893.....	135,173	1899.....	208,283
1894.....	136,873	1900.....	174,087
1895.....	155,881	1901.....	158,300
1896.....	127,098		

From 1880 to 1890, inclusive, the product and value of the rough stone have been published in these reports, except in the case of the output for 1890, when the value for the unfinished product was given for the novaculite of Arkansas, while in all other cases the value of the finished stones was given. The annual production from 1880 to 1890 was as follows:

*Production of oilstones and whetstones from 1880 to 1890.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Pounds.</i>			<i>Pounds.</i>	
1880.....	420,000	\$8,000	1886.....	1,160,000	\$15,000
1881.....	500,000	8,580	1887.....	1,200,000	16,000
1882.....	600,000	10,000	1888.....	1,500,000	18,000
1883.....	600,000	10,000	1889.....	5,982,000	32,980
1884.....	800,000	12,000	1890.....		69,909
1885.....	1,000,000	15,000			

#### IMPORTS.

Oilstones and whetstones continue to be imported into the United States in about the same amount that they have been for the last few years. They consist principally of Belgian razor hones, that are made from a slaty mica-schist found in the Ardenne Mountains of Belgium; of razor hones made from a fine, hard, blue-green slaty mica-schist from Sonneberg, Germany; and of a small amount of "Turkey" oilstones from France and Italy.

The following table shows the total value of all kinds of hones, whetstones, etc., imported since 1880:

*Imports of hones and whetstones since 1880.*

Year ending—	Value.	Year ending—	Value.
June 30—		December 31—	
1880 .....	\$14,185	1891 .....	\$35,344
1881 .....	16,631	1892 .....	33,420
1882 .....	27,882	1893 .....	25,301
1883 .....	30,178	1894 .....	26,671
1884 .....	26,513	1895 .....	32,439
1885 .....	21,434	1896 .....	50,588
December 31—		1897 .....	34,485
1886 .....	21,141	1898 .....	30,856
1887 .....	24,093	1899 .....	34,510
1888 .....	30,676	1900 .....	39,316
1889 .....	27,400	1901 .....	64,655
1890 .....	37,454		

#### EXPORTS.

Oilstones and scythestones are also exported, the value of the exports being largely in excess of the imports. The exports consist principally of New Hampshire scythestones, which are shipped into nearly all foreign countries, but find their largest market in Europe. Indiana and Arkansas oilstones are also exported to some extent, with a growing demand for the latter. The amount of the exports of these stones will gradually increase, while there will be but little increase in the imports.

#### GRINDSTONES.

##### SOURCES AND KINDS OF MATERIAL USED.

The grindstones produced in the United States come almost entirely from Ohio and Michigan, and it is from the former State that the chief supply is obtained. As the principal source of the material from which the grindstones are manufactured is the sandstone that is found so extensively in the Lower Carboniferous series of Ohio, a brief description of this sandstone is given.

In the Lower Carboniferous series of Ohio there is a persistent bed, or series of beds, of sandstone which has been found to extend almost continuously from the northern part of West Virginia across the Ohio River northward through the central part of Ohio into Huron County, passing thence eastwardly to near the northeast corner of Trumbull County.<sup>a</sup> This sandstone is called the Berea grit,<sup>b</sup> on account of its having been so extensively quarried at Berea, in Cuyahoga County. The sandstone is found about 300 feet below the rocks

<sup>a</sup> Geol. Survey Ohio, Vol. VI, 1888, p. 311.

<sup>b</sup> Mineral Resources U. S., 1882, p. 478.

of the Coal Measures. Above the Berea grit is the Berea shale, which is prevailingly dark to black, highly fossiliferous, and a constant and immediate cover of the Berea grit throughout its extent in Ohio. The lowest layer of this shale is sometimes composed of sand bound together by pyrite. It varies from 15 to 50 feet in thickness, and in nearly all cases where it has been encountered its boundaries are sharp and distinct, this being especially true in central and southern Ohio.

Beneath the Berea grit is another argillaceous shale, which is known as the Bedford shale,<sup>a</sup> and which is uniformly from 70 to 75 feet in thickness. This shale is confined principally to northern Ohio, and its upper portion is generally of a marked red color, while the lower portion is a dark bluish gray. The thickness of these two shales is variable; sometimes they are nearly equal in thickness; at other times the red largely predominates; and at others the blue shale comes practically in contact with the Berea grit.<sup>b</sup>

The Berea grit, although varying considerably in thickness, from 40 to over 100 feet, and differing locally in character, is generally a rather fine-grained and homogeneous sandstone, which lies in courses varying from a few inches to several feet in thickness, and varies in color from a light drab to a light or steel blue. It is usually divided into two distinct parts, the upper of which is a series of thin beds which may be used for flagging, while the lower is more massive. In some places the division of these two parts is distinctly marked, while in others the whole mass is practically homogeneous. At still other places the upper part has been removed by glacial erosion, and the section exposed in the quarries consists chiefly of the massive sandstone.

As the Berea grit is traced eastward it becomes less massive, and in the eastern counties of Ohio the layers of sandstone are interlain by beds of shale. In the western part of Pennsylvania the Berea grit is hardly distinguishable, the whole mass there being made up of alternate beds of sandstone and shale. A similar change is observed as the Berea grit is followed southward, but in the vicinity of the Ohio River it is still marked by an unusual prevalence of sandy matter, and there are many good, though small, quarries in this section. This grit attains its maximum development in the northwestern portion of the area, as in Lorain County at Elyria and Amherst. In this county the sandstone reaches a thickness of 60 feet, and is more massive throughout than anywhere else within the limits of the State; and it is here that the greatest amount of quarrying has been done.

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<sup>a</sup> Geol. Survey Ohio, Vol. VI, 1888, p. 33.

<sup>b</sup> Geol. Survey Ohio, Vol. I, 1873, pp. 186, 209; Vol. II, 1874, pp. 88, 211; Vol. III, 1878, pp. 21, 301; Vol. VI, 1888, pp. 35, 311.

PRODUCTION.

