COSTS, PROFITS, LOSSES AND ASSESSMENTS, MICHIGAN IRON MINES.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.	1917. Per ton.
"Beyond the Mine" Cost.—*Con.*							
16. Total cost of delivery	a	$2.59303	$2.88015	$2.77818	$2.44743	$2.53415	.....
	b	2.51156	2.75963	2.68238	2.41592	2.50403	.....
17. Royalties	a	.22255	.25390	.26407	.23872	.27134	.....
	b	.21800	.23582	.25783	.23136	.26648	.....
18. Total cost of delivery to operator	a	2.81558	3.13405	3.04225	2.68615	2.80549	.....
	b	2.72956	2.99545	2.94021	2.64728	2.77051	.....
Profit and Loss.							
19. Receipts from sale of ore		2.92708	3.41137	2.92249	2.79402	3.36144	.....
20. Profit or loss to operator	a	.11150	.27732	.11976	.10787	.55595	.....
	b	.19750	.41592	.01772	.14674	.59093	.....
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.44374	.64210	.27001	.49665	.95298	.....
	b	.52309	.75989	.36020	.52380	.98185	.....
22. Assessed valuation per ton by Board of State Tax Commissioners		.....	.43561	.45237	.43546	.42923	$0.43439

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

PART II. NON-METALLIC MINERALS.

R. A. SMITH.

PORTLAND CEMENT INDUSTRY.

R. A. SMITH.

PORTLAND CEMENT INDUSTRY.

CLASSIFICATION OF CEMENTS.

The chief cementing materials* used in modern structural work may be classified as follows:

Nonhydraulic cements	Plaster of Paris, cement plaster, Keene's cement, etc. Common lime
Hydraulic cements	Hydraulic lime Natural cements Portland cement Puzzolan cement

For a discussion of the non-hydraulic cements the reader is referred to publications 8, 19, and 21, respectively the Mineral Resources of Michigan for 1911, 1914, and 1915.

HYDRAULIC CEMENTS.

Hydraulic cements have the property of setting under water. This property is due to the formation, during the process of burning, of compounds of lime, silica, alumina, and iron oxide, and varies greatly in the different cements. The last three given above are of chief commercial importance.

Hydraulic limes.† Limes burned at a comparatively low temperature from limestone containing 5 to 10 per cent of sand and clayey material are termed hydraulic limes. Hydraulic limes contain considerable free lime in addition to the silicates, aluminates and ferrites formed in burning, thus they will slake, though slowly, in the condition that they come from the kiln, and possess hydraulic properties. If the sandy and clayey material is much in excess of 10 percent, the resulting lime fails to slake without first being finely ground and is a true hydraulic cement.

No hydraulic limes are produced in Michigan although some strata in the Traverse formation in the northern part of the Southern Peninsula and in the Trenton limestone in the Northern Peninsula apparently have the proper composition.

Natural Cements. Natural cements are made by burning at a

*Bull, 522, U. S. Geol. Surv., 1912, Eckel, Portland Cement Materials and Industry of the United States.

†S. V. Peppel. The Uses of Limestone in Ohio, Bull. 4, p. 252, Ohio Geol. Surv. 1906.

comparatively low temperature (slightly above that for lime burning) an impure limestone containing over 10 per cent of siliceous and argillaceous matter and then grinding the product to a powder. Natural cements will not slake in the condition in which they come from the kiln but, after grinding finely, and adding water, they will set rapidly, either in air or under water. Most of the limestone from which natural cements are made in the United States contains from 13 to 35 per cent of clayey material of which 10 to 22 per cent is silica. Natural cements are usually yellow or brown in color. They are lower in specific gravity and set more rapidly than Portland cement but develop less tensile strength.

Natural cement is not made in Michigan, but certain limestones in the Traverse formation in the northern part of the Southern Peninsula appear to have the necessary composition for, and possibly some of the less magnesian portions of the Trenton limestone in the Northern Peninsula may be found satisfactory for the manufacture of natural cement.

Portland Cement. Portland cement is made by burning to incipient fusion an intimate mixture of finely pulverized and properly proportioned argillaceous and calcareous materials with the addition of such other substances, not exceeding 3 per cent, as may be necessary to control certain properties, and then grinding the resulting semi-fused mass or "clinker" to a fine powder. The mixture is usually made by mixing marl or limestone and clay or shale in such porportions that it will contain about three parts of lime to one of clayey materials. Unlike natural cement, Portland cement is made from carefully proportioned mixtures and is burned at a high temperature, approaching 3,000° F., in kilns of special design and lining. The composition* of actual mixtures ready for burning is given in the analyses below:

	1	2	3	4
	Per cent.	Per cent.	Per cent.	Per cent.
Silica ($Si O_2$)	12.85	12.92	13.52	14.94
Alumina (Al_2O_3)	4.92	4.83	6.56	2.66
Iron Oxide (Fe_2O_3)	1.21	1.77	.....	1.10
Calcium Carbonate	76.36	75.53	75.13	75.59
Magnesium Carbonate	2.13	4.34	4.32	4.64
Total	97.47	99.39	99.53	98.93

In burning, the lime combines with the silica, alumina, and iron oxide, forming a semi-fused mass ("clinker") of silicates, aluminates and ferrites, in fairly definite proportions. The clinker is

*Min. Res. 1907, Pt. II, p. 483, U. S. Geol. Surv.

ground to a powder which is Portland cement. This is of a gray color, will set under water, is heavier than natural cements, and will develop a higher tensile strength.

Formerly 4 per cent of magnesia was considered the maximum permissible in the finished product but recent investigations by the U. S. Bureau of Standards* indicate that cements containing magnesia up to 7.5 per cent, when properly made, are satisfactory.

Puzzolan Cement. Puzzolan cement is a finely ground mechanical mixture of silliceous and aluminous materials, such as blast furnace slag or volcanic ash, and slaked lime. The mixture is not burned at any stage. When finely ground, the powder will set under water. Puzzolan cements are generally of light bluish color and of less specific gravity and tensile strength than Portland cement.

They are more adapted for use under water than in air. No Puzzolan cements are made in Michigan, though some of the blast furnaces can easily obtain abundant supplies of suitable limestone.

HISTORY† OF CEMENTS.

Ancient Cements. There seems to be no evidence that the Egyptian, Greek, or Roman builders used cements of the Portland type. The earliest known cementing materials were common limes and plasters, similar to those used today. The Romans discovered that puzzuolana, a volcanic ash found abundantly near Naples, when powdered and mixed with black lime, has hydraulic properties similar to modern hydraulic cements. Indeed, the name Puzzolan cement has been derived from this ancient cement material. The modern Puzzolan cement, however, is made chiefly from blast furnace slag. The Romans used Puzzolan cements in many of the early structures. In the Middle Ages, the use of these primitive cements seems to have been forgotten and common lime mortar was the only binding material used even in the largest buildings and structures.

Natural Cements. Lime mortar was practically the only cementing material used until near the end of the eighteenth century when Smeaton, an English engineer, discovered that the hydraulic properties of limes were due not to their purity but to their clayey impurities. In 1796, Parker, another Englishman, invented a new cement much like our modern natural cements, which he named "Roman" cement, though it was entirely different from any cement known to the Romans. Parker discovered that, when certain concretions of clay and limy matter, which were abundant in some of

*Min. Res. U. S., 1914, Part II, pp. 245-246.
†E. C. Eckel, Bull. 522, p. 18, U. S. Geol. Surv. 1913.

the coastal formations in England, were burned at a temperature slightly higher than that used in burning ordinary lime, the product would not slake in water but when powdered and mixed into a paste with water would harden not only in air but also under water. A similar cement was invented in France almost at the same time. These fore-runners of the modern natural cements soon came into general use in England and France and other parts of Europe.

During the construction of the middle division of the Erie Canal in New York, it was found that lime burned from a certain limestone in the town of Sullivan, Madison County, refused to slake. Canvass White, an associate engineer under Benjamin Wright, engineer in charge, examined and tested both the stone and the lime and decided that the stone was natural cement rock. Further tests proved the correctness of his conclusion and the first American natural cement was used extensively in the construction of the locks and walls of the middle division of the canal.

According to an analysis made in 1822 by Seybert, of a sample of the stone used, the total impurities was about 15.5 per cent and indicates that the calcined product was more a hydraulic lime than a natural cement.

The extensive use of the cement on the canal led to further search for other deposits of cement rock. Wright in a letter dated in 1820, stated that this "is found in great abundance in the counties of Madison, Onondaga, and Cayuga," thus outlining what later became the natural cement district of central New York. In the same letter he also makes the statement: "I do not know that it is found in the counties west of Cayuga, but I presume from the geological character of that country it may be found in all the country west to Niagara and propably farther west." His conclusion proved correct for within a few years cement rock was found in Erie county, the most western part of the state.

Within a few years of White's discovery, the natural cement industry had begun at a number of places in New York. The industry grew rapidly in the United States and furnished the cementing material for most of the engineering works up to the close of the nineteenth century. The industry was developed in sixteen different states, but, it never obtained a foothold in Michigan, though the state has an abundance of rock apparently suitable for the manufacture of natural cement.

Portland Cement. In 1824, Joseph Aspdin of Leeds, England, patented a process for making a cement which he called Portland cement, from a fancied resemblance to a well known English building stone—the öolitic limestone of Portland. The specifications for his patent, though vague as to the precise proportions of the raw materials and the temperature at which the mixture was to be burned, gives clearly the general method of manufacturing Portland cement by a wet mixing and grinding process. The proper proportions of the mixture and the temperature of burning were evidently known to Aspdin but were carelessly or purposely withheld from the specifications. His method tacitly specified that a pure limestone was to be burned to lime and the lime mixed with a definite quantity of clay. The mixture was to be pulverized in a wet state, dried, crushed, and then calcined in a vertical kiln. The final step was to pulverize the product to a powder which was the material Aspdin termed "Portland" cement.

Aspdin's was the chief process in use until 1875 when it was superseded by cheaper and simpler processes.

For some years the industry grew slowly in England and also on the Continent, due chiefly to the strong adherence to the use of natural cements and the necessarily higher price of Portland cement. Soon after 1850 the growth of the industry was much more rapid and Portland cement began to displace the older natural cements and gradually it became an important import into the United States.

The Portland cement industry in America, however, did not really begin until about the early seventies of the last century, when experimental manufacturing was independently begun almost simultaneously in New York, eastern and western Pennsylvania, Michigan and Maine. Apparently the first attempt in the United States to manufacture Portland cement was made at Kalamazoo, Michigan in 1872. The raw materials were marl and clay which were burned in a vertical kiln and the clinker ground by millstones. The venture was a financial failure on account of the high cost of production and the plant was abandoned in 1882.

In 1874, true Portland cement was being manufactured in western Pennsylvania from limestone and clay. There were other experimental attempts about the same time in the Hudson river district but none of these led to any development of the industry.

The foundations of the industry, however, began in the early seventies in the Lehigh region of Pennsylvania as a by-product of the natural cement industry. The experiment of selecting stone from the natural cement rock quarries, which had the proper composition for making Portland cement was begun by D. O. Saylor and his associates and resulted in the production of a small though variable tonnage of good Portland cement. Within 10 or 15 years small plants were erected in several other localities, but the indus-

try failed to grow in the face of competition from Portland cement imported from England.

As would be expected, the American manufacturers followed closely the English methods of grinding the raw materials wet, mixing them to a paste with water, and after partially drying, forming the mixture into bricks or balls, and charging them, often by hand, into a vertical kiln for burning. After burning, the kilns were unloaded by hand and the clinker ground by millstones, a most laborious and expensive process. In England, labor was very cheap and fuel expensive; in America, labor expensive and fuel cheap. To adjust the industry to the conditions in this country, the American cement manufacturers overcame the excessive labor costs by introducing the rotary kiln and modern grinding machinery. These changes, especially the first, revolutionized the industry and gave to it an impetus which has made possible its present great development.

The Rotary Kiln. The Ransome patents taken out in 1885 in Great Britain and in 1886 in the United States are the bases from which the modern rotary kilns have been directly developed. The modern rotary kiln consists essentially of a slightly inclined steel cylinder lined with fire brick and arranged to rotate. As the kiln rotates the raw mixture is fed into the upper end and travels slowly by gravity to the lower end where it falls out as burned clinker. The fuel,—gas, petroleum, or powdered coal,—is blown in at the lower end, the flame traversing the length of the kiln.

At South Rondout, New York, it was discovered that mixed and ground materials could be charged into the kilns without wetting, thus eliminating a step from the older process. The discovery that naturally wet materials,—marl and clay, could be successfully charged into the kilns without preliminary drying was made in 1891 at Montezuma, New York. Thus originated the two principal methods now in use, the dry process used with limestone or cement rock, and the wet process, with marl. The dry process is the most economical and is almost universally used except in Michigan where most of the early plants and more than half of the present plants are using marl and so the wet process.

The Ransome kiln was designed to use producer gas but petroleum was the fuel used in the first kiln successfully operated in the United States and was the principal fuel used for a number of years. In 1895, powdered coal was substituted for petroleum and was a very important step in the development of manufacturing practice. This is now the standard fuel used in this country, except in the regions where natural gas and petroleum abound. Powdered coal is used in all of the Michigan plants.

The next most important development in the rotary kiln was its increase in size, particularly in length. By 1903, the rotary kiln had been standardized to a length of 60 feet and, with dry materials, had a rated capacity of 200 barrels of cement per day. About this time the Edison plant demonstrated that a nominal lengthening of the kiln greatly increased its capacity and a rapid lengthening began about 1905 until most of the kilns installed now are between 100 and 150 feet in length and there are in use a considerable number over 150 feet, and a few from 225 to 250 feet in length. At present no standardization of the kiln is in sight. Some of the larger kilns now in use have a capacity of over 800 barrels per day.

The success of the rotary kiln is attested by the fact that foreign Portland cement makers with cheap labor and high fuel costs have not been able to compete in American markets with the American manufacturers with cheap fuel and high labor costs.

Development in Michigan. As stated in a previous paragraph, the first attempt to manufacture Portland cement in the United States was made in 1872 at Kalamazoo, marl and surface clay being the raw materials used. The attempt was given up a number of years later on account of the excessively high cost of production.

No further attempt* was made to manufacture cement in Michigan until the Peerless Portland Cement Company was organized at Union City, Branch county, August 23, 1896. The first kilns were vertical but these were replaced by modern rotary kilns in 1902. This company is still in operation but a new plant with 84-foot rotary kilns was built in 1911 to replace the old one destroyed by fire. In 1897, the Bronson Portland Cement Company built a plant at Bronson, Branch county, and a year later, the Coldwater Portland Cement Company now the Wolverine Portland Cement Company was organized, plants being built first at Coldwater and later at Quincy. All of these plants used marl and clay or shale.

The "boom" years of the Portland cement industry in Michigan were between 1899 and 1901, twenty companies being organized in this period for the manufacture of cement from marl. Some companies made very elaborate plans but never reached beyond that stage. Only ten reached the productive stage and but five of these are now in operation. Since 1896, thirty-five different Portland cement plants have been projected or built in Michigan. Twelve are now in operation and one building.

The following is an annotated† list of all the Portland cement plants built or projected in Michigan:

*C. W. Cook, Pub. 8, Geol. Ser. 6, Mineral Resources of Michigan for 1911, p. 338.
†C. W. Cook, Cement, pp. 347-350, Pub. 8, Geol. Ser. 6, Mineral Resources of Michigan for 1911, Mich. Geol. & Biol. Surv.

TABLE I.

Name.	Location.	Capital stock and bonds.	Process.	Raw materials.
Aetna Portland Cement Co.	Fenton		Wet	Marl and clay
Alpena Portland Cement Co.	Alpena	$500,000	Dry	Limestone and clay
Bellaire Portland Cement Co.	Bellaire			
Burt Portland Cement Co.	Bellevue	Not Inc.	Dry	Limestone and shale.
Bronson Portland Cement Co.	Bronson	500,000	Wet	Marl and shale
Chamite Cement and Clay Product Co.	Bronson		Wet	Marl and Shale
Clare Portland Cement Co.	Grant to Clare Co.	1,000,000	Wet	Marl and shale
Coldwater Portland C. Co.	Coldwater	300,000	Wet	Marl and shale
Detroit Portland Cement Co.	Fenton	1,000,000	Wet	Marl and clay
Eagle Portland Cement Co.	Kalamazoo		Vertical kilns	Marl and clay
Egyptian Portland C. Co.	Fenton	1,650,000	Wet	Marl and clay
Elk Portland Cement Co.	Elk Rapids	500,000	Originally wet	Originally marl and shale; later limestone.
Elk Cement and Lime Co.	Elk Rapids	750,000	Dry	Limestone and shale.
El Cajon Portland C. Co.	Alpena			
Farwell Portland Cement Co.	Farwell	525,000		
German Portland Cement Co	White Pigeon	300,000	Wet	Marl and clay
Gt. Lake Portland C. Co.	Charlevoix			
Gt. Northern Portland C. Co.	Marlborough	5,000,000	Wet	Marl and clay
Hecla Cement and Coal Co.	Bay City	5,000,000	Wet	Marl and clay
Hecla Portland Cement Co.	Bay City		Dry	Limestone and clay
Hecla (The) Co.	Bay City		Dry	Limestone and clay
Huron Portland Cement Co.	Alpena	2,000,000	Dry	Limestone and shale.
Logan Portland Cement Co.	Fenton		Wet	Marl and clay
Lupton Portland Cement Co.	Lupton	1,250,000	Wet	Marl and clay
Millen Portland Cement Co.	Chelsea		Vertical kilns.	Marl and clay
Michigan Portland C. Co.	Gray Village	500,000	Wet	Marl and clay
Michigan Portland C. Co.	Coldwater	2,500,000		
Michigan Alkali Co.	Wyandotte			Caustic soda and refuse and shale
New Aetna Portland C. Co.	Fenton		Wet	Marl and clay
New Bronson Portland C. Co.	Bronson	110,000	Wet	Marl and shale
New Egyptian Portland C. Co.	Fenton		Wet	Marl and clay
Newaygo Portland C. Co.	Newaygo	500,000	Wet	Limestone and shale.
Omega Portland Cement Co.	Mosherville	320,000	Wet	Marl and clay
Peerless Portland Cement Co.	Union City	1,200,000	Wet	Marl and shale
Peninsular Portland C. C.	Cement City	1,293,000	Wet	Marl and clay
Petoskey Portland C. Co.	Petoskey	1,500,000	Dry	Limestone and shale.
Pyramid Portland C. Co.	Spring Arbor	525,000	Wet	Marl and clay
Standard Portland C. Co.	Lakeland	1,000,000	Wet	Marl and clay
Standiford Portland C. Co.	Athens		Wet	Marl and clay
Three Rivers Portland C. Co.	Three Rivers	20,000	Wet	Marl and clay
Toledo Portland Cement Co.	Manchester			
Twentieth Century P. C. Co.	Fenton	750,000	Wet	Marl and clay
Wayne Portland Cement Co.	Brighton	800,000	Wet	Marl and clay
Watervale Portland C. Co.	Lima	1,000,000	Wet	Marl and clay
West German Portland C. Co.	Chelsea	1,000,000	Wet	Marl and clay
White Portland Cement Co.			Vertical kilns	Marl and clay
Wolverine Portland C. Co.	Coldwater	1,000,000	Wet	Marl and shale
Wolverine Portland C. Co.	Quincy			Marl and shale
Wyandotte Portland C. Co.	Wyandotte	1,000	Wet and dry	Limestone and clay
Zenith Portland Cement Co.	Grass Lake	1,000,000	Wet	Marl and clay