The total value of the production of all kinds of grindstones in 1901 was \$580,703, or \$129,323 less than the production of 1900, which was \$710,026, being higher than that of any previous year. The next highest value was reached in 1882, when it was \$700,000. The value of the output in 1901 was nearly \$100,000 less than that of 1899, which was \$675,586. The tonnage was considerably greater in 1899, in 1900, and in 1901 than in 1882, for in the last-named year the price of the grindstones was \$15 per ton, and during the last three years the price has been from \$9 to \$10 per ton. The decidedly marked increase in the production of grindstones during the last three years has been largely due to the prosperous condition of the country, resulting in a large increase in all kinds of manufacturing, and in part to the export trade that has started in grindstones. The manufacture of the large number of agricultural machines that are now being made is one of the main industries that have caused a large increase in the number of grindstones demanded, and they have caused a smaller demand for scythestones.

Some manufacturers, in making their reports of production to the Survey, use the ton as the unit of measurement, while others state the number of grindstones made and sold. In 1901 the manufacturers who stated the number of grindstones sold reported a product aggregating 40,948 pieces, valued at \$396,238, as compared with 6,085 pieces, valued at \$81,772, in 1900. The product reported by weight amounted to 16,807 tons, valued at \$165,665, while in 1900 the amount was 46,406 tons, valued at \$619,399.

In the following table is shown the value of grindstones, including pulpstones, produced in the United States since 1880:

*Value of grindstones produced in the United States since 1880.*

Year.	Value.	Year.	Value.
1880 .....	\$500,000	1891 .....	\$476,113
1881 .....	500,000	1892 .....	272,244
1882 .....	700,000	1893 .....	338,787
1883 .....	600,000	1894 .....	223,214
1884 .....	570,000	1895 .....	205,768
1885 .....	500,000	1896 .....	326,826
1886 .....	250,000	1897 .....	368,058
1887 .....	224,400	1898 .....	489,769
1888 .....	281,800	1899 .....	675,586
1889 .....	439,587	1900 .....	710,026
1890 .....	450,000	1901 .....	580,703

## IMPORTS.

Grindstones continue to be imported into the United States, and these imports are kept up largely by the demand of the large pulp manufacturers for the Newcastle pulpstones, which are obtained from Newcastle-upon-Tyne, in England. Other imported grindstones are a coarse, hard one from Bavaria, which is used for razor grinding, and a very hard one from Edinburgh, Scotland, called the Craigleith, that is used for special purposes in the glass trade. In reporting the imports of grindstones the Bureau of Statistics of the Treasury Department limits the statements to the value, no figures relating to the quantity having been published since 1883.

The amount and value of the grindstones imported into the United States since 1868 are given below:

*Grindstones imported and entered for consumption in the United States, 1868 to 1901, inclusive.*

Year ending—	Finished.		Unfinished or rough.		Total value.
	Quantity.	Value.	Quantity.	Value.	
June 30—	<i>Long tons.</i>		<i>Long tons.</i>		
1868.....		\$25,640		\$35,215	\$60,855
1869.....		15,878		99,715	115,593
1870.....		29,161		96,444	125,605
1871.....	385	43,781	3,957.15	60,935	104,716
1872.....	1,202	13,453	10,774.80	100,494	113,947
1873.....	1,437	17,033	8,376.84	94,900	111,933
1874.....	1,443	18,485	7,721.44	87,525	106,010
1875.....	1,373	17,642	7,656.17	90,172	107,814
1876.....	1,681	20,262	6,079.34	69,927	90,189
1877.....	1,245	18,546	4,979.75	58,575	77,121
1878.....	1,463	21,688	3,669.41	46,441	68,129
1879.....	1,603	24,904	4,584.16	52,343	77,247
1880.....	1,573	24,375	4,578.59	51,899	76,274
1881.....	2,064	30,288	5,044.71	56,840	87,128
1882.....	1,705	30,286	5,945.61	66,939	97,225
1883.....	1,755	28,055	6,945.63	77,797	105,852
1884.....					* 86,286
1885.....					50,579
December 31—					
1886.....					39,149
1887.....					50,312
1888.....					51,755
1889.....					57,720
1890.....					45,115
1891.....					21,028
1892.....					61,052
1893.....					59,569
1894.....					52,688
1895.....					54,276
1896.....					66,195
1897.....					49,496
1898.....					62,973
1899.....					63,852
1900.....					92,581
1901.....					88,871

\* Since 1884 not separately classified.

Grindstones have begun to be exported in considerable numbers, so that now the total of the exports is greater than that of the imports, which are for the most part pulpstones. The use of the American pulpstone is gradually increasing, and will in the end cause the importation of these stones to decrease.

## BUHRSTONES AND MILLSTONES.

### KINDS AND SOURCES.

There are many varieties of stone that are used in the manufacture of buhrstones or millstones, and these names are retained on account of the stones formerly being used for the same purposes as the regular buhr. The American millstone varies from a sandstone to a quartz conglomerate, which occurs along the eastern slopes of the Appalachian Mountains from New York to North Carolina, and is known by different names, according to the locality from which it is obtained. The New York millstone quarries are located in a belt of sandstone and conglomerate on the Shawangunk Mountains, extending across the towns of Rochester, Marbletown, Wawarsing, Gardener, and New Paltz, in Ulster County. The stones vary greatly, some being very fine grained, while others are coarse, according to the portion of the rock from which they are manufactured. They are all, however, known as "Esopus stone." The largest stone made is 6 feet in diameter, and the smallest is 18 inches. The face of these stones varies from 1 to 2 feet. In Pennsylvania the quarries are located in Lancaster County, and the millstones are known as "Turkey Hill" and "Cocalico," the former being found on Turkey Hill, near Bowmansville, and the latter near Durlach and Lincoln. In the vicinity of Prices Fork, Montgomery County, Va., a sandstone conglomerate occurs on Brush Mountain. Quarries have been opened in it for a distance of 3 miles. The stone occurs in various colors from white and gray to bluish, and is also of different grades of grit. These stones are known on the market as "Brush Mountain" stone. There is practically the same variation in the sizes of the stone manufactured at all these different quarries. At Faith, Rowan County, N. C., in the Dunn Mountain granite belt, a stone is being quarried and manufactured into millstones. The demand for this stone is increasing, and it is expected that the production in 1902 will be from two to three times that of 1901. The stones are used mostly for grinding corn, oats, etc., and are sold in North Carolina, Georgia, and other Southern States. The four localities just mentioned were the only ones at which millstones were quarried during 1901, and there was an increase of production from each of them. In Moore County, N. C., millstones were formerly obtained and were known by the

name of "North Carolina grit." A buhrstone or millstone was also formerly obtained from the Berea grit (sandstone) at Peninsula, Ohio, the grit being similar to that which is now used in the manufacture of the Peninsula pulpstone. In many of the isolated mountain districts, especially of the Southern States, there is a great variety of stones that are being used for buhrstones. The owners of many of the small mills of these mountain districts, who grind wheat and corn, often quarry in their vicinity the stone they use and work it up themselves. At a number of places in North Carolina where scrap mica is ground buhrstones are used, some of which are quarried locally.

There are still a good many buhrstones imported from France, Belgium, and Germany, and these are of a decidedly different character and are considered to give better satisfaction than the American stone. This may have been true when the buhrstones were used principally for making wheat flour, but there is no reason why the American stone should not give just as good satisfaction for the purposes for which they are now used. The French buhr is considered the best, and both it and the Belgian are hard and porous rocks, consisting of small particles of quartz mixed with calcareous material. The German buhr is said to be a basaltic lava. These various stones are usually brought into this country in pieces and then made up into the buhrstone, thus escaping the higher duty of a finished product.

Whereas formerly there were a large number of buhrstones used in the United States, principally in grinding wheat, there are now but very few used for that purpose on account of the introduction of the roller-mill process. It is only in certain mountain districts where railroad facilities are wanting that buhrstones are still used for this purpose. They are now used quite extensively for grinding the coarser cereals, mineral paint ores, fertilizers, cement rock, barytes, and other minerals, and such use is increasing each year. For such grinding American stones seem to be and should be as satisfactory as the foreign.

#### PRODUCTION.

There has been a continual increase in the production of buhrstones since 1894, when it had dropped down to its lowest point, the value of the production being only \$13,887. In 1901 the value of the buhrstones produced was \$57,197, as compared with a value of \$32,858 in 1900, and of \$28,115 in 1899. Although there is but little chance of the production of buhrstones equaling the value of the production of the early eighties, which was from \$150,000 to \$200,000 per year, yet there will probably be a continued increase for a number of years to come. The importation of buhrstones began to decline sharply in 1883, and there has been a gradual falling off since then.

The value of the production of buhrstones in the United States since 1880 is given in the following table:

*Value of buhrstones produced in the United States from 1880 to 1901.*

Year.	Value.	Year.	Value.
1880 .....	\$200,000	1891 .....	\$16,587
1881 .....	150,000	1892 .....	23,417
1882 .....	200,000	1893 .....	16,639
1883 .....	150,000	1894 .....	13,887
1884 .....	150,000	1895 .....	22,542
1885 .....	100,000	1896 .....	22,567
1886 .....	140,000	1897 .....	25,932
1887 .....	100,000	1898 .....	25,934
1888 .....	81,000	1899 .....	28,115
1889 .....	35,155	1900 .....	32,858
1890 .....	23,720	1901 .....	57,179

IMPORTS.

Although there was a considerable increase in the importation of buhrstones and millstones in 1900, and again in 1901, over that of any year since 1894, yet the general tendency has been for the imports to grow less, not only on account of the introduction of the roller process for making wheat flour, but because the buhrstones produced in this country are as satisfactory as the foreign ones for the purposes for which the stones are now used.

The value of buhrstones and millstones imported into the United States since 1868 is given in the following table:

*Value of buhrstones and millstones imported into the United States from 1868 to 1901, inclusive.*

Year ending—	Rough.	Made into millstones.	Total.	Year ending—	Rough.	Made into millstones.	Total.
June 30—				December 31—			
1868 .....	\$74,224		\$74,224	1886 .....	\$29,273	\$662	\$29,935
1869 .....	57,942	\$2,419	60,361	1887 .....	23,816	191	24,007
1870 .....	58,601	2,297	60,898	1888 .....	36,523	705	37,228
1871 .....	35,406	3,698	39,104	1889 .....	40,432	452	40,884
1872 .....	69,062	5,967	75,029	1890 .....	32,892	1,103	33,995
1873 .....	60,463	8,115	68,578	1891 .....	23,997	42	24,039
1874 .....	36,540	43,170	79,710	1892 .....	33,657	529	34,186
1875 .....	48,068	66,991	115,059	1893 .....	29,532	729	30,261
1876 .....	37,759	46,328	84,087	1894 .....			* 18,087
1877 .....	60,857	23,068	83,925	1895 .....			* 20,316
1878 .....	87,679	1,928	89,607	1896 .....			* 26,965
1879 .....	101,484	5,088	106,572	1897 .....			* 22,956
1880 .....	120,441	4,631	125,072	1898 .....	22,974	1,025	23,999
1881 .....	100,417	3,495	103,912	1899 .....	18,368	513	18,881
1882 .....	103,287	747	104,034	1900 .....	27,960	944	28,904
1883 .....	73,413	272	73,685	1901 .....	40,885	1,302	42,187
1884 .....	45,837	263	46,100				
1885 .....	35,022	455	35,477				

\* Not separately classified.

## PUMICE.

Pumice is a general name given to the loose, spongy, cellular, or frothlike parts of lava. This peculiar structure is undoubtedly due to the escape of steam or gas through its mass while in a state of fusion. It is among the acid lavas that the most perfect forms of pumice are found, although some of the basic kinds sometimes assume a similar structure. Pumice is buoyant and floats readily on water, owing to its extremely porous nature. When examined under the microscope, an acid pumice stone is observed to be made up of a groundmass of glass, crowded with an extremely large number of minute cavities that are elongated in the direction of the flow of the lava, and with abundant crystallites. The solid pumice stone that is found comes under this head.