TABLE I.—*Continued.*

Fuel.	No. of kilns.	Size.	Rated capacity.	Employees.	Remarks.
Coal	8	6′ x 60′	1,000		Successor to Detroit P. C. Co. See new Aetna Portland Cement Co.
Coal	6		1,000		Has not operated in two years.
					Plant never built.
Coal	8	6½′ x 60′	2,000		Began producing September, 1905.
Coal	10		1,000		See Chamite and Clay Products Co.
Coal	10		1,000		Successor to the Bronson Portland Cement Co. See New Bronson P. C. Co.
					Plant never built.
Coal					See Michigan Portland Cement Co.
Coal	8		1,000		See Aetna Portland Cement Co.
Coke	4		100		Suspended operations about 1882.
Coal	9		1,200		Plants ordered sold by the courts. No operations for two years.
					See Elk Cement and Lime Co.
Coal	5		1,000		Successor to Elk Rapids Portland Cement Co. Receivers appointed Jan. 4, 1911.
					Plant never completed.
					Plant never completed.
					Never progressed beyond the newspaper stage.
Coal					Plant dismantled.
Coal					See Hecla Portland Cement Co.
Coal					Successor to Hecla Cement and Coal Co. See Hecla (The) Co.
Coal	6				Successor to Hecla P. C. Co. In hands of receivers. Future operations doubtful.
Coal	7	8′ x 110′	5,000		
Coal					Successor to Twentieth Century Portland Cement Co. Plant never built.
Coal					Plant never built.
Coke					Successor to the White P. C. Co. See Michigan Portland Cement Co., Gray Village.
Coal	3	8′ x 125′	1,200		Successor to Millen Portland Cement Co. Began operations July 13, 1911.
					Successor to the Coldwater Portland Cement Co. See Wolverine Portland Cement Co.
					See Wyandotte Portland Cement Co.
Coal	8	6′ x 60′	1,100		Successor to the Aetna Portland Cement Co.
Coal	10		1,000		Successor to the Chamite Cement & Clay Prod. Co. New company has never operated.
Coal	9	5′ x 80′	1,300		Successor to Egyptian P. C. Co. in 1914.
Coal	8	6′ x 90′ / 9′ x 180′	2,250		New company incorporated June 16, 1911. Old capital stock and bonds, $3,000,000.
Coal	5		500		
Coal	9	6½′ x 84′	1,800		Originally a vertical kiln plant.
Coal	3	9′ x 205′	1,800		
Coal			2,000		Plant projected.
Coal					Plant never built. Marl lands now owned and operated by Peerless Portland Cement Co.
Coal					Plant never built.
Coal					Plant never built.
Coal					Plant never built.
Coal					Plant never completed.
Coal					Plant never built. See Logan Portland C. Co.
Coal					Plant never built.
Coal					Plant never built.
					Plant never built.
Coke					See Millen Portland Cement Co.
Coal	3	8½′ x 225′	1,500		Successor to Michigan Portland Cement Co., Coldwater.
Coal	7	6′ x 120′	1,600		
Coal	3	7′ x 100′	1,000		Successor to Michigan Alkali Co.
Coal					Plant never built.

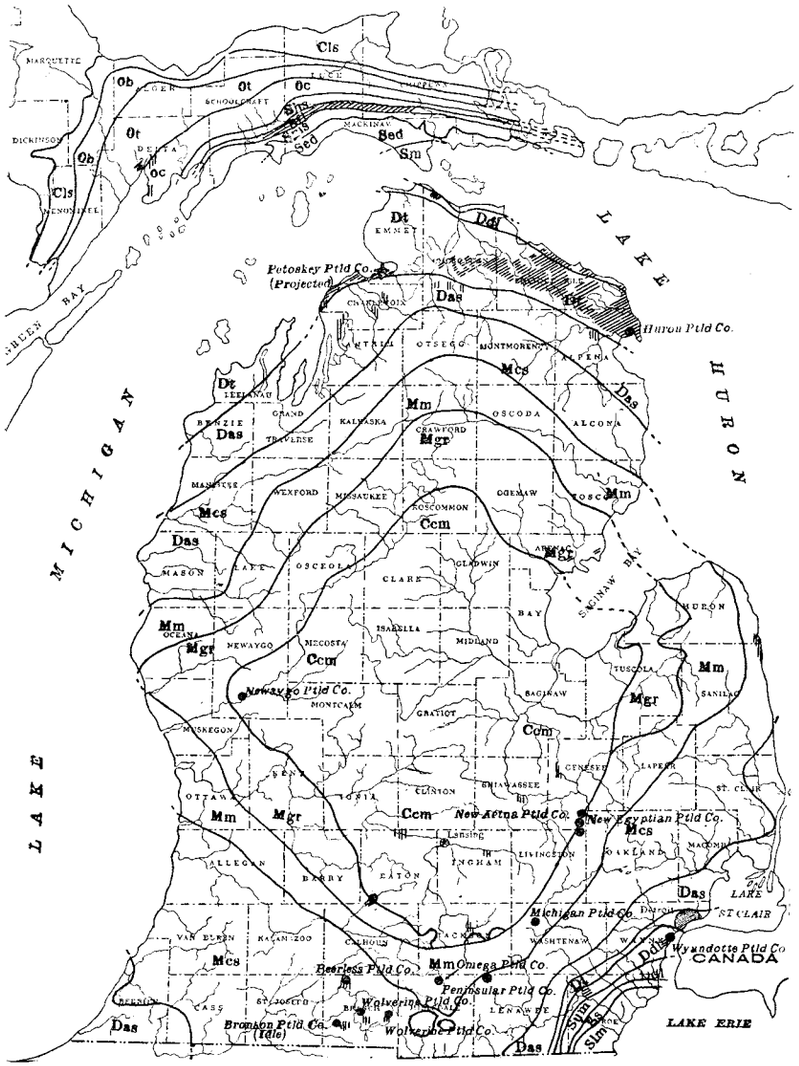

Figure 4. Geological map showing location of Portland cement plants and principle areas in which occur deposits of limestone and shale suitable for use in making Portland cement.

Legend: Cambrian.—Cis = Lake Superior sandstone; Ordovician.—Ob = Beekmantown or "Calciferous" sandstone, Ot. = "Trenton" limestone, Oc = Cincinnati shales; Silurian.—Shs = Hendricks series. Sfi = Fiborn limestone, Sms = Manistique series, Sed = Engadine dolomite, Sm = Monroe formation, Sum = Upper Monroe dolomites, Ss = Sylvania sandstone, Slm = Lower Monroe dolomites; Devonian.—Das = Antrim shale, Dt = Traverse formation, Dll = Dundee limestone; Mississippian,—Mcs = Coldwater shale, Mgr = Grand Rapids group; Upper Carboniferous,—Ccm = Coal measures.

Improvements in Grinding. In the early days of the industry, the cracker and millstones formed the chief grinding machinery but these have been replaced by larger and more efficient reducers—the gyratory crusher, which is used almost exclusively for the first stages in reduction, and the ball and tube mills for the fine stages of grinding, though there appears to be a tendency to return to some of the modified earlier types, such as the Griffin and the Huntington mills.

RAW MATERIALS.

According to Eckel*, Portland cement is an artificial product of relatively definite composition, containing approximately 60 to 65 per cent of lime, 20 to 25 per cent of silica, and 5 to 12 per cent of iron oxide and alumina.

Three general stages in manufacture are necessary in forming this product, viz., (1) intimate mixing of raw materials of proper physical and chemical composition and in the proper proportion; (2) burning of the raw mixture at a high temperature (about 3,000° F.) until it forms a semi-fused mass or clinker; and (3) grinding of the clinker to a fine powder, which is the Portland cement of commerce.

There are three general classes of raw materials required in making Portland cement, viz., (1) cement materials proper—limestone, cement rock, marl, shells, clay, shale, etc., used in making the raw cement mixture; (2) fuels—coal, oil, or gas, used for burning the mixture and furnishing power; and (3) fluxes and retarders—gypsum, lime chloride, alkalies, fluorite, etc., added at different stages of manufacture to secure certain properties in the finished cement.

The ordinary raw cement mixture, when normal natural raw materials are used, usually contains about 75 per cent of calcium carbonate, ($CaCO_3$) 20 per cent of silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3), and 5 per cent of magnesium carbonate, alkalies, sulphur, and other unnecessary substances.

Formerly 4 per cent was considered the limit of magnesia in the finished cement but recent investigations by the U. S. Bureau of Standards†, show that the magnesia may be 7.5 per cent or even more, if the cement is properly made.

*Bull. 522. 1913. Portland Cement Materials of the United States, p. 40.
†Min. Res. U. S., 1914, Part II, Cement, pp. 245-246.

Raw Materials Used.

Theoretically almost any combination of calcareous and siliceous argillaceous materials, which will give a composition within certain prescribed limits can be used in making Portland cement but in actual practice only those materials which naturally, or with a minimum amount of labor give the proper mixture and are abundant and easily accessible, are used. In most plants, limestone, chalk, and marl furnish the calcium carbonate; and clay and shale or slate, the silica and alumina. At some plants the lime material is the chemically precipitated calcium carbonate waste from alkali works, and at others the silica and alumina are in the form of blast furnace slag. The chief combinations of materials now used in the United States are (1) argillaceous limestone (cement rock) and high calcium limestone, (2) hard high calcium limestone and clay or shale, (3) marl and clay or shale, and (4) slag and high calcium limestone. The first two are much the more important, although the last is rapidly increasing in importance.

Since the limestone resources of Michigan are largely in the northern part of the state, and marl deposits are abundant in many localities, nearly all of the early cement companies in Michigan planned to use marl and clay or shale and, at the present time, eight of the twelve operating plants are using these materials and produce most of the marl and clay or shale cement made in the United States. The fuel costs are higher and the kiln capacity is lower when marl is used and this has caused one of the companies to use limestone. Were suitable limestone deposits available in the southern part of the state, doubtless other marl using companies would use limestone.

Marl.

The term marl is sometimes used in a loose sense to mean an indefinite mixture of clay and calcium carbonate, but from the standpoint of the cement manufacturer it refers to the nearly pure deposits of finely divided calcium carbonate found in the bottom of lakes, or beneath marshes, formerly the sites of fresh water lakes. Marl deposits are due largely to the work of organic agencies, both vegetable and animal, but the former is by far the most important. Certain algae, notably *chara fragilis,* common in many of the lakes of Michigan, are active agents in precipitating calcium carbonate from the water. Mollusca, generally of very small size thrive in the carbonated waters of marl lakes and shells of these organisms locally form from 5 to 10 per cent or more of marl deposits. All

of the marl deposits in Michigan are of recent origin and in many of the lakes the process of marl formation is still going on.

There are two chief varieties of marl in the state, the white and the gray, but no sharp line can be drawn between them. The gray color is due in some places to an admixture of organic matter not found in the white variety. When wet, marl resembles a white or gray mud, but when dry, due to more or less cementation, it becomes a loosely aggregated friable mass. Marl generally contains considerable organic matter, sand, and clay. Magnesian carbonate is another impurity and this, though present generally in small amounts, usually from ½ to 3 per cent, may exceed 5 per cent or more. The various impurities in many marl deposits makes them unsuitable for use in making cement.

More than one hundred marl deposits (see Fig. 5), each above 50 acres in extent, and with an average depth of at least 10 feet, have been discovered in the Southern Peninsula of Michigan and probably this is less than one-fourth of the total number in the Peninsula. Some of the deposits are very large, the areas varying from 500 to over 1,000 acres the marl having an average depth of 20 feet or more. Numerous marl deposits are also known to exist in the Northern Peninsula. Twenty-two counties in the state contain deposits of marl with as estimated total area of 27,000 acres.

Owing to injurious impurities, unfavorable operating conditions, lack of transportation facilities, and distance from markets, suitable clays and shales, and cheap fuel supplies, many of the deposits cannot be developed for the manufacture of cement under present conditions. It will be many years, however, before the easily accessible high grade marl reserves are exhausted.

The composition of various marls now or formerly utilized for cement is given in the following tables:

*ANALYSES OF MICHIGAN MARLS, NOW OR

Locality.	Analyst.	SiO_2	Al_2O_3		Fe_2O_3	CaCO
Bronson Branch Co.	W. H. Simmons	1.75	.....	1.57	.....	*49.24*
Coldwater, Branch Co.	E. D. Campbell	0.52	0.51	.....	0.53	51.66
Fenton, Genesee Co.	**C. W. Cook	1.13	.....	0.44	.....	.....
Mud Lake, Genesee Co.	E. D. Campbell	0.48	0.17	.....	0.51	52.28
Four Mile Lake, Washtenaw Co.	E. D. Campbell	6.66	3.17	.....	1.36	*47.09*
Cobbs Lake, Hillsdale Co.	E. D. Campbell	0.20	0.50	.....	0.60	50.12
Union City Branch Co.	A. Lundteigen	1.95	.....	1.10	.....	52.25
Goose Lake, Lenawee Co.	J. G. Dean	0.22	.....	0.76	.....	51.56
Spring Arbor, Jackson Co.	Delos Fall	0.58	0.76	.....	.....	.....
Great Marl Lake, Newaygo Co.	Not given	1.24	.....	0.80	.....	.....

ANALYSES OF MARL DEPOSITS,

Lccality.	Analyst.	SiO_2	Al_2O_3	Fe_2O_3		CaCO
Grayling Lake Crawford Co.	R. C. Kedzie	1.90	0.14	.....	0.10	45.16
Lupton, Ogemaw Co.	Lathbury & Spackman	0.24	.....	0.08	.....	52.97
Mills' Lake, Ogemaw Co.	Lathbury & Spackman	0.70	.....	0.46	.....	50.43
Pleasant Lake, St. Joseph Co.	Lathbury & Spackman	0.84	.....	0.28	.....	51.28
Runyan Lake Livingston Co.	E. D. Campbell	0.28	0.65	.....	0.67	52.66
Wetzel Lake, Antrim Co.	E. D. Campbell	1.44	0.28	.....	0.16	51.93
White Pigeon, St. Joseph Co.	H. A. Huston	0.37	.....	0.56	.....	51.00
Zukey Lake	E. D. Campbell	0.96	.....	.....	0.62	*52.60*

*I. C. Russell, Portland Cement Industry in Michigan, 22d Ann. Rept. Pt. III, p. 650-651 U. S. G. S.
**Min. Res. Mich. for 1911, p. 341.
Figures in italics computed from analyses as reported.

FORMERLY UTILIZED FOR CEMENT MANUFACTURE.

$CaCO_3$	MgO	$MgCO_3$	SO_3	Loss on ignition.	Organic matter.	Remarks.
87.92	*0.44*	0.92	0.15	.....	7.50	New Bronson Portland C. Co., Bronson.
92.25	1.37	*2.87*	0.89	.....	.....	Wolverine Portland C. Co., Coldwater.
91.29	.....	4.58	Trace	.....	1.90	Egyptian Portland Cement Co., Fenton.
93.25	1.85	*3.88*	0.55	45.72	.....	New Aetna Portland Cement Co., Fenton.
84.09	*1.77*	3.72	1.25	.....	.....	Michigan Portland C. Co., Gray Village.
89.50	0.83	*1.74*	0.58	45.86	.....	Omega Portland Cement Co., Mosherville.
93.32	.....	.....	.....	42.40	.....	Peerless Portland Cement Co., Union Cy. Marl formerly used, but now exhausted.
92.07	1.26	2.63	.....	46.20	.....	Peninsular Portland C. Co., Cement City.
94.75	0.99	.....	0.63	.....	.....	Average analysis of 25 borings at Spring Arbor, Jackson Co., Marl now utilized by Peerless Portland Cement Co. at Union City.
90.90	.....	2.97	.....	.....	4.07	Marl formerly used by Newaygo P. C. Co., Newaygo. Company now uses limestone and shale, the first shipped in from Petoskey and the second from Sec. 26, T. 32 N. R. 8 W.

PROSPECTED, BUT NOT UTILIZED.

$CaCO_3$	MgO	$MgCO_3$	SO_3	Loss on ignition. CO_2	Organic matter.	Remarks.
79.86	0.32	*0.67*	0.56	43.10	5.69	Also K_2O=0.37; Na_2O=2.65; P_2O_5=0.01 Mich. Agr. Expt. Sta. Bull. 99, 1893.
94.58	1.13	*2.37*	0.08	45.49	.....	Prospectus of Lupton Portland C. Co.
90.07	1.26	*2.65*	.....	47.08	.....	Hecla Portland Cement and Coal Co.
91.57	1.77	.....	.....	45.60	.....	Three Rivers Portland Cement Co.
94.00	1.75	*3.67*	0.38	42.44	.....	Near Fenton.
92.75	1.15	*2.41*	0.034	44.25	.....	
91.09	1.02	*2.14*	.....	40.68	4.61	Prospectus German Portland Cement Co.
93.92	1.79	*2.76*	0.58	.....	.....	Standard Portland Cement Co.

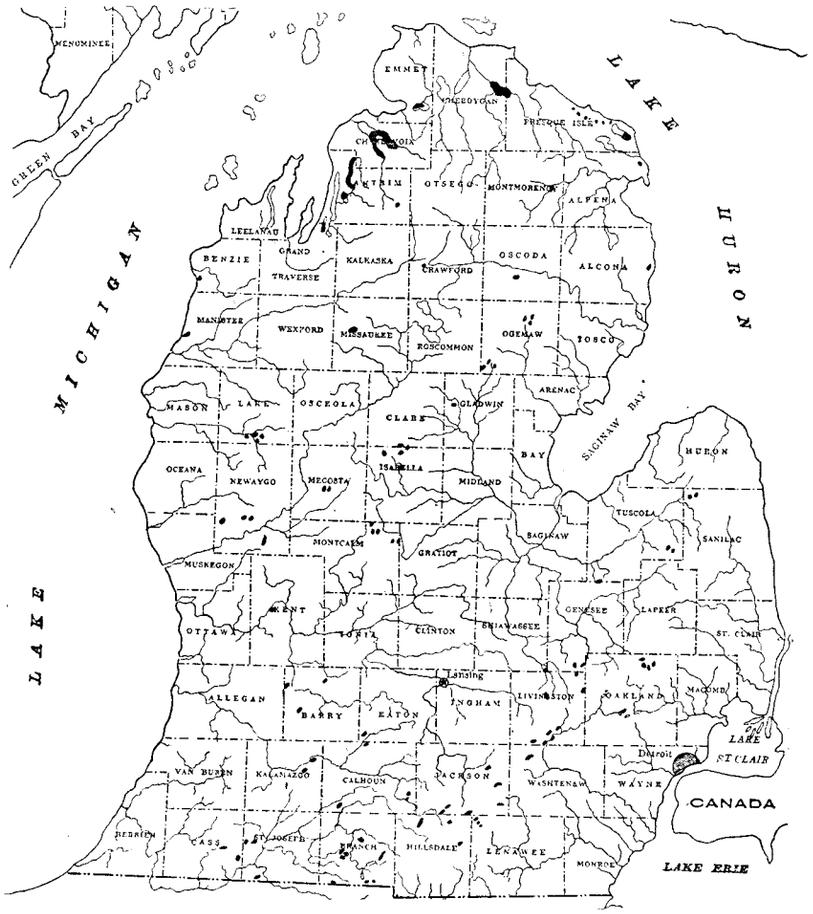

Figure 5. Map of known marl deposits in the Southern Peninsula of Michigan. The number shown is probably less than one-fourth of the total number. Adapted from Plate XLV, Cement Industry in Michigan, Pt. III, 22d Ann. Rept., U. S. G. S.

Limestone.*

Michigan has enormous limestone resources, but much of the limestone is high in magnesium carbonate and is therefore not suitable for the manufacture of Portland cement. Moreover, most of the easily accessible deposits of high calcium limestone are located in the northern part of the Southern Peninsula or in the eastern half of the Northern Peninsula far from large markets and cheap

*For a more complete discussion of the limestone resources of Michigan see Pub. 21, Geol. Ser. 17, Mineral Resources of Michigan for 1915, pp. 101-312, Mich. Geol. and Biol. Surv.

fuel supplies. The only important deposits of high calcium stone in the southern part of the state are at Sibley, Wayne county, Bellevue, Eaton County, and possibly near Dundee, Monroe county.

The principal formations containing limestone sufficiently pure to be used for Portland cement are the Bayport limestone of the Upper Mississippian, the Traverse formation and the Dundee limestone of the Devonian, and the lower portion of the "Niagara" of the Silurian.

Bayport Limestone. The principal exposures of the Bayport limestone occur near Bayport, Huron county; at several places in Arenac county; at Bellevue, Eaton county, and at many places in Jackson county. Many of the beds in the Bayport are very cherty or sandy and cannot be used for the manufacture of cement. At Bellevue, the main bed is very pure and is extensively quarried by the Burt Portland Cement Co. for making cement. Near Omer, Arenac county, it is utilized for burning chemical lime and it is suitable for the manufacture of Portland cement, but the known beds of high grade limestone in Arenac county are thin and of limited extent, or are associated with sandy and cherty limestones and sandstone. With more careful exploration probably other deposits of pure limestone will be discovered in this county. At Bayport an upper bed, averaging about 90 per cent in calcium carbonate was formerly burned for hot lime but this bed is now exhausted. Most of the other beds are very cherty, sandy, or high in magnesium carbonate and not suitable for making cement.

In Jackson county, the Bayport limestone occurs as large scattered masses buried in the drift and forms the capping on many of the rock hills. The deposits thus far discovered are either too sandy or magnesian or appear to be too small to warrant development for cement manufacture. It is possible that with more careful exploration deposits of sufficient size and purity will be found. The Bayport is underlain by calcareous shale and argillaceous limestone of the Michigan series but between the two there is a conglomerate composed of pebbles of limestone, dolomite and sandstone with a shaly matrix. The shale, where the conglomeratic zone is thin, could be utilized with the overlying limestone.

The following analyses are fairly representative of the purer phases of the Bayport limestone:

*ANALYSES OF BAYPORT (MAXVILLE) LIMESTONE.

	Analyst.	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	$MgCO_3$	MgO	CaO	Remarks.
S. E. ¼, Sec. 1, T. 19 N., R. 5 E. 4 mi. N. E. of Omer, Arenac Co.	R. C. Banks, Univ. Mich.	4.78	1.52	92.53	1.00	0.478	51.86	Composite sample from top of 3-foot bed in Jas. McDonnell quarry. Samples collected by R. A. Smith.
Bellevue, Eaton Co.	R. C. Banks, Univ. Mich.	2.56	1.59	94.78	1.03	0.492	53.79	Composite sample from 12-foot face on east side of quarry. Burt Ptld. Cem. Co. Samples collected by R. A. Smith.
Parma, 1 mi. N. E. of Jackson Co.	Michigan Ptld. Cem. Co., 1915.	2.74	1.26	94.32	....	Trace	52.86	Hand samples. Anal. furnished by N. S. Potter, Jr., Gen. Mgr. Mich. Ptld. Cem. Co.
Jackson, 6 mi. N., Jackson Co.	Michigan Ptld. Cem. Co., 1915.	2.59	0.88	96.96	....	0.003	54.34	

*For other analyses of Bayport limestone see Pub. 21, Geol. Ser. 17, Min. Res. Mich. for 1915, pp. 274-277, 288-289, 294-295, Mich. Geol. and Biol. Surv.

The "Niagara" limestone underlies a broad belt in the Northern Peninsula extending from Garden Peninsula in southeastern Delta county eastward along the lake shore to Drummond Island, Chippewa county. It is widely exposed in many localities. The upper part of the formation, the Engadine dolomite and the Manistique series, is composed almost entirely of dolomite and heavy magnesian limestone. The lower part of the formation, the Hendricks series, including the Fiborn limestone, is largely high calcium and low magnesian limestone.

The Fiborn limestone is by far of most economic importance, because of its large exposures and high average purity. It is exposed or near the surface in several areas from a point five miles north of Whitedale, Schoolcraft county eastward to a point about nine miles east of Trout Lake Junction, Chippewa county, a distance of about sixty miles. The principal areas of exposures are five miles north of Whitedale and in the vicinity of Blaney quarry, Schoolcraft county; about two miles north of Huntspur, about one mile west of Gould City, four miles north of Engadine, in the vicinity of Hendricks and Fiborn quarries, and three miles west of Trout Lake, Mackinac county; and in the vicinity of Scotts' quarry about nine miles east of Trout Lake, Chippewa county. Other exposures probably occur elsewhere especially on the eastern part of Drummond Island. The deposits are very large, quarrying conditions exceptionally favorable, and the stone of excellent quality for cement manufacture, but the deposits are situated far from large markets, and cheap coal fuel supplies and most of the deposits are remote from beds of suitable clay or shale.

Known exposures of the lower beds of the Hendricks series are few and apparently of limited extent excepting perhaps the eastern part of Drummond Island. It is probable that further search will reveal the presence of other more important exposures.

The following analyses are typical of the composition of the Fiborn limestone:

ANALYSES OF FIBORN LIMESTONE.

Locality.	Analyst.	SiO_2	Fe_2O_3	Al_2O_3 R_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	Remarks.
Nicholsonville, 2 mi. N. of Blaney Jc., Schoolcraft Co.	L. C. Nadell & C. H. Wirth, Univ. Mich.	0.77	....	0.91	95.87	53.73	3.76	1.80	Composite of samples from top to bottom of 26-foot of Blaney quarry of White Marble Lime Co., Manistique.
Fiborn Quarry, Mackinac Co.	L. C. Nadell & C. H. Wirth, Univ. Mich.	0.58	....	0.46	98.46	55.19	2.55	1.22	Composite of samples from top to bottom of 27-foot face of quarry of Fiborn Limestone Company.
Hendricks Quarry, Mackinac Co.	L. C. Nadell & C. H. Wirth, Univ. Mich.	1.00	....	0.34	98.21	55.05	1.69	0.81	Upper 16 feet. Composite of samples from quarry of Union Carbide Co.
Gould City, 1 mi. W. of, Mackinac Co.	L. C. Nadell & C. H. Wirth, Univ. Mich.	0.77	....	0.53	96.87	54.30	3.40	1.63	From large deposit 1 mile West of Gould City.

Dundee Limestone. The Dundee limestone forms a belt in the northern part of the Southern Peninsula, skirting the shore of Lake Michigan and Lake Huron from McGulpins Point, Emmet county, southeast to Presque Isle, Presque Isle county, and also underlies the surface in a narrow belt from two to nine miles wide from the eastern part of Wayne county southeast through Monroe and Lenawee counties into Ohio. It is essentially a true limestone formation, containing no dolomite and only a relatively small amount of magnesian stone except near the base of the formation. Generally it is composed of gray to buff or brown bituminous granular limestone, locally with cherty horizons. Some of the beds are remarkably pure, containing from 97 to nearly 99 per cent of calcium carbonate but some of the beds, especially near the base contain from three to over 20 per cent of magnesium carbonate.

Unfortunately the formation is extensively exposed or near the surface only in the northern and northeastern part of the Southern Peninsula far from manufacturing centers. Several relatively unimportant exposures occur in the northern part of Emmet and Cheboygan counties in the vicinity of Mackinaw City, at McGulpins Point west of the city, and along the lower course of Mill Creek four miles southeast. Very large exposures occur in the vicinity of Rogers, Adams Point, and Trout Lake, Presque Isle county. Other exposures occur elsewhere in the eastern part of the county. Near Rogers, the Dundee limestone forms a high ridge for two or three miles along the lake shore and a plateau on Adams point peninsula. The Michigan Limestone and Chemical Company of Rogers City has opened the largest quarry in the world in the eastern end of the ridge at Calcite about two miles east of Rogers. The average* of cargo analyses as shipped by the company for the season of 1914 gave 97.38 per cent calcium carbonate and only 1.81 per cent of magnesium carbonate. The Dundee in the northern part of the state is practically free from chert or siliceous impurities. The general high average purity of the stone makes it very suitable for use in cement manufacture.

In the southeastern part of the state, the Dundee limestone is exposed only at Sibley, Wayne county, at Dundee, and at the mouth of the Macon river two miles northeast of Dundee, Monroe county. Elsewhere it is deeply buried by drift. The exposures are of the lower and apparently more magnesian portion of the formation. Much of the stone is too magnesian for use in cement manufacture. Chert is also abundant at some horizons in these deposits.

The following analyses may be taken as fairly representative of the composition of the Dundee limestone in various portions of the state:

*C. D. Bradley, General Manager of the Michigan Limestone and Chemical Company.

ANALYSES OF DUNDEE LIMESTONE.

Location or quarry.	Analyst or authority.	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	SO_3	Remarks.
Rogers, Presque Isle Co.	Not given	0.33	0.16	98.14	....	1.16	......	0.06	Ave. analysis of core to 84 feet.
		0.34	....	97.85	54.84	1.26	0.60	......	Ave. of 235 analyses. Mich. Limestone & Chem. Co., Rogers.
Mill Creek, Cheboygan Co.	R. C. Banks, Univ. Mich.	1.67	0.73	95.29	53.34	2.11	1.00	......	Composite sample from 22 foot face.
Sibley quarry, Wayne Co., Drill Core.	Laboratory, Church & Co., Sibley.	1.98	1.67	87.63	49.11	8.72	4.17	......	Top 5 feet.
		1.90	1.82	87.26	48.90	9.02	4.31	......	5–10 feet.
		2.78	1.67	83.99	47.07	11.56	5.53	......	10–16 feet.
		2.39	1.89	81.08	45.44	14.63	6.99	......	16–20 feet.
		0.73	1.19	93.26	52.26	4.82	2.30	......	20–25 feet.
		2.21	1.96	81.81	45.84	14.02	6.70	......	25–27 feet.
		8.16	0.72	75.99	42.58	15.13	7.23	......	27–33 feet.
		7.24	0.99	82.72	46.35	9.06	4.33	......	33–55 feet.
		2.63	0.66	92.54	52.54	4.17	1.99	......	35–40 feet.
Christiancy or Macon quarry, Monroe Co.	G. A. Kirchmeier.	0.48	0.16	90.80	50.88	6.87	3.28	......	Bed A. Top.
		1.10	0.12	86.80	48.64	11.60	5.81	......	Bed B 4 ft. to 4 ft. 6 in. thick.
		2.78	0.56	77.60	43.49	17.40	8.32	......	Bed C. 7 ft. to 8 ft. thick.
		0.81	0.41	95.00	53.24	3.86	1.84	......	Bed D.

Traverse Formation. The Traverse formation is a series of limestones and blue shales, generally calcareous, with a heavy shale, the Bell, at the base. Some of the beds of limestone are very pure but many contain considerable percentages of alumina, silica, or magnesia. The interbedded shales and also the Bell shale are generally very calcareous. Locally there are coral reefs, which are of great purity. A large number of exposures occur in Alpena, Presque Isle, Cheboygan, Charlevoix, and Emmet counties and quarries are operated at Charlevoix, Bay Shore, Petoskey, Afton, Alpena, and Rockport. Only at Alpena and near Petoskey, however, is limestone quarried for the manufacture of cement. In the quarry of the Michigan Alkali Co., at Alpena, some of the beds are very shaly and the Huron Portland Cement Co. utilizes the refuse stone, i. e., stone too small or too shaly for other purposes, for the manufacture of Portland cement.

In the vicinity of Petoskey and Bay Shore, much of the limestone is too high in magnesia to be used for making cement but some of the purer beds west of Petoskey are quarried and the stone sold to Portland cement companies for this purpose.

The Petoskey Portland Cement Company was organized in the spring of 1917 and plans are under way for the erection of a modern plant on the largest developed area of high calcium stone in the Petoskey region.

The quarry of the Great Lakes Stone and Lime Company at Rockport, Alpena county, has been opened in some high calcium beds directly above the Bell shale at the base of the Traverse formation. The association of shale and low magnesian limestone coupled with a means of cheap water transportation make very favorable conditions for the establishment of a cement plant. In the quarry of the Charlevoix Rock Products Co., near Charlevoix such geologic conditions exist, a 10 foot bed of soft blue shale forming the floor of the quarry.

In general it may be stated that the Traverse formation contains an enormous amount of high calcium limestone suitable for making Portland cement.

The following table of analyses shows the variable composition of the Traverse limestones:

ANALYSES OF TRAVERSE LIMESTONE.

Locality.	Analyst.	SiO_2	Fe_2O_3 Al_2O_3	R_2O_3*	$CaCO_3$	CaO	$MgCO_3$	MgO	Organic matter.	Remarks.
Alpena, Alpena Co....	R. C. Banks, Univ. Mich.	0.41	....	0.90	90.43	*50.68*	8.31	*3.97*	.....	Top beds 7 feet thick on E. side of Michigan Alkali Co. quarry to 7 feet. Composite sample collected by R. A. Smith for Mich. Geol. Surv.
Alpena, Alpena Co....	R. C. Banks, Univ. Mich.	1.13	....	0.75	94.54	*52.98*	2.61	*1.25*	.....	Beds from 7-16 feet. Michigan Alkali Co. quarry. Composite sample.
Alpena, Alpena Co....	R. C. Banks, Univ. Mich.	4.03	....	1.78	92.38	*51.77*	1.80	*0.86*	.....	Beds from 16-20 feet, thick. Composite sample.
Alpena. Alpena Co....	R. C. Banks, Univ. Mich.	1.46	....	0.75	95.58	*53.56*	2.11	*1.01*	.....	Beds from 22 to 25 feet. Composite sample.
Alpena, Alpena Co....	R. C. Banks, Univ. Mich.	2.09	....	0.66	94.78	*53.12*	2.45	*1.17*	.....	Beds 32 to 40 feet. Bottom of upper quarry. Composite sample.
Alpena County Co....	R. C. Banks, Univ. Mich.	1.05	....	1.02	96.40	*54.03*	1.52	*0.73*	.....	Beds from 40 to 63 feet, lower quarry. Composite sample.
Alpena, Alpena Co....	R. C. Banks, Univ. Mich.	0.21	0.33	.....	99.33	*55.67*	0.21	*0.10*	.....	Ave. analysis of large blast of white coral limestone, Alpena Portland Cement Co., quarry.
Afton, Cheboygan Co. N. W. ¼, N. E. ¼, Sec. 36, T. 35 N., R. 2 E.	Not given....	2.10	0.34	.....	96.52	*54.09*	0.90	0.43	0.08	Core analysis, 4 feet to 42 feet quarry of Campbell Stone Co.
Afton, Cheboygan Co..	R. C. Banks, Univ. Mich.	0.54	....	0.45	97.32	*54.54*	1.08	*0.52*	.....	Top bed of Afton quarry, Campbell stone Co. Composite sample.
Afton, Cheboygan Co..	R. C. Banks, Univ. Mich.	0.63	....	0.62	92.50	*51.90*	2.56	*1.22*	2.61	From 6-foot bed of black coralline limestone. Bed rejected on account of bituminous matter.
Afton, Cheboygan Co..	R. C. Banks, Univ. Mich.	0.24	....	1.44	96.97	*54.34*	0.12	*0.05*	.....	"Paper Stone" bed, 4 feet thick. Sold to paper mills.
Afton, Cheboygan Co..	R. C. Banks, Univ. Mich.	0.28	....	0.37	98.04	*54.94*	1.07	*0.51*	.....	Bituminous laminated beds 8-feet in thickness. Composite sample.
Afton, Cheboygan Co..	R. C. Banks, Univ. Mich.	1.75	....	0.64	95.75	*53.66*	1.24	*0.59*	.....	Lower 12 feet in quarry. Composite sample.
Petoskey, Emmet Co..	R. C. Banks,	0.09	....	0.46	62.86	*35.23*	36.44	*17.42*	.....	Top corraline beds 12-18 feet thick, quarry B. of Northern Lime Co.
W. E. Smith, L. G. Grimes, et. al., property 5 mi. W. of Petoskey.	R. C. Banks,	0.71	....	0.41	93.96	*52.66*	4.65	*2.22*	.....	
W. E. Smith, L. G. Grimes, et. al., property 5 mi. W. of Petoskey.	R. C. Banks, Univ. Mich.	0.26	....	0.28	94.78	*53.12*	4.18	*2.00*	.....	High calcium bed, No. 6 from top Quarry B, Northern Lime Co. Composite sample.
W. E. Smith, L. G. Grimes, et. al., property 5 mi. W. of Petoskey.	R. C. Banks, Univ. Mich.	0.22	....	0.23	86.14	*47.28*	13.11	*6.27*	.....	Beds Nos. 2, 3, 4, 7, and 8 from top of quarry. Composite sample.
Black Lake, Presque Isle Co.	R. C. Banks, Univ. Mich.	0.39	....	0.52	96.84	*54.27*	2.03	*0.97*	.....	Samples from top to bottom of 40 foot face, Black Lake quarry, Onaway Limestone Co.
4 mi. west of Petoskey.	R. C. Banks, Univ. Mich.	1.00	....	0.81	93.00	*52.12*	4.96	*2.37*	.....	From east end of quarry of Petoskey Crushed Stone Co.
2 mi. west of Charlevoix	R. C. Banks, Univ. Mich.	0.29	....	0.51	97.16	*54.62*	1.44	*0.69*	.....	From top to bottom of 22 foot face, South side of quarry of Charlevoix Rock Products Co.
Rockport, Alpena Co..	R. C. Banks, Univ. Mich.	0.19	....	0.77	97.25	*54.50*	1.84	*0.88*	.....	Composite sample from top to bottom of quarry of Great Lake Stone & Lime Co.

*Chiefly iron and alumina.
Figures in italics calculated.

Shales and Clays.