Pumice, as it is known commercially, is also made from another volcanic product called volcanic ash. This includes the finer detritus that is ejected in many eruptions and is often deposited at considerable distances. It is an exceedingly fine, light-gray powder, resembling an ash, but when examined under the microscope it is seen to consist partly of minute rough, rounded, angular, or flaky grains of a glassy nature, and partly of minute crystallites, and it is in reality merely a lava in extremely fine subdivision. When these components have had an opportunity to accumulate, they have sometimes become consolidated into rock formations. Where they have been deposited in the sea or lakes they are liable to have their outer margin pass insensibly into ordinary sediments.

The following analyses will give an idea of the chemical composition of pumice:

*Analyses of pumice from Utah and Nebraska.\**

Constituent.	1.	2.
	Millard County, Utah.	Ne- braska.
	<i>Per ct.</i>	<i>Per ct.</i>
Silica ( $\text{SiO}_2$ ) .....	72.58	71.97
Alumina ( $\text{Al}_2\text{O}_3$ ) .....	15.66	14.86
Ferric oxide ( $\text{Fe}_2\text{O}_3$ ) .....	.96	.88
Lime ( $\text{CaO}$ ) .....	.73	.77
Soda and potash ( $\text{Na}_2\text{O}$ and $\text{K}_2\text{O}$ ) .....	8.28	8.28
Loss on ignition .....	3.64	3.64

Both the solid pumice stone and the volcanic ash are mined as a source of commercial pumice. Where necessary, it is crushed and bolted and is used in the manufacture of various polishing powders and scouring stones.

During the summer of 1897 several extensive deposits of pumice were discovered in Nebraska, in the Tertiary deposits, the most exten-

\* By W. H. Andrews, Nineteenth Ann. Rept. U. S. Geol. Survey, Part VI.

sive exposure being in Sioux, Dawes, Scotts Bluff, Banner, and Cheyenne counties. Another deposit was discovered in South Dakota about 3 miles east of Pine Ridge Agency. The volcanic ash of which these deposits are composed was probably brought by the winds from volcanoes in Colorado and New Mexico, and deposited in the lakes and other water courses which at that time covered this region. A deposit of lump pumice stone was found in Millard County, Utah, and is the only known deposit of lump pumice stone in the United States. These deposits were described in detail in the Nineteenth Annual Report of the Geological Survey, Part VI, page 529. A large deposit of pumice is reported as occurring in Sonoma County, Cal.

On account of the distance of these deposits from the railroad and from the large markets, they have not been able to compete with the pumice imported from Lipari, which is shipped largely as ballast and which sells in New York, after being ground and bolted, at from 2 to 2½ cents per pound. For this reason the production of pumice in the United States, which was begun in 1897 by the shipment of 158 tons, and of over 600 tons in 1898, has ceased.

Pumice has been found in Hawaii in sufficient quantity to more than furnish the demand of this country if it can compete with that from Lipari.

Almost the entire demand for pumice has been supplied from a deposit in the northwestern part of the island of Lipari, which is just north of the island of Sicily in the Tyrrhenian Sea, about 80 per cent of that used in the United States being shipped directly here from that island. The deposit covers about 3,706 acres and varies in depth from 3 to 13 feet, consisting of an irregular mixture of pumice stone and volcanic ash. There are from 200 to 220 small quarries located on the deposit, but the majority of them are worked only from May to October. As the pumice stone is quarried, it is sold to merchants, who sort it according to color, weight, and size, and then send it to Lipari, where it is cleaned and prepared for market, the refuse stone and small pieces being ground to powder in handmills.

The amount of pumice imported into the United States can not be even approximately given, as no record of it is kept by the Bureau of Statistics of the Treasury Department, only the value of the pumice imported being recorded. Since 1893, with the exception of 1896, the value of the imports has varied between \$43,788 and \$65,930. In 1896 no imports at all were reported.

#### INFUSORIAL EARTH AND TRIPOLI.

Under this head are included all porous, siliceous earths of organic origin, such as infusorial earths, diatomaceous earth, and tripoli. These are formed from the siliceous shells of diatoms and other microscopic species, and occur in deposits that are often many miles in area. Deposits of these earths occur in many of the States on the eastern

slopes of the Appalachian Mountains and in two of the Western States, Nevada and California. Besides these two States, large deposits of infusorial earth or tripoli have been found in Maine, New Hampshire, Massachusetts, Connecticut, New Jersey, Maryland, Virginia, Georgia, Alabama, and Arkansas. A porous siliceous rock which occurs near Carthage, Newton County, Mo., is included here, as it is used for the same purposes, although it is not of the same origin as the infusorial earths. The infusorial-earth deposits of Maine occur near Blue Hill, Hancock County, and were operated during 1901. The only deposit that is being worked in New Hampshire is the one on Troy Mountain, Troy, Cheshire County. The material, after being mined, is calcined, bolted, and manufactured at Keene into cleaning powders and polishers by the producers of the raw material. A deposit of tripoli was worked during 1901 at Framingham, Middlesex County, Mass., the material being crushed, burned, and washed before being placed on the market. Mining is carried on quite extensively at the infusorial-earth deposit in Calvert County, Md. In King George County, Va., near Wilmot, on the Potomac River, a deposit of infusorial earth is being opened up which is reported to be a horizontal bed 16 to 30 feet thick and exposed for 1,000 feet along the river. The material is very smooth and uniform throughout the deposit, and is free from gravel, dirt, etc. A considerable part of the material mined is to be used in the manufacture of hollow, furnace, and building brick and an infusorial-earth plastic asbestos cement. Another deposit in Virginia that has been worked quite extensively is near Richmond, in Henrico County. In Murray County, Ga., a tripoli deposit, located about 10 miles east of Dalton, has been worked to some extent. The material, before shipping, is finely ground. The siliceous material that is found near Carthage, Newton County, Mo., is evidently residual silica left from an impure siliceous limestone by the leaching out of the calcium carbonate. Its character is such that it answers all the purposes of an infusorial earth or tripoli so far as polishing qualities are concerned, and on account of its exceeding porosity and yet compact nature it makes an excellent material for water filters, and it can be readily cut into any desirable shape. On account of this material being used for water filters its production is larger than that of any other deposit of this character. In Esmeralda County, Nev., a limited amount of infusorial earth is mined each year, the product being sacked for shipment just as it is quarried. There was no production of infusorial earth or tripoli in Connecticut, New Jersey, Alabama, Arkansas, or California during 1901, but in Connecticut there was some quartz mined and ground and sold under the name of tripoli.

Perhaps the largest and most noted of infusorial-earth deposits<sup>a</sup> are those at Niederohe and Oberohe, in the Lueneburg Heath, North Germany, a few miles from Unterleuss, the nearest railroad station. This

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<sup>a</sup> Oil, Paint, and Drug Reporter, June 3, 1901.

material is sometimes found 5 to 6 meters below the surface; the stripping of this covering is usually done in spring and fall, and during the summer the infusorial earth is quarried, dried, and prepared for market. These deposits vary from 6 to 15 meters in thickness. A large amount of this material is exported to all parts of the world.

#### USES.

Infusorial earth, tripoli, etc., are included with the abrasives because they are used to a certain extent in the manufacture of polishing powders and scouring soaps, although this is not their only use. Owing to its porous nature infusorial earth has been found to make an excellent absorbent for the manufacture of dynamite from nitroglycerin, and its nonconductivity of heat gives it value for packing for boilers, steam pipes, and safes, and as a base for fire- and heat-retarding cements. It is also being used to a considerable extent for the manufacture of fireproof building materials, such as solid brick, hollow brick for partition walls, floors, etc.

#### PRODUCTION.

There is considerable variation in the quantity and value of infusorial earth produced in the United States from year to year, and this is due partly to the varying demand for the material as other minerals are substituted for it in some of its uses, and partly to a production of the raw product in one year sufficient to last the manufacturers a year or more. The variation given in the values of the production is chiefly due to the different conditions of the material as it is marketed, some being sold just as it is mined, although most of it is subjected to treatment. The production of 1901 amounted to 4,020 tons, valued at \$52,950, as compared with 3,615 tons, valued at \$24,207, in 1900. This increase in value is partly due to the large production of the American Tripoli Company, of Seneca, Mo.

The quantity and value of infusorial earth obtained in the United States since 1880 are given in the following table:

*Production of infusorial earth from 1880 to 1901.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Short tons.</i>			<i>Short tons.</i>	
1880.....	1,833	\$45,660	1891.....		\$21,988
1881.....	1,000	10,000	1892.....		43,655
1882.....	1,000	8,000	1893.....		22,582
1883.....	1,000	5,000	1894.....	2,584	11,718
1884.....	1,000	5,000	1895.....	4,954	20,514
1885.....	1,000	5,000	1896.....	3,846	26,792
1886.....	1,200	6,000	1897.....	3,833	22,385
1887.....	3,000	15,000	1898.....	2,733	16,691
1888.....	1,500	7,500	1899.....	3,302	25,302
1889.....	3,466	23,372	1900.....	3,615	24,207
1890.....	2,532	50,240	1901.....	4,020	52,950

## CRYSTALLINE QUARTZ.

Under this head is included the crystalline quartz which is used principally as a wood finisher, and the entire production of this mineral for this purpose is credited to Connecticut. Some quartz is pulverized and sold under the name of tripoli. The quartz rock which is used for wood finishing must be very pure and white and is crushed and ground to an impalpable powder. It is then floated, precipitated, dried, and bolted. Considerable of the quartz is ground by the dry process, but it does not make as good a product for this purpose as that made by the wet process, nor does it bring as high a price. This flour quartz is combined with a proper portion of japans, oils, etc., to make a paste. When used, the paste is reduced with turpentine or benzine, so that it will flow freely under the brush, and it is then painted on the smooth, fresh surface of the wood. After being left until it becomes "set up," which takes from a few minutes to half an hour, it is wiped off the surface, leaving the pores of the wood filled with minute particles of quartz which have been carried into them by the oil. Wood that has been treated in this way will take a high polish.

There is considerable quartz sand used in the stonecutting trade, especially by the marble men, as an abrasive. A limited amount of quartz is crushed and sized and used in the manufacture of sandpaper.

## PRODUCTION.

There were 14,050 tons of crystalline quartz, valued at \$41,500, produced in 1901, as compared with 14,461 tons, valued at \$40,705, in 1900. These values are for the crude quartz and not after it has been prepared for market, when its value is from three to four times as much. The quantity and value of crystalline quartz produced in the United States since 1894, the first year it was obtained, are given in the following table:

*Production of quartz crystal since 1894.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Short tons.</i>			<i>Short tons.</i>	
1894.....	6,024	\$18,054	1898.....	8,312	\$23,990
1895.....	9,000	27,000	1899.....	13,600	39,000
1896.....	6,000	18,000	1900.....	14,461	40,705
1897.....	7,500	22,500	1901.....	14,050	41,500

## GARNET.

## OCCURRENCE.

Garnet is one of the commoner minerals, is found in many of the crystalline rocks, and is often a product of contact metamorphism. It is usually associated with mica (muscovite) in pegmatitic dikes, although sometimes occurring but sparingly.

PRODUCTION.

The statistics of the production of garnet in the United States have only been taken since 1894, and there has been considerable variation in both the production and the value. On account of the variation of quality of the garnet from the different localities, the price varies from \$20 to \$60 per ton when cleaned and prepared for market. The higher price has been obtained for the North Carolina garnet. Until 1900 the North Carolina garnet was not included in these statistics, and this is one reason for the increase in production and value of garnet during 1900 and 1901. The production for 1901, as reported to the Survey, is 4,444 tons, valued at \$158,100, as compared with 3,185 tons, valued at \$123,475, in 1900, which is an increase of 1,259 tons and of \$34,625 in value. The average value per ton of the garnet produced in 1901 was \$35.57, as compared with an average value of \$38.76 per ton in 1900. The production of each year since 1894 is given in the following table:

*Production of abrasive garnet since 1894.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Short tons.</i>			<i>Short tons.</i>	
1894.....	2,401	\$90,660	1898.....	2,967	\$86,850
1895.....	3,325	95,050	1899.....	2,765	98,325
1896.....	2,686	68,877	1900.....	3,185	123,475
1897.....	2,554	80,853	1901.....	4,444	158,100

CORUNDUM AND EMERY.