Suitable shales for use in cement manufacture occur in the "Utica" shale, the Cincinnati series, the Traverse, Antrim, and Coldwater formations, the Michigan series, and the Coal Measures, but, at present, shales from only the Antrim, Coldwater, and Michigan series are utilized in making cement. The surface clays are generally too sandy for this purpose.

"Utica" shale and Cincinnati Series. The so-called Utica shale and the Cincinnati series form a belt extending northeast from Green Bay, then curving eastward to St. Mary's river. The Utica is exposed only along the bed of the Whitefish river in Delta county and apparently there are but few places where quarryable conditions are favorable. The shale is black and very bituminous. Though no analyses are available, it is probable that the shale is suitable for cement manufacture.

The Cincinnati series is extensively exposed on the west side of the peninsula between Little and Big Bays de Noc. Where exposed it is very calcareous, and contains beds of limestone. Twenty-six samples of stone from a bluff near Stonington, Delta county, were analyzed by Prof. Koenig of the Michigan College of Mines and the content of calcium carbonate varied from 32 to over 66 per cent. It is possible that the beds of calcareous shale and argillaceous limestone in the vicinity of Stonington may be adapted for the manufacture of cement with a minimum admixture of pure limestone.

Traverse Shales. The Bell shale generally 50 to 80 feet thick forms the base of the Traverse formation. It underlies the surface in a narrow belt along the outer margin of the Traverse formation. It is soft, generally very calcareous, and in the northern part of the state contains thin beds of limestone. On account of its soft character it generally underlies valleys and has few exposures. It is exposed near Bell, Presque Isle county and forms the floor of Grand Lake. Probably it underlies the surface at shallow depth northwest of Grand Lake and in other places in Presque Isle county. The Bell forms the lower part of the bluff in which the Great Lakes Stone and Lime Company have opened their quarry at Rockport, Alpena county. The occurrence of shale and high calcium limestone together and near water transportation makes very favorable conditions for the manufacture of cement. A bed of shale similarly forms the floor of the Charlevoix Rock Products Co., Charlevoix, Charlevoix county.

At the Huron Portland Cement Co., Alpena, Alpena county, interbedded shale furnishes a part of the necessary siliceo-argillaceous material.

No analyses of the Bell shale or of the interbedded shales of the Traverse are available.

Antrim Shale. The Antrim shale underlies a broad arcuate belt stretching northeast from Manistee county to Cheboygan county and then southeast to Thunder Bay and into Alcona county. It is exposed at numerous points in Charlevoix, Emmet, Cheboygan, and Alpena counties. In southeastern Michigan the Antrim is deeply buried under drift. The more important deposits are near Norwood, Ellsworth, East Jordan, Boyne Falls and Walloon Lake Junction, Charlevoix county, and at Paxton, Alpena county. Numerous exposures of Antrim shale are reported to occur in the southern part of Chegoygan county. Except at the top and where weathered, the Antrim shale is generally black and very bituminous and locally contains numerous concretions of iron carbonate and nodules of pyrite. The Newaygo Portland Cement Co. at Newaygo, Newaygo county, obtains its shale from a deposit near Ellsworth in section 26, town 32 north, range 8 west, Antrim county. Other exposures of this shale which belongs to the upper blue portion of the Antrim, occur in the vicinity of Ellsworth. At Norwood the shale is black and very pyritic and forms strong bluffs along the lake shore for a half mile or more. Exposures of high calcium limestone, occur about one and one-half miles north of the village. The occurrence of suitable shale and limestone in close proximity and on water transportation routes makes a very favorable condition for the location of a Portland cement plant at this place.

The Huron Portland Cement Co., of Alpena, obtains its shale from a quarry at Paxton, 10 miles west of Alpena, Alpena county. The shale is brownish black with some blue streaks and contains so much bituminous matter that great care must be exercised in drying to prevent its taking fire. According to Mr. W. M. Smith, Chemist for the company, the average content of volatile matter is over 13 per cent and some strata contain over 18 per cent. Otherwise the shale is said to be very satisfactory for making cement.

ANALYSES OF ANTRIM SHALE.

Location.	Analyst.	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	alkalies.	Water, Organ. etc.	SO_3	Fixed C.
		%	%							
*Near Alpena	A. N. Clark	55.95	17.43	7.67	2.14	1.55	2.86	12.40	......	......
Near Alpena	H. Ries	58.60	17.66	7.44	2.14	2.14	......	11.97	......	......
Near Alpena	W. H. Johnson	70.54	15.33	5.31	CaO 2.38	MgO 0.78	5.56	Analyses of ash. Shale as received contained 17.96 per cent of moisture and volatile matter and 6.49 per cent of fixed carbox.		

*Geol. Survey Mich. Vol. VIII, Pt. 1, p. 46.

Coldwater Shale. The Coldwater shale underlies several thousand square miles of the surface in the Southern Peninsula but it is exposed or is at shallow depth only in a few places in Branch, Huron and Sanilic counties. It is generally from 800 to 1,000 feet thick and is largely blue shale, but it contains sandy horizons and true sandstone. Locally there are many concretions of iron carbonate.

Large deposits of Coldwater shale occur near Union City, Coldwater, and Bronson, Branch county. The Wolverine Portland Cement Co., obtains its shale from a deposit near Coldwater, and the Peerless Portland Cement Co., from a quarry near Union City. The Bronson Portland Cement Company at first obtained its shale from a shallow mine near Bronson in the same county, but later used surface clays obtained from northern Ohio. Excellent but undeveloped exposures of the Coldwater shale occur along the shore of Lake Huron from Forestville, Sanilac county to White Rock, Huron county. Where the overburden is not excessive, it is probable that the Coldwater shale could be readily mined.

The range in composition of the shale at Union City and Coldwater is shown by the following analyses:

*ANALYSES OF COLDWATER SHALE.

Locality.	Analyst.	SiO_2 per cent.	Fe_2O_3 Al_2O_3 per cent.	CaO per cent.	MgO per cent.	SO_3 per cent.	Alkalies per cent.	Moisture organic, etc. per cent.
†Union City	A. Lundteigen	67.89 to 52.20	29.89 to 23.33	1.42 to 0.00	2.16 to 0.26	Trace to 0.00	8.55 to 6.00	20.50 to 10.00
†Coldwater	H. E. Brown	61.25 to 57.26	29.89 to 24.65	1.50 to 1.25	2.31 to 1.49	1.34 to .65	3.45 to 2.25	8.32 to 6.19
Bronson	‡H. Ries	62.10	27.90	0.65	0.96	0.49	....	7.90
Coldwater	‡H. Ries	53.44	24.80	0.76	0.25	....	....	20.75
White Rock	‡H. Ries	58.70	18.31	**1.80	**0.98	....	3.67	9.35

†I. C. Russell, Portland Cement Industry in Michigan, 22d Ann. Rept. U. S. Geol. Surv. Pt. III, p. 666.
‡Vol. VIII, Pt. I, p. 414, Mich. Geol. Surv.
**As carbonate.
*I. C. Russell, The Portland cement industry in Michigan, 22d Ann. Rept. pt. III. pp. 666-667, U. S. Geol. Surv.

Michigan Series. The Michigan Series is composed of greenish shales, some very calcareous, argillaceous limestones, and beds of gypsum. Some of the shales have the proper composition for use in cement but others are too high in soluble salts. At Bellevue, the Burt Portland Cement Co. utilizes greenish blue shale, and a very argillaceous limestone beneath the Bayport limestone. The composition of the shale is shown below:

ANALYSIS OF SHALE FROM BOTTOM OF CEMENT QUARRY

Analyst.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
C. H. Denman	59.40	11.05	3.45	13.45	2.00

Similar shale underlies the exposures of Bayport limestone north of Jackson near the mouth of the Portage River, Jackson county.

Coal Measures. The Saginaw formation or Upper Coal Measures contains an abundance of shale, though locally very sandy, but many of the beds apparently would be suitable for use in making cement. According to Ries* there are three general types of shales in the Coal Measures: first, a light gray, sandy, shaly clay, popularly called "fire clay"; second, a black, fine grained, brittle shale with dull luster, sometimes called "cannel coal"; and third, a dark grayish black, fine grained, hard, yet brittle shale. The first is low in alumina (see Anal. No. 1) and iron and of doubtful use for cement manufacture under present methods. The second, on account of the high content of bituminous and carbonaceous matter, would probably require more or less careful manipulation. The last type is associated with coal seams in Saginaw and Bay counties and is quarried at Corunna, Shiawassee county, and Flushing, Genesee county for the manufacture of paving brick. Some of the shale at Corunna is used by the Portland Cement Co, near Fenton, Genesee county for the manufacture of cement. Similar shales are mined near Bay City for making paving brick. The following analyses show that most of the shales in the Coal Measures are lower in silica than is considered desirable for use in making Portland cement under present practice but further investigations may develop methods for the satisfactory use of such shales in the manufacture of cement.

*Geol. Surv. Mich. Vol. VIII, Pt. I, 1900, pp. 25-38.

*ANALYSES OF SHALES OF THE COAL MEASURES.

Constituent.	1	2	3	4	5	6	7
Silica, SiO_2	55.30	54.50	52.45	57.10	61.13	54.93	41.38
Alumina, Al_2O_3	14.20	30.75	23.27	20.02	} 26.90	31.43	27.02
Ferric oxide, Fe_2O_3	3.62	3.50	7.93	8.18			
Calcium oxide, CaO	.....	1.05	.....	.....	1.12	.22	.52
Calcium carbonate, $CaCO_3$	.30	.....	1.82	.71	.....	.....	.....
Magnesium oxide, MgO	.....	1.69	.....	.....	.96	1.58	.90
Magnesium carbonate, $MgCO_3$	2.61	.....	1.06	1.47	.....	.....	.....
Sodium oxide, Na_2O	.....	.80	} 4.37	2.76	(?)	(?)	(?)
Potassium oxide, K_2O	.....	2.20					
Alkalies, K_2O, Na_2O	2.15	.....	.....	.....	.....	.....	.....
Water and organic matter	21.82	5.51	9.10	9.76	6.47	7.44	23.11
Total	100.00	100.00	100.00	100.00	96.58	95.60	92.93
Fluxes	8.68	.....	.....	.....	.....	.....	.....
FeO	.....	1.57	1.47	.....	.....	.....	.....

1. So-called "fire clay" from Standard Mine, Saginaw.
2. Fine-grained black shale from Flushing, Genesee county; Geological Survey of Michigan, Vol. VIII, Pt. 1, 1900, p. 30. Analyst, H. Ries.
3 and 4. Shales associated with coal at Bay City, ibid., pp. 35-36. Analyst, A. N. Clark.
5, 6, and 7. Coal mines at Bay City. Analyses furnished by the Hecla Portland Cement and Coal Company. Analysts, Lathbury and Spackman.

Surface Clays.

The surface clays according to Ries† are of three general classes, —drift clays, lake clays, and river silts. The first are always calcareous except where leached at the top and generally contain sand, pebbles and boulders, and are very variable in composition. Locally lime concretions are scattered through the clays. On account of the sand, pebbles, and concretions, drift clays generally are unsuitable for cement making.

Lake clays occur in great abundance along the eastern margin of the state from Alcona county south to Ohio and in a number of localities near Lake Michigan. In the Northern Peninsula, large areas in Ontonagon, Chippewa, and southern Houghton counties are covered with heavy deposits of pinkish lake clay. The lake clays are characteristically fine-grained, generally calcareous and almost entirely free from coarse grit. The content of alumina and iron, however, is generally low in proportion to the silica and this makes them not well adapted for cement making according to present practice.

*I. C. Russell, The Portland cement industry in Michigan, 22d Ann. Rept., pt. III, p. 670, U. S. Geol. Surv.
†Geol. Surv. Mich. Vol. VIII, Pt. I, pp. 42-68.

ANALYSES OF LACUSTRAL* CLAYS.

Constituent.	1	2	3	4	5	6
Sand	.....	.....	1.51	.....	?	.....
Silica, SiO_2	49.75	49.34	66.49	47.75	46.40	61.62
Alumina, Al_2O_3	13.06	14.50	9.87	17.60	} 16.4	17.20
Ferric oxide, Fe_2O_3	5.31	5.37	4.87	9.13		5.99
Calcium oxide, CaO	10.86	9.75	4.72	.....	.....	5.62
Calcium carbonate, $CaCO_3$	.....	.....	.....	2.60	25.36	.....
Magnesium oxide, MgO	4.28	4.77	1.22	.....	.....	2.82
Magnesium carbonate, $MgCO_3$	.....	.....	.....	.70	4.30	.....
Sulphuric anhydride, SO_3	.....	.13	.62	.....	.....	.46
Sodium oxide, Na_2O	?	?	?	} 2.21	.....	.....
Potassium oxide, K_2O	?	?	?			
Water, H_2O	†15.07	†15.55	†9.36	22.01	7.00	†5.34
Total	99.13	99.25	98.66	100.00	99.46	99.00

†Loss on ignition.
1. From near Chelsea, Washtenaw County. Analysis by E. D. Campbell.
2. From near Fenton, Genesee County. Analysis by E. D. Campbell.
3. From near Farmington, Oakland County, Analysis by E. D. Campbell.
4. From near Saginaw. Analysis by H. Reis: Geol. Survey Michigan, Vol. VIII, Pt. I, 1900, p. 55.
5. From near Wyandotte: used in cement making by the Michigan Alkali Company. Analysis by O. Button.
6. Sault Ste. Marie. Analysis by E. D. Campbell.

The river silts found along the margins of streams are generally too sandy for use in cement manufacture. Generally the deposits of silt are too small and thus far they have not been used for making cement.

GYPSUM.

Generally from 1 to 2 per cent of gypsum is added to Portland cement clinker before grinding to regulate the time of setting of the cement when mixed with water. The effect of gypsum is to lengthen the time before the cement begins to harden, or "to acquire its initial set." The gypsum (See Gypsum) is purchased from the various gypsum companies located near Grand Rapids and Grandville, Kent county, and at Alabaster, Iosco county.

FUEL.

All of the cement plants are now equipped with rotary kilns and crushed coal is used for burning the clinker. Most of the coal is obtained from Ohio, and West Virginia. Saginaw Valley coals have been used to a limited extent only as they are generally of lower average grade than the coals from the above mentioned states.

The coal or coke is ground to a fine dust, 98 per cent of which will pass through a 100-mesh sieve. The dust is blown into the lower end of the kilns by an air blast and upon ignition it pro-

*I. C. Russel, The Por
U. S. Geol. Surv.

duces a flame reaching the length of the kiln. The cement mixture is introduced at the opposite end and by the time it has reached the lower end of the rotating kiln it is burned to clinker. This is stored in large bins and later ground in pebble mills.

GROWTH OF INDUSTRY.

Less than 1,000,000 barrels of Portland cement were made in the United States in 1895, a little more than a fifth of the present production of Michigan. With the successful introduction of the rotary kiln in 1890, the present era of concrete construction was inaugurated. Growth from 1895 to 1907 was phenomenal, the production in the latter year nearly reaching 48,000,000 barrels. The financial depression of 1907 caused a temporary check, but growth was resumed the following year and continued almost uninterruptedly up to 1916 when the maximum of 91,521,198 barrels were produced.

In 1898 the production in Michigan was only 77,000 barrels but the next year it leaped to 343,566 barrels, and in 1901 it passed the million mark. Though hampered by low prices and keen competition the industry has maintained a relatively steady growth to the present time. The maximum production of 4,919,023 barrels was attained in 1916. This was a gain of 10.03 per cent over 1915. Both shipments and total value also were greater than in any previous year, the shipments being 5,151,818 barrels valued at $6,-017,911 as compared with 4,727,768 barrels in 1915, valued at $4,-454,608. The average price per barrel was $1.168 or $.224 more than in 1915. This is the highest price obtained since 1907.

All of the companies reported very prosperous conditions in 1916 and it is almost certain that 1917 will be the greatest year in the history of the industry.

PRODUCTION, VALUE, ETC., OF PORTLAND CEMENT IN MICHIGAN AND UNITED STATES, 1896-1916.

Year.	No. of plants in operation.	Michigan Rank.	No. of kilns, Rotary.	Daily capacity, Bbls.	Michigan, cement made. Bbls.	U. S., Cement made. Bbls.	Michigan, per cent made.	*Change per cent cement made.	Michigan, Cement shipped. Bbls.	Michigan, Cement shipped. Value.	U. S., Cement shipped. Value.	Michigan, per cent of value.	Michigan, stock on hand Dec. 31. Bbls.	Michigan, average price per barrel.	U. S., average price per barrel.
1896	1	....	....	....	4,000	1,543,023	0.25	....	....	$7,000	$2,424,011	0.29	....	$1.75	$1.57
1897	2	....	....	....	15,000	2,677,775	0.56	275.0	....	26,250	4,315,891	0.6	....	1.75	1.61
1898	2	....	....	....	77,000	3,692,284	2.11	413.3	....	134,750	5,970,773	2.3	....	1.747	1.62
1899	4	4	....	....	343,566	5,652,266	6.1	346.2	....	513,849	8,074,371	6.36	....	1.492	1.43
1900	6	2	....	....	664,750	8,462,020	7.8	93.4	....	830,960	9,280,525	8.9	....	1.25	1.09
1901	10	3	....	....	1,025,718	12,711,225	8.0	54.1	....	1,128,290	12,532,360	9.0	....	1.10	0.99
1902	10	3	....	....	1,577,006	17,230,644	9.1	53.7	....	2,134,396	20,864,078	10.2	....	1.353	1.21
1903	13	3	....	....	1,955,183	22,342,973	8.7	23.9	....	2,674,780	27,713,319	9.7	....	1.367	1.24
1904	16	4	....	....	2,247,160	26,505,881	8.5	14.9	....	2,365,656	23,355,119	10.1	....	1.052	0.88
1905	16	5	....	....	2,773,283	35,246,812	7.9	23.4	....	2,921,507	33,245,867	8.7	....	1.053	0.94
1906	14	4	....	....	3,747,525	46,463,424	8.06	35.5	....	4,814,965	52,466,186	9.2	....	1.284	1.13
1907	14	4	....	....	3,572,668	48,785,390	7.3	—4.6	....	4,384,731	53,992,551	8.1	....	1.227	1.11
1908	15	7	....	....	2,892,576	51,072,612	5.6	—19.0	....	4,256,215	43,547,679	5.8	....	0.883	0.85
1909	12	7	....	....	3,212,751	64,991,491	4.9	11.6	....	2,619,259	52,858,354	4.9	....	0.815	0.813
1910	12	8	....	....	3,687,719	76,549,951	4.8	11.7	....	3,378,940	68,205,800	4.9	....	0.916	0.891
1911	11	8	96	22,400	3,686,716	78,528,637	4.69	—0.03	....	3,024,676	66,248,817	4.56	506,758	0.82	0.843
1912	11	8	92	19,450	3,494,621	82,438,096	4.23	—5.21	3,651,094	3,145,001	69,109,800	4.55	370,956	0.861	0.813
1913	11	8	83	19,900	4,186,236	92,097,131	4.21	19.79	4,081,281	4,228,879	88,689,377	4.77	473,563	1.036	1.005
1914	11	7	77	19,100	4,285,345	88,230,170	4.85	2.37	4,218,429	4,064,781	86,437,956	4.70	538,846	0.964	0.927
1915	11	5	71	20,800	4,765,294	85,914,907	5.55	11.2	4,727,768	4,454,608	86,891,681	5.11	569,919	0.942	0.86
1916	....	....	68	20,650	4,919,023	91,521,198	5.37	10.03	5,151,818	6,017,911	94,552,296	6.36	336,477	1.168	1.058

*Minus sign indicates decrease.