A distinction is often made between corundum and emery, many not recognizing emery as a variety of corundum. There are three names in constant use to designate the varieties of corundum:

(1) Sapphire, which includes all corundums of whatever color that are transparent to semitransparent;

(2) Corundum, including the translucent to opaque varieties of all colors;

(3) Emery, which is a mechanical admixture of corundum and magnetite or hematite.

It is these last two varieties that are used in the arts for abrasive purposes, emery being used in very much larger quantities than corundum. It is, of course, the presence of corundum in the emery that gives to it its abrasive value; and the abrasive efficiency of the emeries will vary according to the percentage of corundum that they contain.

Next to the diamond, corundum is the hardest mineral known, having a hardness of 9, while the diamond is 10, and it is this hardness that makes the corundum of so great value as an abrasive. Corundums vary slightly in hardness, the sapphire varieties generally being considered the hardest, and of these the blue sapphire stands at the head.

All corundums do not behave alike when heated to the high temperature necessary for the manufacture of the vitrified wheels, and although most corundums can, if properly cleaned, be used in the manufacture of these wheels, some will, when heated, crumble to a powder. It is, therefore, very essential before beginning to operate a corundum deposit to test the ore thoroughly as to whether it can be commercially cleaned, and to ascertain the adaptability of this cleaned product to the manufacture of vitrified and other wheels.

There are noticeable changes in the condition of the corundum and emery industry at the close of 1901 from its condition at the close of 1900. Of these changes the more prominent are the production of artificial corundum, the exploitation and development of the recently discovered corundum deposits in Montana, the production of the corundum occurring in quartz-schist in Clay County, N. C.; the production of corundum at the mines in Ontario, Canada, and its importation into the United States; the transfer of the Chester emery mines to the Ashland Emery and Corundum Company, and the entrance of the Hampden Emery Wheel Company as producers in the Peekskill emery field.

There is a constant increase in the demand for such abrasives as corundum and emery, which is due to the large increase in manufacturing, especially of agricultural machines, and also to the improved methods that have been devised for manufacturing emery and corundum stones and wheels of all shapes and sizes. That the supply could readily exceed the demand is very evident when it is considered that there are only about 16,000 tons of corundum and emery used in the United States. Of this amount, however, there are 11,723 tons imported, so there is room for a large increase in the production of these abrasives in the United States. At the present time there are only about 500 tons of corundum being used, this being due not to the small demand for it, but to the lack of this material on the market. If the price is maintained at 8 to 10 cents per pound, there will be but a relatively small amount of corundum used, but with a slight decrease in price there will be a great increase in the use of corundum, which will be at the expense of the emery. At the same time, with a decrease in price the more favorable must be the location of the deposits for mining and for railroad facilities in order to bear this competition with the emery. With the known occurrences of corundum in the United States there should be no drawback to such production of it as fully to satisfy the market's demand.

#### PRODUCTION.

The production of corundum during 1901 was confined entirely to North Carolina, there being three mines that aided in this production—the Corundum Hill at Cullasagee, Macon County; the Sealy Mountain, Clay County; and the Caney Creek, Jackson County. The output

was small as compared with the possibilities and extent of the corundum deposits that are known in North Carolina. With the development of the deposits of Montana, the production for 1902 should be much greater than that of 1901, which was somewhat larger than that of 1900. The emery production has been confined to the same localities as last year, the mines at Chester, Mass., and those in the vicinity of Peekskill, N. Y. The amount of emery produced was a little less than the year before. The total amount of emery and corundum produced in the United States during 1901 was 4,305 tons, valued at \$146,040, as compared with 4,305 tons, valued at \$102,715, in 1900. If this production is compared with the amount of emery imported, it will be found that it is less than one-half the latter in amount and also less than one-half in value.

The amount and value of the production of emery and corundum in the United States since 1881 are given in the table below, but in each case it is the total amount of the two that is given:

*Annual production of corundum and emery since 1881.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Short tons.</i>			<i>Short tons.</i>	
1881 .....	500	\$80,000	1892 .....	1,771	\$181,300
1882 .....	500	80,000	1893 .....	1,713	142,325
1883 .....	550	100,000	1894 .....	1,495	95,936
1884 .....	600	108,000	1895 .....	2,102	106,256
1885 .....	600	108,000	1896 .....	2,120	113,246
1886 .....	645	116,190	1897 .....	2,165	106,574
1887 .....	600	108,000	1898 .....	4,064	275,064
1888 .....	589	91,620	1899 .....	4,900	150,600
1889 .....	2,245	105,567	1900 .....	4,305	102,715
1890 .....	1,970	89,395	1901 .....	4,305	146,040
1891 .....	2,247	90,230			

#### IMPORTS.

With the development of the Canadian corundum deposits there has been a considerable amount of corundum imported into the United States from this source, and in 1901 it amounted to over 200 tons. There has also been a small amount of corundum imported from India. Of emery, however, there is over twice as much imported as is produced in the United States, and it is obtained from Turkey and the island of Naxos, one of the Cyclades group in the Grecian Archipelago. This large importation is not due to the scarcity of emery in this country, but to the low price at which the Turkish and Grecian ores can be placed on the docks at Boston, New York, or Philadelphia, having been brought over as ballast.