MISCELLANEOUS NON-METALLIC MINERALS.

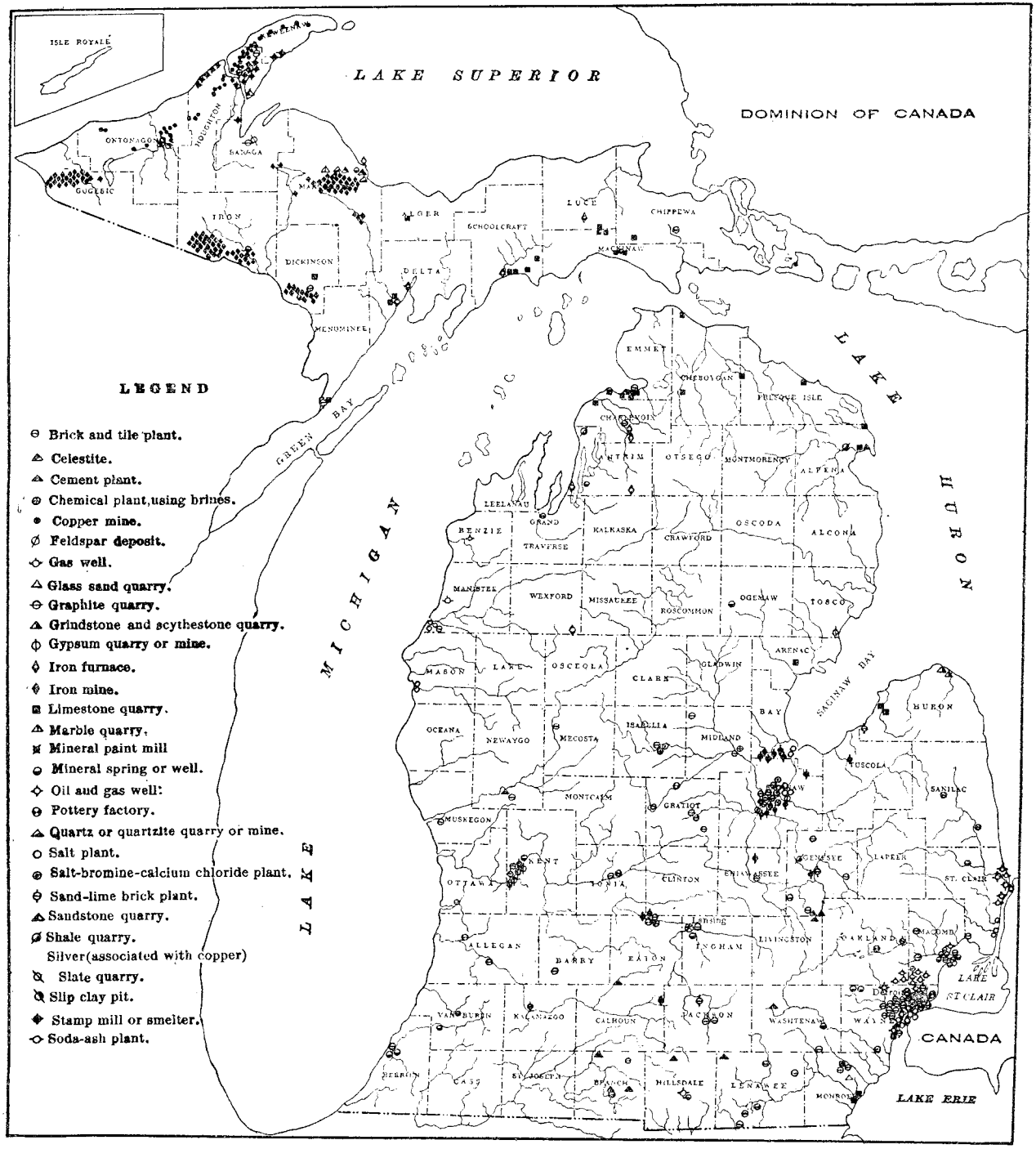

Fig. 6.—MAP SHOWING LOCATION OF MINERAL INDUSTRIES IN MICHIGAN.

Both the quantity and the value of salt produced in Michigan in 1916 were greater than in any previous year. The total production in 1916 was 14,918,278 barrels valued at $4,612,567 as compared with 12,588,788 barrels in 1915 valued at $4,304,731. This represents a gain of 2,329,492 barrels or 18.5 per cent in quantity and $307,836 or only 7.3 per cent in value. The relatively small gain in value was due to the lower average price of $3.09 per barrel or $.033 less than in 1915.

From 1880 to 1892, Michigan held first rank in production in the United States. In 1893, New York gained first rank and held it continuously, with the exception of the year 1901 until 1905 when Michigan again took the lead and continued first excepting in the two years 1910 and 1911 when New York led by a narrow margin. With the exception of 1910, Michigan has also held first rank in value since 1908.

Thirty years ago the center of the salt industry was in Saginaw Valley, chiefly along Saginaw River from Saginaw to Bay City. The industry was carried on in connection with the lumber mills and waste steam and fuel from the mills were utilized by more than a hundred lumber concerns in evaporating natural brines which were obtained from the Upper Marshall sandstone at depths varying from about 600 feet in Saginaw to nearly 1,000 feet in Bay City. With the decline of the lumber industry in Saginaw Valley the salt industry became relatively unimportant. In 1915 and 1916 only 3.6 per cent of the total output of the state was produced in this district.

The war has revived the industry through the great demand for bromine from abroad. Under present conditions salt is manufactured rather as a by-product of the bromine industry. The total output for 1916 in this district was 561,164 barrels valued at $259,539.

The chief salt producing districts are in eastern Michigan along the Detroit-St. Clair rivers and in western Michigan at Ludington and Manistee. In these districts, artificial brines are used for the manufacture of salt. The brine is obtained by forcing water through casings down to rock salt beds and then back to the surface. Rock salt is mined by the Detroit Rock Salt Co. at Oakwood,

a suburb on the west side of Detroit. The salt is obtained from a 20 foot bed at a depth of about 1,040 feet. The salt is shipped to large cities for curing fish, meats, and hides, for the manufacture of ice cream and for general refrigeration purposes. Over 96 per cent of the state output of salt for the last three years came from these two districts.

The salt industry in Wayne county has made a most remarkable growth. Salt was first produced in this county in 1895, the output for that year being 13,077 barrels. In 1906 the production exceeded 1,000,000 barrels and in 1916 it was 9,041,650 barrels valued at $1,210,125 or 13.34 cents per barrel. Much of the salt produced in Wayne county is in the form of brine which is used in the manufacture of soda ash, bleach, caustic, etc., and this accounts for the low average value per barrel. The Solvay Process Co., at Delray, the Michigan Alkali Co., at Ford City and Wyandotte, and the Pennsylvania Salt Co., at Wyandotte, use great quantities of brine in the manufacture of these products.

In St. Clair county, the chief salt producing centers are Port Huron, St. Clair, and Marine City. The output of St. Clair county in 1916 was only 2,469,443 barrels or 16.6 per cent of the state output, yet the value was $1,950,098 or 41.6 per cent of the total value for the state. The exceptionally high value for this county is due to the fact that much of the salt produced is of the better grades, 44.4 per cent being table and dairy salt.

In the Manistee-Ludington district, salt is made at Manistee and Filer City, on Manistee Lake, Manistee county, and at Ludington, Mason county. In this district, the salt industry is still largely carried on in connection with the lumber industry, waste steam and waste fuel being utilized for evaporating artificial brines. This district produced 2,861,736 barrels of salt valued at $1,188,805. This is equivalent to 19.2 per cent of the total quantity and 25.8 per cent of the value for the state. Most of the product is packer's salt, i. e., common fine and common coarse.

The Marshall brines especially near the center of the state contain appreciable amounts of bromine and relatively large percentages of calcium chloride. In the early days of the salt industry, the bitterns or "mother liquors" left after the precipitation of the salt by evaporation, were thrown away. The bitterns were discovered to be rich in bromine and calcium chloride and many salt and chemical plants began the recovery of bromine, chiefly in the form of bromide, and also of calcium chloride. Competition with German bromine and bromine products drove the price so low that the recovery of bromine was abandoned by all of the salt manufacturing concerns, though it was still extensively produced by the Dow Chemical Co. at Midland, Midland county. The great demand and high prices for bromine and bromine chemicals, caused by the war has revived the industry, bromine being recovered at Midland, Midland county, Saginaw, and at St. Charles, Saginaw county. Michigan produces more than half of the bromine made in the United States.

Calcium chloride is recovered as a by-product of the salt industry at Mt. Pleasant, Isabella county, and at Saginaw and St. Charles, Saginaw county. It is also produced on a large scale as a waste product by the soda ash plants in Wayne county, but, as it is not an original constituent of the brine, its value is not included in the statistics of the salt industry.

The rock salt occurs in the Salina formation of Silurian age. There are three known rock salt areas, one in southeastern Michigan, a second in Alpena and Presque Isle counties, and a third in Mason and Manistee counties. South of the line from Muskegon through Kalamazoo to Trenton, Wayne county, no rock salt has been found, though wells have penetrated completely through the rock salt bearing formation at many places. The area of rock salt in southeastern Michigan so far known extends from Trenton, Wayne county, northeast along Detroit and St. Clair rivers into western Ontario. The total area known to be underlain by rock salt in southeastern Michigan and western Ontario is several thousand square miles. The rock salt area extends northwest from Detroit River to and beyond Romulus and Dearborn in Wayne county, and Royal Oak in Oakland county but how far the salt area continues in this direction is unknown, since there are no wells northwest of these places deep enough to reach the salt bearing horizons. The aggregate thickness of the salt beds at Royal Oak and Dearborn is greater than to the southeast along Detroit River, thus indicating a considerable extension to the northwest of these places. In southeastern Michigan, the salt beds are very numerous and some of them very thick. There is an upper, thick, and apparently persistent bed from 60 to 125 feet in thickness and a lower very thick and continuous bed having a maximum thickness of over 350 feet, though it probably contains partings of dolomite or shale. The average aggregate thickness of the salt beds along Detroit and St. Clair rivers is about 400 feet, but at Royal Oak and Dearborn 609 and 556 feet of salt respectively were penetrated and at the former place the bottom of the Salina apparently was not reached.

In Alpena and Presque Isle counties, the salt area while undoubtedly very large is of unknown extent. Rock salt was struck at

Onaway, Grand Lake, and Alpena in great quantities, and the greatest aggregate thickness of rock salt yet penetrated in Michigan or Ontario, Canada, is at Onaway, Presque Isle county. A test hole drilled for oil at this place penetrated over 800 feet of rock salt in a section of 1,200 feet. The lowest bed is 225 feet in thickness, and perhaps is to be correlated with the thick bed in the Detroit river region. At Grand Lake salt beds aggregating over 300 feet in thickness were penetrated in a deep well without reaching the bottom of the rock salt formation.

In the Manistee-Ludington district, the salt beds are few and thin. In the vicinity of Manistee only one bed is known. This has a thickness of 20 to 30 feet. At Ludington, however, four beds respectively 20, 12, 7, and 5 feet in thickness have been penetrated in some wells.

The depth to the first salt bed in southeastern Michigan varies from a minimum of 730 feet at Detroit to 1,500 and 1,600 feet at Port Huron and St. Clair. The depth at Alpena, Alpena county is about 1,270 feet; at Grand Lake, 1,284 feet; and 1,630 feet at Onaway, Presque Isle county.

The total area of the rock salt districts in Michigan is unknown but it is undoubtedly several thousand square miles and present evidence, though not conclusive, indicates that the three known rock salt districts are but parts of the same great rock salt area.

PRODUCTION AND VALUE OF SALT IN MICHIGAN AND UNITED STATES, 1860-1916.

Year.	U. S. Production. Quantity, bbls.	Michigan production.		Per cent of total. Michigan.	Rank. Quantity.	Value. Michigan.	Michigan.	
		State Salt Inspectors.* Quantity, bbls.	U. S. G. S.† Quantity, bbls.				Rank-Value.	Price, bbl.
1860	.....	4,000	.....	.....	....	.....	.....	.....
1861	.....	125,000	.....	.....	....	.....	.....	.....
1862	.....	243,000	.....	.....	....	.....	.....	.....
1863	.....	466,000	.....	.....	....	.....	.....	.....
1864	.....	529,073	.....	.....	....	.....	.....	.....
1865	.....	477,200	.....	.....	....	.....	.....	.....
1866	.....	407,997	.....	.....	....	$734,395	.....	$1.80
1867	.....	474,721	.....	.....	....	840,255	.....	1.77
1868	.....	555,690	.....	.....	....	1,028,027	.....	1.85
1869	.....	561,288	.....	.....	....	786,835	.....	1.58
1870	.....	621,352	.....	.....	....	820,185	.....	1.32
1871	.....	728,175	.....	.....	....	1,063,135	.....	1.46
1872	.....	724,481	.....	.....	....	1,057,742	.....	1.46
1873	.....	821,346	.....	.....	....	1,127,984	.....	1.37
1874	.....	1,026,970	.....	.....	....	1,220,094	.....	1.19
1875	.....	1,081,856	.....	.....	....	1,190,042	.....	1.10
1876	.....	1,482,729	.....	.....	....	1,556,865	.....	1.05
1877	.....	1,660,997	.....	.....	....	1,411,847	.....	0.85
1878	.....	1,855,884	.....	.....	....	1,577,501	.....	0.85
1879	.....	2,058,040	.....	.....	....	2,099,200	.....	1.02
1880	5,961,060	2,676,588	2,485,177	41.69	1	2,271,931	.....	0.75
1881	6,200,000	2,750,299	.....	44.35	1	2,418,171	.....	0.85
1882	6,412,373	3,037,317	3,037,317	47.36	1	2,126,122	.....	0.70
1883	6,192,231	2,894,672	2,894,672	46.74	1	2,344,684	.....	0.81
1884	6,514,937	3,161,806	3,161,806	48.53	1	2,392,648	.....	0.757
1885	7,038,653	3,297,403	3,297,403	46.84	1	2,967,663	.....	0.900
1886	7,707,081	3,667,257	3,667,257	47.58	1	2,426,989	.....	0.661
1887	8,003,962	3,944,309	3,944,309	49.17	1	2,291,842	.....	0.581
1888	8,055,881	3,866,228	3,866,228	47.99	1	2,261,743	.....	0.585
1889	8,005,565	3,846,979	3,856,929	48.17	1	2,088,909	.....	0.541
1890	8,776,991	3,838,637	3,838,632	43.72	1	2,302,579	.....	0.600
1891	9,987,945	3,927,671	3,966,748	39.52	1	2,037,289	.....	0.513
1892	11,698,890	3,812,504	3,829,478	32.81	1	2,046,963	.....	0.523
1893	11,897,208	3,514,485	3,057,898	25.70	2	888,837	.....	0.287
1894	12,968,417	3,138,941	3,341,425	26.53	2	1,243,619	.....	0.375
1895	13,669,649	3,529,362	3,343,395	24.46	2	1,048,251	.....	0.315
1896	13,850,726	3,336,242	3,164,238	22.89	2	718,408	.....	0.229
1897	15,973,202	3,622,764	3,993,225	24.99	2	1,243,619	.....	0.313
1898	17,612,634	4,171,916	5,263,564	29.88	2	1,628,081	.....	0.311
1899	19,708,614	4,732,669	7,117,382	36.14	2	2,205,924	.....	0.309
1900	20,869,342	4,738,085	7,210,621	34.55	2	2,033,731	2	0.282
1901	20,566,661	5,580,101	7,729,641	37.58	1	2,437,677	1	0.328
1902	23,849,231	4,994,245	8,131,781	34.10	2	1,535,823	2	0.188
1903	18,968,089	4,387,982	4,297,542	22.65	2	1,119,984	2	0.260
1904	22,030,002	5,390,812	5,425,904	24.62	2	1,579,206	2	0.309
1905	25,966,122	5,671,253	9,492,173	35.24	1	1,851,332	2	0.196
1906	28,172,380	5,644,559	9,936,802	36.31	1	2,018,760	2	0.203
1907	29,704,128	6,298,463	10,786,630	35.39	1	2,231,129	2	0.208
1908	28,822,062	6,247,073	10,194,279	35.34	1	2,458,303	1	0.241
1909	30,107,646‡	6,055,661	9,966,744	33.10	1	2,732,556	1	0.274
1910	30,305,656‡	5,597,276	9,452,022	31.18	2	2,231,262	2	0.236
1911	31,183,968‡	.....	10,320,074	33.10	2	2,633,155	1	0.255
1912	33,324,808‡	.....	10,946,739	32.84	1	2,974,429	1	0.277
1913	34,393,227‡	.....	11,528,800	33.52	1	3,293,032	1	0.285
1914	34,402,772‡	.....	11,670,976	33.92	1	3,299,005	1	0.283
1915	38,231,496‡	.....	12,588,788	32.93	1	4,304,731	1	0.342
1916	.....	.....	14,918,278	.....	1	4,612,567	1	0.309
Tot'l.	.....	.....	236,724,878	.....	....	$98,815,061	.....	.....

*Office of State Salt Inspector abolished in 1911.
†In cooperation with the Michigan Geological Survey after 1909.
‡Includes production of Hawaii and Porto Rico, 1909-1913, 1915-1916 and of Porto Rico in 1914.

PRODUCTION AND VALUE OF SALT IN MICHIGAN BY GRADES, 1906-1916.

Year.	Table and dairy.		Packers.			
			Common fine.		Common coarse.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Barrels.		Barrels.		Barrels.	
1906	509,905	$362,368	2,927,478	$757,470	2,021,287	$618,727
1907	657,509	392,641	3,601,270	914,154	1,743,840	471,378
1908	584,452	620,647	3,454,062	968,617	2,020,956	610,286
1909	585,370	732,907	3,530,303	1,125,095	2,103,719	647,878
1910	798,434	565,653	2,216,181	734,828	1,992,465	596,301
1911	817,486	742,702	2,362,075	698,203	2,070,745	745,720
1912	905,593	920,782	2,225,337	645,692	2,086,492	835,673
1913	1,028,000	1,037,402	2,704,936	852,135	2,259,164	896,521
1914	1,092,344	1,025,164	2,668,989	911,016	2,380,378	870,715
1915	1,233,117	1,420,382	3,096,644	1,181,337	2,265,352	1,001,167
1916	1,305,950	1,461,085	3,109,857	1,221,901	2,133,600	1,064,709

Year.	Packers.		Other, rock, etc.		Brine and other. *	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Barrels.		Barrels.		Barrels.	
1906	91,098	$33,733	.....	.....	4,387,043	$246,462
1907	119,459	48,455	.....	.....	4,664,552	235,729
1908	134,726	53,669	.....	.....	3,991,083	205,084
1909	93,357	3,983	.....	.....	3,648,395	185,051
1910	92,426	43,942	.....	.....	4,104,934	211,317
1911	105,401	45,421	576,595	$181,865	4,387,772	219,244
1912	223,866	84,638	763,908	250,680	4,737,038	236,852
1913	50,557	25,371	727,364	244,172	4,756,779	237,431
1914	†	†	712,530	252,024	4,816,735	240,086
1915	†	†	919,735	321,354	5,073,940	380,491
1916	†	†	1,012,942	368,022	7,365,927	506,850

Year.	Total.	
	Quantity.	Value.
	Barrels.	
1906	9,936,802	$2,018,760
1907	10,786,630	2,062,357
1908	10,194,270	2,458,303
1909	9,966,744	2,732,556
1910	9,452,022	2,231,262
1911	10,320,074	2,633,155
1912	10,946,739	2,974,429
1913	11,528,800	3,293,032
1914	11,670,976	3,299,005
1915	12,588,788	4,304,731
1916	14,918,278	4,612,567

*Brine only after 1910.
†See common fine and common coarse after 1913.

GYPSUM.*

From 1868 to 1890, the annual production of gypsum in Michigan never reached 70,000 tons; the production in the latter year, however, attained the maximum of 74,877 tons. The maximum value of gypsum and gypsum products was attained in 1883, the value being $377,567. The growth of the industry began in 1890. The output reached 139,557 tons in 1892 but the financial depression throughout the country during 1892-3 disorganized the industry, the production decreasing in 1895 to only 66,519 tons, or less than half that in 1892. From 1896 to the present, the growth has been almost uninterrupted reaching the maximum production of 457,375 tons in 1916, valued at $1,066,588. This represents a gain in amount and value over 1915 of 67,384 tons, or 17 per cent in amount and $380,290 or 57 per cent in value. The large gain in value is due largely to war conditions.

In the early days of the gypsum industry, four-fifths of the raw gypsum was ground into land plaster and from 1869 to 1887 more than half of the gypsum mined was ground into this product. With the more general use of patent fertilizers, the demand for land plaster has more or less gradually decreased so that the production in 1916 was only 9,072 tons as compared with the maximum of 44,972 tons in 1873.

The growth of the gypsum industry is due largely to the invention and introduction into the building trades of gypsum plasters, plaster board, fire-proofing, calcimines, and other gypsum products. Since 1887, the grinding of land plaster has become relatively insignificant in comparison with the manufacture of building products. In 1916, the value of land plaster was only $16,658 as compared with $975,626 for calcined products.

The most important of these products is mixed wall plaster. In 1916 this product was valued at $668,795, or 62.7 per cent of the total value of raw and calcined products for the state. Stucco is next in importance with a value of $279,597, or 26.2 per cent of the total value. The value of these two products is practically 90 per cent of the total value for the state.

In 1916, five mines, two quarries and eight mills were in operation. One mill was abandoned at Grand Rapids but another was erected by the United States Gypsum Co., at Detroit. Five mines, one quarry and six mills are located at Grand Rapids, Kent county, one quarry and mill at Alabaster, Iosco county, and one mill at Detroit. At least three, and probably four, gypsum beds are

*For a more complete report on the gypsum industry of Michigan, see Pub. 19, Geol. Ser. 16, Min. Res. of Mich. for 1914, Mich. Geol. & Biol. Surv.

worked in Kent county. The two upper beds at Grand Rapids, respectively 6 and 12 feet thick, are near the surface. Formerly these were quarried but, because of the heavy overburden and water troubles which were increasing with the progress of quarrying the quarries have given place to mines. In the western part of Grand Rapids a third bed about 22 feet thick with a parting of shale one-feet thick near the center occurs about 60 feet below the surface. At Grandville an upper bed, about 11 feet thick is directly overlain by sand and gravel and is separated below from a 14-foot bed of gypsum by about four feet of hard limestone. These two beds may be equivalent of the 22-foot "split" in West Grand Rapids. The upper bed was formerly quarried but, because of heavy overburden and water the quarries have been replaced by mines opened in the lower bed. Numerous explorations show that there are several other minable gypsum beds in the Grand Rapids-Grandville district.

In the Alabaster district the upper gypsum bed, which is extensively quarried at Alabaster is from 18 to 23 feet thick. Test holes north of Alabaster show the presence of a number of deeper gypsum beds, 5 to 25 feet thick.

In the vicinity of Turner, Twining, and the deserted village of Harmon City, Arenac county, a bed of gypsum, called the Turner bed occurs 50 to 100 feet above the Alabaster bed. Locally, as in the vicinity of Turner, this bed is of minable thickness.

Gypsum beds occur on St. Ignace Peninsula and on St. Martins and other adjacent islands. Test holes in the vicinity of St. Ignace are reported to show beds of gypsum totalling 60 feet in thickness, three of the beds being 9, 13, and 21 feet thick respectively.

Available data indicates the presence of seven quarryable beds of gypsum in this district, but locally it is probable that water will be troublesome.

Gypsum was quarried near Pt. Aux Chenes as early as 1850. On account of various troubles, chief of which were water and a scourge of smallpox, the quarry was operated only intermittently for a number of years. Finally, when an ice-floe carried away the dock, the quarry was abandoned.

Thick gypsum beds are reported by well drillers in the vicinity of Ionia, Ionia county, and Cass City, Tuscola county, and beds 6 to 12 feet thick are known at comparatively shallow depths at Bellevue, and Eaton Rapids, Eaton county. In brief, the gypsum deposits of Michigan may be said to be practically inexhaustible.

PRODUCTION OF GYPSUM IN MICHIGAN, 1868-1916.

Year.	Ground into land plaster. Tons.	Gypsum calcined into plaster. Tons.	Sold crude. Tons.	Total production. Tons.	Total value.	Rank.	
						Quantity.	Value.
Before 1868.	132,043	14,285	.....	146,328	$671,022	.....	.....
1868.....	28,837	6,244	.....	35,081	165,298	.....	.....
1869.....	29,996	7,355	.....	37,351	178,824	.....	.....
1870.....	31,437	8,246	.....	39,683	191,718	.....	.....
1871.....	41,126	8,694	.....	49,820	234,054	.....	.....
1872.....	43,536	10,673	.....	54,209	259,524	.....	.....
1873.....	44,972	14,724	.....	59,696	297,678	.....	.....
1874.....	39,126	14,723	.....	53,849	274,284	.....	.....
1875.....	27,019	10,914	.....	37,933	195,386	.....	.....
1876.....	39,131	11,498	.....	50,629	248,504	.....	.....
1877.....	40,000	9,819	.....	49,819	238,550	.....	.....
1878.....	40,000	8,634	.....	48,634	229,070	.....	.....
1879.....	43,658	9,070	.....	52,728	247,192	.....	.....
1880.....	49,570	18,929	.....	68,499	349,710	.....	.....
1881.....	33,178	20,145	.....	53,323	293,872	.....	.....
1882.....	37,821	24,136	.....	61,957	344,374	.....	.....
1883.....	40,082	28,410	.....	68,492	377,567	.....	.....
1884.....	27,888	27,959	.....	55,847	335,382	.....	.....
1885.....	28,184	25,281	.....	53,465	286,802	.....	.....
1886.....	29,373	27,370	.....	56,748	308,094	.....	.....
1887.....	28,794	30,376	.....	59,170	329,392	.....	.....
1888.....	22,177	35,125	.....	57,302	347,531	.....	.....
1889.....	19,823	36,800	.....	56,623	353,869	.....	.....
1890.....	12,714	47,163	15,000	74,877	192,099	.....	.....
1891.....	15,100	53,600	11,000	97,700	223,725	.....	.....
1892.....	14,458	77,599	47,500	139,557	306,527	.....	.....
1893.....	16,263	77,327	31,000	124,590	303,921	.....	.....
1894.....	11,982	47,976	20,000	79,958	189,620	.....	.....
1895.....	9,003	51,028	6,488	66,519	174,007	.....	.....
1896.....	6,582	60,352	700	67,634	146,424	.....	.....
1897.....	7,193	71,680	16,001	94,874	193,576	.....	.....
1898.....	13,345	77,852	1,984	93,181	204,310	.....	.....
1899.....	17,196	88,315	39,266	144,776	283,537	.....	.....
1900.....	10,354	86,972	33,328	129,654	285,119	2	2
1901.....	9,808	129,256	46,086	185,150	267,243	1	1
1902.....	13,022	158,320	68,885	240,227	459,621	1	1
1903.....	18,409	198,119	52,565	269,093	700,912	1	1
1904.....	18,294	185,422	34,669	238,385	541,197	1	1
1905.....	20,285	203,313	24,284	247,882	634,434	1	2
1906.....	30,220	208,715	27,517	341,716	753,878	1	2
1907.....	15,500	197,666	36,543	317,261	681,351	3	3
1908.....	11,414	192,403	40,324	327,810	491,928	1	3
1909.....	11,890	344,171	45,781	394,907	1,213,347	2	1
1910.....	7,097	240,905	64,566	357,174	667,199	2	2
1911.....	15,548	206,299	79,050	347,296	523,926	3	4
1912.....	10,103	243,656	63,819	384,297	621,547	2	3
1913.....	9,604	278,368	60,706	423,896	721,325	3	3
1914.....	9,322	249,648	61,227	393,006	705,841	3	3
1915.....	9,799	245,484	69,572	389,791	686,309	3	4
1916.....	9,072	292,109	80,298	457,375	1,066,599	.....	.....
Totals..	1,251,348	4,723,228	1,078,159	7,741,742	$19,998,219	.....	.....

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1916.

Year.	Crude gypsum mined.	Gypsum sold crude.							
		To Portland cement mills.		As land plaster.		For other purposes.		Total sold crude.	
	Quantity.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Tons.		Tons.		Tons.		Tons.	
1911	347,296	63,489	$69,497	15,548	$15,706	13	$52	79,050	$85,255
1912	384,297	53,711	52,420	10,103	9,375	5	50	63,819	61,845
1913	423,896	*	*	9,604	10,222	10,320	9,011	60,706	55,969
1914	393,006	*	*	9,322	10,761	.....	.....	61,227	51,242
1915	389,791	*	*	9,799	9,894	*	*	69,572	63,236
1916	457,375	.....	.....	9,072	16,658	.....	.....	80,298	90,973

Year.	Gypsum sold calcined.									
	As mixed wall plaster.		As plaster of Paris, etc.		As stucco.		As dental plaster.		To plate glass works.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1911	146,920	$381,362	47,989	$88,168	.....	.....	20	$110	11,370	$19,031
1912	146,099	368,676	937	3,229	82,010	$168,734	3	12	6,214	8,078
1913	166,711	437,720	*	*	95,402	202,675	*	*	*	*
1914	163,972	475,638	*	*	83,780	173,172	*	*	.....	.....
1915	155,861	426,432	*	*	80,172	177,317	*	*	*	*
1916	193,816	668,795	224	1,325	87,405	279,597	*	*	*	*

*Included in total.

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1916.—*Concluded.*

Year.	Gypsum sold calcined.				Total value.	Kettles in mills.		Daily capacity.	Shifts run by mills during year.		No. mines and quarries.	No. mills.
	For other purposes.		Total sold calcined.									
	Quantity.	Value.	Quantity.	Value.		No.	Size.	24 hrs.	Total No.	Hrs. in shift.		
	Tons.		Tons.									
1911	.....	.....	206,299	$488,671	$573,926	29	8 x 10	2,200	.....	.....	8	8
1912	8,393	$10,973	243,656	559,702	621,547	28	8 x 10	2,140	1,850	11	6	8
1913	9,897	15,850	278,368	665,356	721,325	28	8 x 10	1,785	1,368	11	7	8
1914	1,811	5,433	249,648	654,599	705,841	28	8 x 10	1,860	2,043	11	8	8
1915	*	*	245,484	623,073	686,309	26	8 x 10	.....	.....	.....	8	8
1916	*	*	292,109	975,626	1,066,599	26	10 x 12	.....	.....	.....	8	8

COAL.*

Coal mining began in Michigan as early as 1835 but no records of production are available before 1860, when Michigan was credited with an output of 2,320 tons. Most of the coal in the early days was obtained from veins exposed or at shallow depth in the vicinity of Grand Ledge, Eaton county, Jackson, Jackson county, and Corunna, Shiawassee county. Ten years later the production reached 28,150 tons, in 1880, 100,800 tons, and for the following two years it exceeded 100,000 tons annually. In 1883, a sharp decline began and in the following year the production fell to only 36,712 tons. It was not until 1897 that the production again exceeded the 100,000 ton mark. In that year, the Saginaw and Bay county fields were opened and the production jumped to 223,592 tons. The industry grew rapidly and four years later, in 1901, the production was nearly one and a quarter million tons. The maximum output of 2,035,858 tons was reached in 1907. Following that year a rapid decline set in and continued until the maximum of production for 1913 was 1,138,699 tons. The production has remained practically stationary since. According to the State Coal Mine Inspector, the total coal sales for the year ending November 30, 1916, were 1,076,215 tons. This does not include coal used for steam and heat, therefore, it is probable that the total production is practically the same as in 1915.

The scarcity of coal and the resulting high prices in the winter and spring of 1917 has given a new impetus to the industry and probably the production in 1917 will show a large increase. The output, however, has been curtailed more or less by a shortage of cars and doubtless this will be the condition for most of 1917.

*For a more complete report on the coal industry in Michigan see Publication 19, Geol. Ser. 16, Mineral Resources of Michigan for 1914, pp. 247-270, also Vol. VIII, Pt. 2, Coal, by A. C. Lane.

PRODUCTION OF COAL IN MICHIGAN, 1869-1916, IN SHORT TONS.

Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.
1860	2,320	1871	32,000	1882	135,339	1893	45,979	1904	1,342,840
1861	3,000	1872	33,600	1883	71,296	1894	70,022	1905	1,473,211
1862	5,000	1873	56,000	1884	36,712	1895	112,322	1906	1,346,338
1863	8,000	1874	58,000	1885	45,178	1896	92,882	1907	2,035,858
1864	12,000	1875	62,500	1886	60,434	1897	223,592	1908	1,855,019
1865	15,000	1876	66,000	1887	71,461	1898	315,722	1909	1,784,692
1866	20,000	1877	69,197	1888	81,407	1899	624,708	1910	1,534,967
1867	25,000	1878	85,322	1889	67,431	1900	849,475	1911	1,476,074
1868	28,000	1879	82,015	1890	74,977	1901	1,241,241	1912	1,164,973
1869	29,980	1880	100,800	1891	80,307	1902	964,718	1913	1,138,639
1870	28,150	1881	112,000	1892	77,990	1903	1,367,619	1914	1,283,030
								1915	1,156,138
								*1916	1,076,215

*Report of State Coal Mine Inspector, State Department of Labor.

PRODUCTION, COST OF MINING, PROFITS, AND VALUE OF COAL IN MICHIGAN, 1900-1916.

Year.	*Number active mines.	Average number employees per month.	**Average daily wage.	†Total tons of coal mined.	Total cost of coal mined.	Average cost per ton.	***Total tons of coal mined.	***Total value of coal mined.	***Average price received per ton.	‡Profit made per ton.
1900	31	1,676	$2 34	871,388	$1,209,228	$1.387	849,475	$1,259,683	$1.483	$0.096
1901	30	1,847	2 44	1,016,496	1,442,415	1.419	1,241,241	1,753,064	1.412	.007
1902	32	1,616	2 75	899,967	1,284,342	1.427	964,718	1,653,192	1.714	.287
1903	34	3,014	2 91	1,601,984	2,529,027	1.579	1,367,619	2,707,527	1.979	.400
1904	33	2,733	3 01	1,408,375	2,266,098	1.609	1,342,840	2,424,935	1.806	.197
1905	38	2,776	2 96	1,413,307	2,244,434	1.588	1,473,211	2,512,697	1.705	.117
1906	38	2,106	2 40	1,367,385	2,090,489	1.529	1,346,338	2,427,404	1.803	.274
1907	37	2,897	3 24	1,911,201	3,162,837	1.655	2,035,858	3,660,833	1.798	.143
1908	38	3,115	3 02	1,842,778	3,089,759	1.677	1,835,019	3,322,904	1.811	.134
1909	36	2,907	2 93	1,736,573	2,865,083	1.650	1,784,692	3,199,351	1.793	.143
1910	34	2,471	3 07	1,462,276	2,626,342	1.796	1,534,967	2,930,771	1.909	.103
1911	32	2,539	3 39	1,389,585	2,623,244	1.887	1,476,074	2,791,461	1.891	.004
1912	26	1,886	3 19	1,160,768	2,170,076	1.869	1,201,230	2,399,451	1.989	.120
1913	24	2,076	3 49	1,138,163	2,250,559	1.977	1,231,786	2,455,227	1.993	.016
1914	23	2,146	3 35	1,153,869	2,285,281	1.99	1,283,030	2,559,786	1.99	.000
1915	20	1,942	3 45	1,069,798	1,929,386	1.77	1,156,138	2,372,797	2.05	.280
1916	18	1,794	3 57	1,076,215	2,049,812	1.90	.....	.....	.....	.....

*Compiled and adapted from reports of State Coal Mine Inspector, Ann. Repts. State Department of Labor.
**For year beginning Dec. 1 and ending Nov. 30.
***From Mineral Resources of United States, U. S. G. S.
†Does not include coal used for steam and heat.
‡Not including depreciation, interest on capital invested, etc.