There are now being imported into the United States nearly 12,000 tons of emery per year, and the total consumption is only a little over 16,000 tons. Thus the imports are nearly three times the home production. There is plenty of opportunity for a decided increase in the production of emery in this country to replace a part, at least, of that imported. This may also be said of corundum; for if a good clean product were placed on the market, it would be used to the extent of

1,000 or 1,500 tons, to the exclusion of the same amount of emery; and with an even slight decrease in price of the corundum, it would be used in much larger quantity. In the following table are given the amount and value of emery imported from 1867 to 1901:

*Emery imported into the United States from 1867 to 1901, inclusive.*

Year ending—	Grains.		Ore or rock.		Pulverized or ground.		Other manu- fac- tures.	Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
June 30—	<i>Pounds.</i>		<i>Long tons.</i>		<i>Pounds.</i>			
1867 .....			428	\$14,373	924,431	\$38,131		\$52,504
1868 .....			85	4,531	834,286	33,549		38,080
1869 .....			964	35,205	924,161	42,711		77,916
1870 .....			742	25,335	644,080	29,531		54,866
1871 .....			615	15,870	613,624	28,941		44,811
1872 .....			1,641	41,321	804,977	36,103		77,424
1873 .....	610,117	\$29,706	755	26,065	343,828	15,041	\$107	70,919
1874 .....	331,580	16,216	1,281	43,886	69,890	2,167	97	62,366
1875 .....	487,725	23,345	961	31,972	85,853	2,990	20	58,327
1876 .....	385,246	18,999	1,395	40,027	77,382	2,533	94	61,653
1877 .....	343,697	16,615	852	21,964	96,351	3,603		42,182
1878 .....	334,291	16,359	1,475	38,454	65,068	1,754	34	56,601
1879 .....	496,633	24,456	2,478	58,065	133,556	4,985		87,506
1880 .....	411,340	20,066	3,400	76,481	223,855	9,202	145	105,894
1881 .....	454,790	22,101	2,884	67,781	177,174	7,497	53	97,432
1882 .....	520,214	25,314	2,765	69,432	117,008	3,708	241	98,695
1883 .....	474,105	22,767	2,447	59,282	93,010	3,172	269	85,490
1884 .....	143,267	5,802	4,145	121,719	513,161	21,181	188	148,890
1885 .....	228,329	9,886	2,445	55,368	194,314	8,789	757	74,800
December 31—								
1886 .....	161,297	6,910	3,782	88,925	365,947	24,952	851	121,638
1887 .....	367,239	14,290	2,078	45,033	*144,380	6,796	2,090	68,209
1888 .....	430,397	16,216	5,175	93,287			8,743	118,246
1889 .....	503,347	18,937	5,234	88,727			111,302	218,966
1890 .....	534,968	20,382	3,867	97,939			5,046	123,367
1891 .....	90,658	3,729	2,530	67,573				71,302
1892 .....	566,448	22,586	5,280	95,625			2,412	120,623
1893 .....	516,953	20,073	5,066	103,875			3,819	127,767
1894 .....	597,713	18,645	2,804	51,487			1,841	71,973
1895 .....	678,761	25,066	6,803	80,386			27,586	133,038
1896 .....	755,693	28,493	6,389	119,738				148,231
1897 .....	539,176	20,865	5,213	107,655			2,211	130,531
1898 .....	577,655	23,320	5,547	106,269			3,810	133,399
1899 .....	728,299	29,124	7,435	116,493			11,514	157,131
1900 .....	661,482	26,520	11,392	202,980			10,006	239,506
1901 .....	1,086,729	43,217	12,411	210,856			10,926	294,999

\* To June 30 only; since classed with grains.

It may be of interest to give here the output of the Canadian corundum mines, whose commercial product was placed on the market in 1901 for the first time. The total amount of corundum ore mined in 1901 was 4,133 tons, from which there were produced 868,590 pounds

of commercial corundum, showing the ore to be carrying a little over 10 per cent of corundum. Of this amount, 171,537 pounds were sold in Canada, 20,331 pounds in England, 5,320 pounds in other parts of Europe, and 576,402 pounds in the United States, the latter country taking over one-half of the entire production.

With corundum there should be a good opportunity for building up an export trade from the United States and Canada; for as far as can be learned no corundum is produced elsewhere, except a very small amount in India. There is a large and growing demand for corundum in Great Britain, Germany, France, and Sweden; and there will be a small demand for it from South American countries and from Australia. The large deposits of the mineral that are known to exist in the United States and Canada should be able to supply the world's demand for this abrasive.

#### ARTIFICIAL ABRASIVES.

During the last fifteen years many experiments and investigations have been made with the view of producing an artificial abrasive that would be equal or superior to the natural products. These experiments have met with success, and there are now three artificial abrasives on the market; and for two of these there is already a considerable demand. These are carborundum, crushed steel, and artificial corundum. The production of the first has increased at a phenomenal rate since its introduction in 1893; and though the production of crushed steel increased rapidly when it was first used, for the last few years there has been but little change in production. Artificial corundum is the latest of the artificial abrasives, and made its first appearance in the latter part of 1901. The effect that these artificial abrasives will have on the production of the natural products can not yet be definitely determined. It will be felt principally among those abrasives that are included under the second group, which have to be mechanically separated from the associated gangue minerals. Crushed steel has a field that is practically not entered by the other abrasives, as the greater portion of that manufactured is used in the stone-cutting trade, particularly by the marble and granite cutters. Carborundum and artificial corundum will be strong competitors of corundum and emery, and perhaps of some garnet, but not of the other abrasives, as they are sold at too low a price. With emery selling at its present price, carborundum and artificial corundum will not have any special competition, as they will be manufactured into a higher grade of abrasive. They will, however, be strong competitors of corundum, which is the best of the natural products. At the present time there is so small an amount of corundum produced that there is really no competition between it and the carborundum. If, however, the corundum should

be mined and placed on the market in much larger quantities the carborundum would be at once one of its strongest competitors. With the emery the carborundum has been already a competitor to some extent, but on account of the greater cost of the carborundum it has not thus far made much inroad on the emery market. These artificial abrasives hold a strong place in the abrasive industry, and their production is constantly increasing. This will continue to be the case, at least with such abrasives as carborundum and artificial corundum, which are in the same scale with the best natural products.

#### CARBORUNDUM.

Carborundum is composed of carbon and silicon, containing 32 per cent of the former and 68 per cent of the latter. As it comes from the furnace it is in the shape of black crystals of great brilliancy and hardness. These are crushed under rolls into grains of various sizes, which are washed in a solution of acid and water to remove soluble material, and then dried and sifted to uniform sizes.