PRODUCTION, COST OF MINING, ETC., OF COAL IN MICHIGAN BY COUNTIES AND MONTHS IN 1916.*

Counties.	No. of active mines.	No. of employees.	Aver. No. hours worked per day.	Aver. No. days worked per month.	Average daily wages.	Aggregate amount paid in wages.	No. mines using powder.	No. kegs of powder used.	No. tons of picked coal mined.	No. tons of machine coal mined.	Total No. tons of coal mined.	Aver. cost per ton.	Total cost of output.
December													
Bay	6	1,029	7.8	25.3	$3 55	$92,441 83	6	1,070	17,772	46,621	64,393	$1 86	$120,169 67
Saginaw	9	939	7.0	23.2	3 28	71,501 49	7	803	6,478	52,336	58,814	1 59	93,523 64
Other counties	18	247	.....	.....	.....	19,937 26	2	.....	1,649	4,662	6,311	1 89	11,908 82
Total	18	2,215	7.9	24.3	$3.40	$183,880 58	15	1,979	25,899	103,619	129,518	$1 74	$225,602 13
January													
Bay	7	1,166	7.9	21.4	$3 55	$89,052 08	7	1,003	13,472	49,987	63,461	$1 79	$114,201 01
Saginaw	6	813	8.0	23.1	3.47	64,289 08	5	743	7,917	45,472	53,389	1 64	87,821 14
Other counties	.....	203	.....	.....	.....	15,103 17	2	.....	1,572	4,603	6,175	2 10	12,988 54
Total	18	2,182	7.9	22.3	$3.48	$168,444 33	14	1,850	22,961	100,062	123,023	$1 74	$215,010 69
February													
Bay	5	892	7.9	18.9	$3 61	$61,900 55	5	739	11,642	35,811	47,453	$1 78	$84,515 96
Saginaw	7	935	7.9	19.5	3 46	63,510 26	7	588	7,145	44,029	51,174	1 60	81,992 93
Other counties	.....	183	.....	.....	.....	11,789 33	1	.....	1,338	3,953	5,291	1 93	10,213 85
Total	16	2,010	7.9	19.2	$3 54	$137,200 14	13	1,424	20,125	83,793	103,918	$1 70	$176,722 74
March													
Bay	5	893	7.9	24.4	$3 58	$68,869 50	4	912	8,949	46,497	55,446	$1 83	$101,757 61
Saginaw	7	902	7.9	22.4	3 44	70,751 52	7	628	5,263	48,045	53,308	1 74	93,231 85
Other counties	.....	186	.....	.....	.....	.....	1	.....	1,356	4,131	5,487	1 94	10,633 84
Total	16	1,981	7.9	23.1	$3 29	$150,452 33	12	1,629	15,568	98,673	114,241	$1 79	$205,623 30

PRODUCTION, COST OF MINING, ETC., OF COAL IN MICHIGAN BY COUNTIES AND MONTHS IN 1916.—*Concluded**

Counties.	No. of active mines.	No. of employees.	Aver. No. hours worked per day.	Aver. No. days worked per month.	Average daily wages.	Aggregate amount paid in wages.	No. mines using powder.	No. kegs of powder used.	No. tons of picked coal mined.	No. tons of machine coal mined.	Total No. tons of coal mined.	Aver. cost per ton.	Total cost of output.
April													
Bay	5	857	7.9	17.3	$3 69	$54,708 30	5	603	9,871	28,817	38,688	$2 02	$78,379 34
Saginaw	7	711	7.7	13.7	3 64	35,456 14	6	312	1,419	26,803	28,222	1 88	53,069 18
Other counties		185					1		532	1,417	1,949	1 90	3,696 83
Total	16	1,753	7.8	15.0	$3 42	$90,325 24	12	949	11,822	57,037	68,859	$1 96	$135,145 35
May													
Bay	4	548	7.7	20.8	$3 53	$42,596 00	3	488	6,624	24,810	31,434	$1 84	$58,089 52
Saginaw	6	650	7.9	16.4	3 60	38,741 38	6	349	3,948	25,274	29,222	1 87	54,934 28
Other counties		139					0		591	1,812	2,403	1 90	4,539 83
Total	13	1,337	7.8	17.9	$3 32	$86,563 38	9	837	11,163	51,896	63,059	$1 86	$117,563 63
June													
Bay	4	519	7.8	20.3	$3 77	$39,719 59	3	396	4,919	21,872	26,791	$2 08	$55,945 13
Saginaw	6	689	7.9	17.9	3 69	45,509 14	4	363	2,661	30,456	33,117	1 90	63,238 88
Other counties		15					0						568 50
Total	12	1,223	7.8	18.1	$3 72	$85,545 43	7	1,077	7,580	52,328	59,908	$2 29	$119,751 51
July													
Bay	5	770	7.9	19.8	$3 73	$54,189 50	5	403	8,073	16,900	24,973	$2 94	$73,537 41
Saginaw	5	692	7.5	15.2	3 73	39,596 76	5	278	4,071	20,004	24,075	2 36	56,878 89
Other counties		145					1		1,119	4,158	5,277	1 93	10,162 18
Total	13	1,607	7.9	18.1	$3 59	$103,690 76	11	744	13,263	41,062	54,325	$2 58	$140,578 48
August													
Bay	4	628	7.8	22.1	$3 84	$52,643 87	4	342	7,050	20,620	27,670	$2 51	$69,568 64
Saginaw	7	760	7.9	20.4	3 91	59,762 74	7	602	6,633	34,076	40,709	1 98	80,840 35
Other counties		159					1		1,313	4,833	6,146	1 90	11,613 72
Total	13	1,547	7.8	21.7	$3 73	$124,106 61	12	1,010	14,996	59,529	74,525	$2 17	$162,112 71
September													
Bay	5	798	7.9	19 5	$3 63	$57,302 80	5	576	8,060	27,433	35,493	$2 16	$76,776 65
Saginaw	7	737	7.9	23.8	3.85	64,189 45	6	425	3,512	49,705	53,217	1 63	87,247 55
Other counties		210					1		1.215	4,168	5.383	1 87	10,072 00
Total	15	1,745	7.9	21.7	$3 60	$137,192 75	12	1,041	12,787	81,306	94,093	$1 85	$174,096 20
October													
Bay	7	1,092	7.8	13.4	$3 77	$55,615 81	7	510	6,112	30,994	37,106	$2 28	$84,776 32
Saginaw	6	655	7.8	13.6	3 95	35,392 90	6	427	1,758	24,653	26,411	1 91	52,521 08
Other counties		182				11,772 00	1		825	2,882	3,707	1 93	7,128 90
Total	16	1,929	7.8	13.9	$3 80	$102,360 16	14	967	8,695	58,529	67,224	$2 14	$144,426 30
November													
Bay	4	761	7.6	23.7	$3 53	$63,900 44	4	490	3,289	39,554	42,843	$1 93	$82,897 61
Saginaw	9	1,020	7.9	22.6	4 03	93,958 29	9	973	11,471	62,989	74,460	1 85	138,082 79
Other counties		223				20,532 00	1		1,244	4,975	6,219	1 96	12,198 24
Total	15	2,004	7.7	23.3	$3 80	$178,390 73	14	1,518	16,004	107,518	123.522	$1 88	$233,178 64
Total for yr.						$1,548,152 44		15,025	130,863	895,352	1,076,215		$2,049,811 68
Average	15	1,794	7.9	20.1	$3 57			1,252	11,071	74,612		$1 90	

*Year ending Nov. 30. Adapted from report of State Coal Mine Inspector, Michigan Department of Labor.

PRODUCTION AND VALUE OF COAL BY COUNTIES.

Year.	Bay.			Eaton.	Jackson.	Saginaw.			Other Counties.†		
	Total coal mined.	Total value.	Average price per ton.	Total coal mined.	Total coal mined.	Total coal mined.	Total value.	Average price per ton.	Total coal mined.	Total value.	Average price per ton.
	Tons.			Tons.	Tons.	Tons.			Tons.		
1899....	104,588	....	....	3,421	21,600	455,607	....	....	....	....	....
1900....	190,814	....	....	4,530	23,317	601,112	....	....	....	....	....
1901....	253,821	....	....	4,803	20,288	938,042	....	....	....	....	....
1902....	248,645	....	....	8,800	23,889	670,304	....	....	....	....	....
1903....	325,021	....	....	7,393	23,307	1,011,898	....	....	....	....	....
1904....	410,634	....	....	9,057	16,860	906,289	....	....	....	....	....
1905....	544,154	....	....	4,058	9,196	915,803	....	....	....	....	....
1906....	481,398	....	....	18,507	8,658	835,475	....	....	....	....	....
1907....	962,574	....	....	5,982	5,645	1,047,927	....	....	....	....	....
1908....	782,503	....	....	2,286	5,539	999,338	....	....	....	....	....
1909....	822,577	....	....	558	1,500	859,434	1,290,933	1.93	101,115	207,545	2.05
1910....	766,470	1,432,293	1.87	100	....	667,282	1,267,652	1.90	90,036	200,825	2.23
1911....	717,084	1,320,484	1.84	1,000	....	667,954	1,267,652	1.90	90,036	200,825	2.23
1912....	630,931	1,237,449	1.96	374	....	504,612	1,025,959	2.03	70,313	136,043	1.92
1913....	591,718	1,176,095	1.99	155	457	596,193	1,194,553	2.00	43,263	84,579	1.93
1914....	617,415	1,215,469	1.97	82	1,287	584,648	1,194,430	2.04	79,598	149,887	1.86
1915....	551,772	1,081,452	1.96	a	a	539,036	1,126,717	2.09	65,330	164,628	2.52
*1916...	495,751	....	....	a	a	526,118	....	....	54,346	....	....

*Compiled from reports of State Coal Mine Inspector, Michigan Dept. Labor. Does not include coal used for steam and heat.
†Includes Calhoun, Eaton, Genesee, Ingham, Jackson, Shiawassee, and Tuscola, except as indicated.
(a) Included under "Other counties."

LIMESTONE.*

The growth of the limestone industry in Michigan was relatively steady from 1899 to 1904 but very rapid from that date to the present. In 1899, the total value of limestone products, including lime was only $281,769, and in 1904, $501,708. Ten years later, in 1914 the value of the products, exclusive of lime, which amounted to $287.648, was $1,457,961 or nearly three times that of both lime and limestone products in 1904. Large increases were made in 1915 and 1916, the total value of all products, except lime being respectively $1,828,766 and $2,389,763. The percentage of gain in 1916 was 30.6 per cent as compared with 25.4 per cent in 1915.

The chief increases were in stone for blast furnace flux, for the manufacture of soda ash and allied products, for concrete and for railway (?) ballast. The production of flux stone in 1910 was only 341,027 tons valued at $186,046 as compared with 2,254,984 tons valued at $763,029 in 1915 and 3,033,155 tons valued at $1,207,326 in 1916. The large increases for 1915 and 1916 in flux stone were due largely to the general industrial prosperity incident to the war and also to the development on a large scale of extensive deposits of very high grade limestone especially adapted for fluxing purposes. This stone is successfully invading the flux stone markets formerly dominated by limestone from other states.

Most of the high calcium limestone is located in Alpena, Presque Isle, Cheboygan, Emmet, and Charlevoix counties in the northern part of the Southern Peninsula and in Schoolcraft, Mackinac, and Chippewa counties in the Northern Peninsula. Important deposits occur at Sibley, Wayne county, and Bellevue, Eaton county. An undeveloped deposit occurs about two miles northeast of Dundee, Monroe county. Small deposits of uncertain commercial importance occur near the mouth of Portage river about six miles north of Jackson, Jackson county, and about three miles northeast of Omer, Arenac county. The reserves of high calcium limestone in the northern part of the state are practically inexhaustible.

Enormous deposits of very pure high magnesian limestone or dolomite occur in the Northern Peninsula near the lake shore from Seul Choix Pt., Schoolcraft county, eastward to Point Detour, Chippewa county. This dolomite is adapted for lining open hearth furnaces and for paper making. Extensive areas of impure limestone suitable for concrete, road material, and ballast occur in the vicinity of the high grade limestone areas in the Northern Peninsula. Low grade magnesian limestone or dolomite occurs in abundance in Monroe and Huron counties.

*For a complete report on the limestone resources of Michigan see Pub. 21, Geol. Ser. 17, Min. Res. of Mich. for 1915, pp. 103-112.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1915.

Year.	Rough building. Value.	Dressed building. Value.	Paving. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone. Road making. Tons.	Crushed stone. Road making. Value.
1899	$30,299	*	$62,815				$1,111		
1900	32,362	*	105,266				799		
1901	47,785	*		*	$380	$5,098	*		$31,605
1902	58,707	*		$489	200	3,101	5,740		56,261
1903	36,528	*	49,000	250	5,150	710	800		61,342
1904	32,941	$805	37,665			2,800	2,405		58,655
1905	17,071			160		744	1,568		112,113
1906	9,368	641	90,723	75		4,654	1,204		78,437
1907	15,120	100	56,500			1,433	1,234		131,708
1908	7,276		10,825	300	100	15,907	1,574		182,510
1909	4,450	7,445				1,572	3,615		132,902
1910	3,522		35,500			2,205	908		110,184
1911	7,526					165	380	$224,307	113,574
1912	9,997					380	75	603,553	295,449
1913	8,274					3,511	610	532,311	266,316
1914	3,537					1,651	6,727	505,133	242,839
1915	4,262		*			743	104	482,262	194,970
1916	5,633					*	*	834,215	420,467
Total	$334,658					$44,674	$28,854		$2,489,332

*Included in total for year.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1915.—*Continued.*

Year.	Crushed stone. Railroad ballast. Tons.	Crushed stone. Railroad ballast. Value.	Crushed stone. Concrete. Tons.	Crushed stone. Concrete. Value.	For blast furnace flux. Tons.	For blast furnace flux. Value.	To sugar factories. Value.	To alkali works. Value.
1899						$27,512		
1900						3,200		
1901		$18,200		$75,643		13,488		
1902		40,810		49,430		32,246		
1903		35,340		48,504		15,502		
1904		57,100		60,745		62,586		
1905		43,649		107,396		109,883		
1906		103,442		61,852		81,517	$224,356	
1907		46,516		97,762		109,429	22,234	
1908		33,900		73,200		56,841	32,594	
1909		42,445		112,829		91,915	25,845	
1910		42,358		178,318		100,149	69,647	
1911	91,713	34,998	306,385	137,285	341,027	186,046	65,141	*
1912	54,327	28,368	185,423	97,298	295,941	137,812	36,944	$508,044
1913	116,000	48,400	292,616	145,965	1,202,817	494,495	38,215	320,961
1914	38,000	20,600	362,209	166,959	1,604,240	565,012	69,477	269,087
1915	60,159	19,640	398,948	217,304	2,254,984	763,029	46,143	481,759
1916	186,949	57,950	323,479	155,084	3,033,155	1,207,326	41,709	438,783
Total		$671,716		$1,785,484		$4,057,988	$672,305	$2,018,638

*Concealed—included in total.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1915.—*Concluded.*

Year.	To carbonic acid plants.	To paper mills.	Fertilizer.		Other purposes.	To lime burners.	Rank of state.	Total.
	Value.	Value.	Tons.	Value.			Value.	Value.
1899	....	....	....	....	$2,375	$157,657	....	$281,769
1900	....	....	....	....	124,220	65,000	12	330,847
1901	....	....	....	....	101,399	136,173	12	429,771
1902	....	....	....	....	68,164	98,000	13	413,148
1903	....	....	....	....	4,747	132,600	14	390,473
1904	....	....	....	....	5,323	180,683	10	501,708
1905	....	....	....	....	142,790	9,380	12	544,754
1906	....	....	....	....	....	....	10	656,269
1907	....	....	....	....	278,297	....	11	760,333
1908	....	....	....	....	253,990	....	9	669,017
1909	....	....	....	....	327,571	....	11	750,589
1910	....	....	....	....	299,305	....	9	842,126
1911	....	$12,558	....	$3,003	440,857	....	8	1,005,751
1912	....	8,150	....	3,447	13,596	....	8	1,139,560
1913	....	10,723	....	7,048	395,874	....	7	1,408,703
1914	$53,138	8,307	10,907	11,104	39,523	....	8	1,457,961
1915	*	8,620	....	9,746	31,529	....	7	1,828,766
1916	....	11,827	....	11,088	39,896	....	....	2,389,763
Total	....	$60,185	....	$45,446	$2,569,456	....	....	$15,801,309

*Included in total.

LIME.

From 1904 to 1914 the lime industry in Michigan made no growth, the production being 63,601 tons in 1904, and only 66,359 tons in 1914. In 1915 there was an increase to 81,359 tons but this was 1,749 tons less than the maximum in 1909. In 1916 there was a large decrease to 52,878 tons. This was due largely to the fact that the Charlevoix Rock Products Co. went into the hands of the receivers and ceased operations for the year.

The lack of growth in the lime industry is due to several causes, chief of which are (1) the growing scarcity of suitable cheap wood fuel for burning lime, (2) the substitution of concrete for stone and lime-mortar in construction work, (3) the rapidly growing use of gypsum wall plasters and plaster substitutes, and (4) the unfavorable location of suitable limestone in relation to markets. Formerly, because of the abundance of cheap wood fuel and the difficulty of obtaining lime, lime-burning flourished in many localities in the state, inferior or hard burning limestone often being utilized. The cheapness of good lime, the ease of obtaining it with the development of means of transportation, and the growing scarcity of cheap fuel combined to drive most of the local burners out of business, especially those using inferior or hard burning stone. At present, no lime is produced in the central and southern portions of the state with the exception of a small amount in Arenac county. Lime is burned only at Menominee, Menominee county, Manistique and Marblehead, Schoolcraft county, and Rexton, Mackinac county in the Northern Peninsula and at Alpena, Alpena county, Afton, Cheboygan county, Petoskey and Bay Shore, Emmet county, and near Omer, Arenac county, in the Southern Peninsula.

Most of the exposures are in the northern part of the state relatively distant from ready markets. This makes it difficult for the Michigan burners to compete in the southern more populous portion of the state with lime producers in northern Ohio, Indiana, and Illinois, situated near cheap coal fuel supplies.

Concrete mortar is more easily and rapidly handled than stone and lime mortar and has largely displaced these materials in the building trades. For similar reasons gypsum wall plasters and plaster board have largely displaced sand-lime mortar for plastering.

Much of the lime produced is of the "hot" variety but considerable mild magnesian lime is burned at Manistique, Marblehead, Petoskey and Bay Shore. Hydrated lime is produced at Afton, and Manistique.

The total production in 1916 was 86,477 tons valued at $385,341 as compared with 81,359 tons valued at $349,979 in 1915. This was a net increase of 6.2 per cent in quantity and 10.1 per cent in value. The average price in 1916 was $4.45 per ton or .16 per ton more than in 1915.

PRODUCTION AND VALUE OF LIME IN MICHIGAN, 1904-1916.

Year.	Total lime burned.		Average price per ton.	No. of plants operating.	Rank of state, Production.
	Quantity, Tons.	Value.			
1904	63,601	$256,955	$4 04	.....	.....
1905	48,089	192,844	4 01	.....	.....
1906	68,133	281,465	4 13	13	.....
1907	65,822	276,534	4 20	12	16
1908	68,050	282,023	4 14	10	15
1909	83,108	354,135	4 26	12	13
1910	72,345	303,377	4 19	10	14
1911	80,709	352,608	4 37	14	14
1912	74,720	311,448	4 17	11	16
1913	77,088	331,852	4 05	10	14
1914	66,507	287,648	4 33	10	14
1915	81,359	349,979	4 29	10	15
1916	86,447	385,341	4 45	7	.....

BRICK AND TILE PRODUCTS.

Raw Materials. Most of the surface clays (see Clay) in Michigan are of low grade and of three general classes, (1) morainic clays or drift clays, (2) lake clays, and (3) river silts. The morainic clays are usually calcareous, containing from 10 to 15 per cent or more of lime. They also contain sand, pebbles, and boulders, hence the name boulder clay. Due to their sandy or calcareous nature, most of the clays are adapted for making only common brick and tile or low grade pottery. The high lime content causes most of the clays to burn white or cream colored. In some places, leaching has removed the lime to the depth of a few feet and clay from this surface portion burns red.

Exposures of clay or shale beds suitable for the manufacture of fire, vitrified, and front brick, vitrified tile, fire-proofing, and other high grade products are not abundant. Near Rockland, Ontonagon county, some of the lake clays belong to the slip varieties and are used for glazing pottery. At Grand Ledge, Eaton county, Jackson, Jackson county, Corunna, Shiawassee county, near Bay City, Bay county and Flushing, Genesee county, shales belonging to the coal measures have been utilized for vitrified and front brick, vitrified tile, sewer pipe, conduits, fireproofing, etc. For the past two years a project for the manufacture of front brick from Coal Measures shales has been under way at Williamston, Ingham county.