The manufacture of carborundum, which was started in 1893, has had a remarkable growth since that time, and its production has increased from a few hundred pounds to nearly 4,000,000 pounds per year. This material was discovered by Mr. E. G. Achison, formerly of Monongahela, Pa., who was conducting a series of experiments in the hope of securing a substitute for the diamond as an abrasive. When first manufactured considerable difficulty was experienced in obtaining a uniform product, and a great deal of complaint was made of the material put on the market, for some lots would have excellent abrasive qualities, while others would be of but little value for abrasive purposes. One of the principal objections to the carborundum was its brittleness and the ease with which it was converted into a powder; and thus while it would cut very readily when first used, it would very soon crush to a fine powder when used in the form of grains, or the grains would break off when used in the form of a wheel. Experiments were constantly made to remedy this defect, with the result that now a nearly uniform product is being turned out by the Carborundum Company, and is giving good satisfaction as an abrasive, although the crystals are still brittle. The first use that was made of carborundum was by the lapidaries in the place of diamond powder; but now it is being used to a certain extent as a general abrasive material, and is made into hones, wheels, and other forms. The price has been reduced from \$15 per pound until it can now be bought for from \$160 to \$200 per ton. When first made the production would not average much over one-quarter of a pound per day; but in 1893 it had increased to 15,200 pounds, and by the end of 1894 the company had developed its plant and method of manufacture so that

the production reached 100,000 pounds of carborundum per year. In 1895 the company's factory at Niagara Falls was built, and in 1896 it commenced to use 1,000 electrical horsepower, which was increased to 3,000 horsepower in 1898. Besides the plant for the production of the carborundum, the company also has an extensive and complete plant for the manufacture of all kinds of carborundum wheels and stones, and of carborundum paper and cloth. It now has four 16-foot kilns for vitrifying wheels.

*Production.*—The growth of the carborundum industry has been remarkable. During 1901 the total production of carborundum was 3,838,175 pounds, valued at from 8 to 10 cents per pound. Much of the carborundum manufactured is now exported. It is interesting in noting the growth of this industry to compare the statistics showing the production of carborundum for each year, and in the following table the production of this abrasive is given for the years 1892 to 1901, inclusive.

*Production of carborundum from 1892 to 1901, inclusive*

Year.	Amount.	Year.	Amount.
	<i>Pounds.</i>		<i>Pounds.</i>
1892 .....	1,000	1897 .....	1,256,400
1893 .....	15,200	1898 .....	1,447,200
1894 .....	52,200	1899 .....	1,741,245
1895 .....	226,000	1900 .....	2,634,900
1896 .....	1,207,800	1901 .....	3,838,175

#### CRUSHED STEEL.

The greater part of the crushed steel that is manufactured is used in the stone-cutting trade, particularly by the marble and granite cutters; and it has a field that is not entered by corundum, and to but a limited extent by emery. The crushed steel is used in sawing, grinding, rubbing, and polishing stone of every kind. It is also used to some extent by brick manufacturers for grinding the finer qualities of brick that are used for arch purposes. Thus, the production of crushed steel is apt to fluctuate with the condition of the building trades. The fine grades of crushed steel, known as steel emery and rouge, are used in considerable quantities by lens workers, glass bevelers, and other glass grinders. The Crushed Steel Company is manufacturing another product, known as "steelite," which is meeting with some success in railroad and other machine shops for use in throttle and other valve grinding.

*Production.*—The production of crushed steel by the Pittsburgh Crushed Steel Company in 1901 amounted to 690,000 pounds, being 10,000 less than the production of 1900. Crushed steel is now being

quoted on the market at  $5\frac{1}{2}$  cents per pound f. o. b. Pittsburg. In the following table is given the production of crushed steel for the last four years:

*Production of crushed steel in the United States from 1898 to 1901, inclusive.*

Year.	Amount.	Year.	Amount.
	<i>Pounds.</i>		<i>Pounds.</i>
1898 .....	660,000	1900.....	700,000
1899 .....	675,000	1901.....	690,000

#### ARTIFICIAL CORUNDUM.

A new industry that has recently been started is the manufacture of artificial corundum. The method of manufacture of this product is a secret process, but it can be stated in general as consisting in the conversion of the mineral bauxite (a hydrous aluminum oxide) into corundum by means of very great heat and pressure in an electrical furnace. Experiments have been conducted for some time along this line, but it was only within the last two years that these experiments reached such a point that they could be considered as favorable commercially.

The idea that bauxite is changed into corundum by heat and pressure is not new, for in 1861 Prof. T. Sterry Hunt, of the geological survey of Canada, in an article on "The origin of some magnesian and aluminous rocks," described the occurrence of bauxite at Baux, in the south of France, and stated that "by an intense heat this substance is converted into crystalline corundum resembling emery in its physical character." In a recent article on the "Occurrence of corundum in quartz-schist in North Carolina,"<sup>a</sup> the schists are considered the result of metamorphism of sandstones and shales formed from alluvial deposits many thousand feet in thickness; and these shales, which were rich in alumina, probably in the form of bauxite, had their excess of alumina crystallized out as corundum during their metamorphism. This view is strengthened by the artificial production of corundum from bauxite by means of high heat and pressure.

The Norton Emery Wheel Company has erected a plant at Niagara Falls for the manufacture of artificial corundum, and already two or three carloads of the material have been manufactured and shipped to the company's factory, where it has been made into wheels, etc. It is reported that they give very good satisfaction. Although all of the experiments made with artificial corundum have not been satisfactory, this has been true of all artificial products in the first stages of their manufacture; and the results obtained from carload lots of material

<sup>a</sup> Am. Jour. Sci., Vol. X, 1900 p. 297.

that were sent to the factory would seem to indicate that the manufacture of a uniform product of this material is assured. The manufacture of artificial corundum is primarily for the use of the Norton Emery Wheel Company; but it will also very probably be manufactured for the general corundum market. The crude material, as it comes from the furnace, is often in rather large masses, which are shipped to Worcester, where it is crushed into grains and graded.

What effect the manufacture of this artificial corundum will have on the production of corundum, and also on the manufacture of carborundum, can not yet be told; but if it proves equal to them in abrasive efficiency it will be a competitor of both, provided its cost of production be sufficiently low for it to be sold at a price corresponding to that of the others.