The Baker Clay Products Co., at Grand Ledge, has a modern plant equipped with continuous kilns and have begun the manufacture of front brick.

Production. In 1916 the value of brick and tile products in Michigan was $2,705,054, exclusive of pottery, as compared with $2,248,068 in 1915. This represents an increase of $456,986, or 20.3 per cent. The quantity of common brick increased from 277,399,000 in 1915 to 279,175,000 in 1916, a gain of .6 per cent. The value, however, increased from $1,461,188 in 1915, to $1,856,587 in 1916, an increase of 27 per cent. The average price of common brick in 1916 was $6.65 as compared with $5.23 in 1915, a gain of $1.42. The value of drain tile increased from $305,156 in 1915 to $548,795 in 1916, a gain of $243,639 or 79.7 per cent.

The manufacture of common brick has made great development in the vicinity of Springwells and West Detroit where extensive beds of suitable lake clays occur. The growth of Detroit in this direction, however, has made the land so valuable for building sites that the brick companies are gradually being forced into other localities.

In 1916, of a total of 279,175 common brick, 226,966 were made in Wayne county. Drain tile is next to common brick in importance with a reported value of $28,345. Sewer pipe is manufactured on a large scale at Grand Ledge and Jackson, but there are only two producers, hence no figures of production and value are given. Grand Ledge is also the chief center in the state for the production of vitrified drain tile. The manufacture of front or face brick in Michigan is in its infancy but with two plants in operation, one at Saginaw, Saginaw county, a new one at Grand Ledge, and another projected at Williamston, Ingham county, the production of this type of brick will become of considerable importance. This will meet a great need in the state, for a large amount of face brick is annually imported from Ohio and bordering states.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1916.

Year.	Common brick.		Average price per M.	Front brick.		Average price per M.	Vitrified brick.		Average price per M.	Fire brick.		Average price per M.
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
1899	200,144,000	$933,176	$4 66	4,290,000	$58,920	$13 73	*	*				
1900	180,892,000	863,250	4 77	8,421,000	48,411	5 75	*	*	$12 42			
1901	215,836,000	1,095,254	5 07	9,476,000	64,031	6 76	*	*	12 30			
1902	237,254,000	1,331,752	5 61	5,684,000	42,792	7 53	*	*	12 26			
1903	215,791,000	1,251,572	5 80	2,225,000	19,000	8 54	*	*	13 27			
1904	205,196,000	1,116,714	5 44	1,080,000	7,500	6 94	*	*	13 28			$13 00
1905	211,558,000	1,152,505	5 45	693,000	5,995	8 65	6,112,000	$81,706	13 37			19 37
1906	206,583,000	1,178,202	5 70	1,474,000	14,162	9 61	6,229,000	81,814	13 13			10 05
1907	200,817,000	1,181,015	5 88	3,956,000	32,116	8 12	7,911,000	94,601	11 96			12 00
1908	181,049,000	994,525	5 49	1,896,000	19,496	10 28	6,165,000	76,630	12 43			
1909	219,820,000	1,250,787	5 69	2,379,000	18,654	7 84	10,473,000	129,283	12 34			
1910	232,551,000	1,363,316	5 86	2,209,000	27,533	12 46	9,080,000	116,446	12 82			
1911	252,465,000	1,301,998	5 16	2,498,000	31,572	12 64	5,597,000	78,336	14 00			18 08
1912	271,189,000	1,592,283	5 87	3,934,000	41,476	10 54	6,600,000	92,000	13 94	*	*	17 78
1913	273,571,000	1,626,287	5 94	505,000	5,941	11 76	8,571,000	126,062	14 71	*	*	16 41
1914	269,154,000	1,633,216	6 07	1,488,000	21,121	14 19	7,733,000	120,562	15 59	*	*	19 78
1915	277,399,000	1,461,188	5 23	*	*	11 28	*	*	14 50	*	*	
1916	279,175,000	1,856,587	6 65				5,539,000	80,915	14 78			
Totals	4,130,444,000											

*Concealed; less than three producers.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1916.—*Concluded.*

Year.	Stove linings.	Drain tile.	Sewer pipe.	Fire-proofing.	Tile (not drain.)	Miscellaneous.	Hollow building tile or blocks.	Per cent of total product in U. S.	Rank of state.	No. of firms operating	Total value.
	Value.	Value.	Value.	Value.	Value.	Value.	Value.				
1899		$140,171	$50,300	$5,900		$22,709		1.68	13	196	$1,254,256
1900		114,747	57,916	2,350		406		1.50	17	189	1,147,378
1901		98,972	*	1,880		637		1.71	14	180	1,497,169
1902		96,645	*	3,290				1.69	13	182	1,660,942
1903		129,028	*				$19,138	1.58	14	178	1,662,414
1904		208,088	*				8,080	1.58	14	168	1,670,892
1905		205,445	*	*			3,585	1.41	16	154	1,719,746
1906		314,098	*				4,290	1.38	16	142	1,793,367
1907		289,868	*			1,500	6,386	1.39	17	136	1,786,190
1908		327,630	*	4,100		40,100		1.54	16	132	1,666,381
1909		364,006	*	*		66,128		1.44	16	122	1,947,059
1910		348,205	*			*		1.53	15	118	2,083,525
1911	$3,971	313,072	*	*	*	228,530	*	1.53	15	111	1,953,442
1912	*	387,945	*	1,461	*	235,459	*	1.73	13	101	2,350,606
1913		415,543	*	*	*	350,000	*	1.73	13	95	2,451,242
1914	*	421,941	*	3,752	*	234,280	*	1.88	10	90	2,434,872
1915		305,156	*	10,850	*	49,755	*	1.79	11	82	2,248,068
1916		548,795	*	2,492	*	216,265					2,705,054
Totals		$5,029,355									$34,032,603

*Concealed under miscellaneous; less than three producers.

CLAY.

The clays* of Michigan are of three general classes, viz.: (1) morainic or drift clays (2) lake clays and (3) river silts. Deposits of kaolin or china clays are not known in Michigan and the chances for the occurrence of commercial deposits of such clays appear to be small. Deposits of kaolin have been reported at various places in the Northern Peninsula, but these so far as investigated, have proved to be white or calcareous lake clays of the slip variety. The morainic clays, boulder and till clays, are always calcareous, some of them being very high in lime, especially in limestone regions. In such regions the clays locally approach the nature of impure marls. The lake clays are generally less calcareous but locally, as in limestone regions, they may contain a large percentage of lime. The river silts are the least calcareous but they are usually gritty. On account of the high content of lime, most of the clays burn white. In many beds, however, there is an upper portion relatively free from lime which burns red, and a lower one very high in lime which burns white or cream color. The absence of lime in the upper portion is due to leaching. In such cases, there is usually a zone of lime balls between the leached and unleached portions.

The morainic or drift clays contain pebbles, and boulders (hence the name "boulder clay,") and locally lime concretions. Screening and washing have been resorted to at some plants to separate the clay but the extra expense is generally prohibitive except in districts where good clays are wanting or where the clays possess special burning qualities. The lake clays are comparatively free from pebbles and coarse sand but some contain much very fine grit. These clays are generally suitable for making common brick and tile. There are inexhaustible supplies of such clays in the eastern portion of the Southern Peninsula from Arenac county south to the Ohio boundary. Large areas of lake clays also occur in Chippewa and Ontonagon counties.

The morainic or boulder clays have been developed for the manufacture of common brick and tile at many places in the state but generally on a small scale. The lake clays in the vicinity of Springwells and West Detroit have been developed very extensively for making common brick. With the growth of the city in this direction the land has become so valuable for building sites that the brick industry is being gradually forced into other localities. Important developments have also been made near Paines and West Saginaw, Saginaw county, and at numerous places in Lenawee, Monroe, and Macomb counties.

*H. Reis, Vol. VIII, pt. I, p. 48, Clays and Shales of Michigan, Mich. Geol. Surv.

In Ontonagon county some of the clays are of the slip variety and are suitable for glazing pottery. A deposit of slip clay is also reported near Harriette, Wexford county.

Most of the surface clays in Michigan are low grade and generally the mining of such clays is merely incidental to the manufacturing of common brick and tile. Nearly all of the clay sold as clay in Michigan is slip clay. It is mined chiefly near Rockland, Ontonagon county, and shipped to potteries in Ohio and other states for glazing. The great distance of the beds from the centers of the pottery industry is a serious obstacle in promoting development. In some years, a small amount of clay is sold for medicinal purposes.

PRODUCTION OF CLAY IN MICHIGAN, 1910-1916.

Year.	Slip clay.		Brick clay.		Miscellaneous clay.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1910	1,363	$3,889	60	$105	1	$400	1,424	$4,394
1911	1,744	5,090	18	32	2	150	1,764	5,272
1912	2,034	6,164	.....	.....	9	9	2,043	6,173
1913	1,710	6,504	.....	.....	.....	.....	1,710	6,504
1914	1,463	4,572	.....	.....	.....	.....	1,463	4,572
1915	1,198	3,805	*	*	*	*	3,142	5,605
1916	.....	10,509	.....	.....	.....	.....	3,454	11,193
Total	.....	.....	.....	.....	.....	.....	.....	$43,713

*Included in total.

POTTERY.

The pottery industry in Michigan has made almost uninterrupted growth since 1899 and since 1908 the growth has been rapid, particularly in the last three years. In 1899, the total value of the pottery output was $29,741; in 1908, $62,409; in 1910, $112,697; in 1915, $521,989; and in 1916, $792,716. The value in 1916 increased $270,727, or 51.8 per cent. The increase was largely due to the greatly increased output of porcelain and decorated ware and porcelain sanitary and electrical supplies.

The products are chiefly porcelain electrical supplies, decorated and white ware, and flower pots. Of seven firms, three, the Detroit Flower Pot Company, and Anton Hupprich, of Detroit, and the Ionia Pottery Company manufacture flower pots exclusively. The Jeffery-DeWitt Co. of Detroit, manufacture a variety of porcelain products,—sanitary ware, insulators, spark plugs, tumbling jars, crucibles, etc. The Mt. Clemens Pottery Company, Macomb county, manufactures decorated ware and the Pontiac Clay Pipe Novelty Co., Oakland county, clap pipes and novelty ware.

The clays used for the manufacture of flower pots are obtained from Michigan but those for porcelain products, pipes, etc., are imported from other states and countries, for, no deposits of china or ball clays have been found in Michigan.

VALUE OF POTTERY PRODUCTS IN MICHIGAN, 1899-1916.

Year.	Rank of state.	No. firms.	Red earthenware. value.	Porcelain electrical supplies. value.	C. C. ware. value.	Miscellaneous, value.	Total value.	Gain per cent.	Per cent. of total product in U. S.
1899	18	4	$29,641	....	$100	....	$29,741	....	.17
1900	17	4	34,317	....	....	....	34,317	15.4	.17
1901	16	5	42,465	....	....	$2,400	44,865	30.2	.20
1902	14	4	44,098	....	....	39,000	83,098	87.4	.41
1903	19	4	42,007	....	....	6,000	48,007	−42.2	.19
1904	17	4	40,621	....	....	3,000	43,621	−9.1	.17
1905	17	5	*	....	*	7,000	45,961	4.5	.16
1906	17	6	43,510	....	....	7,600	51,110	11.2	.16
1907	16	6	54,474	....	....	7,100	61,574	18.5	.20
1908	16	6	54,659	....	....	7,750	62,409	1.5	.25
1909	13	5	60,939	....	....	34,500	95,439	52.9	.31
1910	13	6	94,450	*	....	13,300	112,697	18.1	.33
1911	13	6	80,580	*	*	*	130,490	15.8	.38
1912	10	6	99,555	*	....	*	194,892	49.3	.53
1913	10	5	65,000	*	....	*	222,133	20.8	.59
1914	9	5	106,452	*	*	*	265,194	33.0	.75
1915	8	6	112,863	*	*	*	521,989	96.7	1.40
1916	8	7	123,734	†	†	668,982	792,716	51.8	1.64
Totals	....	....	....	....	....	....	$2,840,253	....	....

*Included in the total.
†Included under miscellaneous.

SAND-LIME BRICK.

The first sand-lime brick plant in the United States was started at Michigan City, Indiana in 1901. The sand-lime brick industry was a "boom" industry and within two years nine plants were in operation, in the process of building, or projected. Under the erroneous impression that sand-lime brick, satisfactory for most purposes could be made much more cheaply than ordinary clay brick, many plants were erected all over the country without proper investigation of marketing conditions, transportation facilities, competition from clay brick or of the character and supply of the raw materials, and methods of manufacture. The industry suffered from the resulting failures and especially from the generally poor character of the product.

The sand-lime brick industry is more adapted to regions where good brick clays are scarce and sand abundant, but for ordinary building purposes, sand-lime brick, where properly made, is now successfully meeting competition from clay brick, in the face of a more or less general prejudice on the part of contractors against sand-lime brick.

Fortunately in Michigan most of the early plants were started in widely separated regions, and for from large clay working industries or were located near large cities which afforded a ready market for a limited production. The industry therefore did not suffer from as large a proportion of failures as in some of the other states and has maintained a relatively steady growth.

Michigan quickly attained first rank as a producer of sand-lime brick, which rank she has held since 1904, with the exception of one year.

The growth has been in increased production rather than in number of plants. In 1904, ten plants were in operation and produced only 10,440,000 brick of all grades, valued $69,765. In 1905, twelve plants were in operation and produced a total of 26,421,000 brick valued at $169,302. Since 1905, the number of operating plants has remained about the same, fluctuating between 10 and 13, but the production and value have greatly increased. The number of operating plants in 1916 was the same as in 1905 but the production was 72,004,000 brick of all grades, valued at $499,711, or about two and three-fourths times the number and nearly three times the value in 1905. This is the maximum in the history of the industry and represents an increase over 1915 of 52.3 per cent in quantity and 74.1 per cent in value. The average price of common brick in 1916 was $6.92 per thousand as compared with $6.04 per thousand in 1915.

General conditions were evidently much improved over 1915, for out of twelve operators, ten reported much better demand and higher prices, one, trade conditions about the same, and one, poorer trade. Labor scarcity was reported by two operators.

The production of front and fancy brick has fluctuated greatly. The production of front brick increased from 580,000 in 1904, to about 2,000,000 in 1907, then decreased the following year to about 900,000. The maximum production of 3,255,000 was reached in 1910. Since 1911 the production of front brick has not exceeded 1,000,000 per year. It appears that front and fancy sand-lime brick as manufactured are not as satisfactory for outside work, or cannot be produced as cheaply as clay front brick.

Since 1904, Michigan has held first rank among the states both in number of operating plants and value of output, with the exception of 1906 when New York took first place. For a number of years, Michigan has produced nearly twice or more than twice as many sand-lime brick as any other state and in 1916 produced one-third of the total value for the United States. In 1916, twelve plants were in operation in Michigan, whereas Florida and Minnesota, the nearest competitors, each possessed four plants. In 1916 a new plant replacing the plant of the Fairview Brick Company, of Detroit, which was burned in 1915, was put in operation by Flood and Hall at Fairview, a suburb of Detroit. Two plants are located at Detroit and one each at Flint, Grand Rapids, Kalamazoo, Menominee, Ripley (Houghton County), Rives Junction (Jackson County), Rochester (Oakland County), Saginaw, Sebewaing (Huron County), and Sibley (Wayne County).

ANNUAL PRODUCTION AND VALUE OF SAND-LIME BRICK IN MICHIGAN AND UNITED STATES, 1904-1916.

Year.	No. of operating firms reporting.—Mich.	No. of operating firms reporting.—U. S.	Michigan production. Common brick. Quantity, (thousands).	Common brick. Value.	Average price per thousand.	Front brick. Quantity, (thousands).	Front brick. Value.	Average price per thousand.	Fancy brick. Quantity, (thousands).	Fancy brick. Value.	Total value Michigan.	Change per cent.—Michigan.	Total value United States.	Per cent of total production of U. S.	Rank. Production.	Rank. Value.
1904...	10	57	9,886	$64,034	$6 64	580	$5,234	$9 02	19	$497	$69,765	....	$463,128	15.6	1	1
1905...	12	84	24,841	155,883	6 28	1,577	12,893	8 17	24	526	169,302	142.7	972,064	17.4	1	1
1906...	11	87	27,281	162,879	5 97	1,796	12,022	6 69	7	20	174,921	3.3	1,170,005	15.0	1	2
1907...	13	94	25,488	158,606	6 22	*2,000	14,234	7 17	......	......	172,840	−1.2	1,225,769	14.1	1	1
1908...	10	87	21,997	131,827	5 99	*900	6,982	7 76	......	......	138,809	−19.7	1,029,699	13.5	1	1
1909...	11	74	34,217	207,082	6 05	*1,600	11,144	6 97	......	......	218,226	57.2	1,150,580	19.0	1	1
1910...	10	76	37,648	218,627	5 81	3,256	22,022	6 76	......	......	240,649	10.3	1,169,153	20.5	1	1
1911...	10	66	32,889	192,224	5 84	2,726	17,777	6 52	......	......	210,001	−12.7	897,664	23.4	1	1
1912...	11	71	48,129	307,106	6 38	1,163	9,626	8 27	......	......	316,732	50.8	1,200,223	26.4	1	1
1913...	12	68	49,373	315,882	6 40	†	†	......	†	†	321,245	1.7	1,238,325	25.9	1	1
1914...	12	62	41,456	248,113	5 98	†	†	......	†	†	255,784	−24.4	1,058,512	23.5	1	1
1915...	11	56	46,513	281,009	6 04	†	†	......	†	†	286,948	11.8	1,135,104	25.3	1	1
1916...	12	53	71,116	491,866	6 92	888	7,845	8 83	......	......	499,711	74.14	1,474,073	33.8	1	1
Total..	....	....	470,834	$2,935,138	$6 23	....	....	......	......	......	$3,074,933	....	....	....	......	......

*Estimated. †Included in total.

SANDSTONE.

For many years before the close of the last century the quarrying of sandstone was an important industry in Michigan. There were numerous quarries, though generally small, in Hillsdale, Jackson, Calhoun, Ionia, Eaton and Huron counties. No records, however, were kept until near the close of the century. In 1899, the production was valued at $178,038, the largest recorded, except in 1902, when the value of the output was $188,073. A rapid decline, though intermittent at first, began in 1900, and continued until 1911, when the industry all but ceased, the value of the output being only $12,985. For the past three years there have been only one or two producers, hence no figures have been given.

The decline of the sandstone industry in Michigan may be ascribed to (1) the poor quality of much of the sandstone, (2) the substitution of concrete in construction work and (3) the greater use of brick and artificial stone.

Quarries formerly were operated in the sandstone of the Coal Measures near Ionia and at other places in Ionia county, and at Grand Ledge, Eaton county; and at many places in the Marshall sandstone in Calhoun, Hillsdale, Jackson, and Huron counties. Most of the sandstone in these formations upon exposure to the weather for a few years, alters more or less uniformly or in spots and streaks to an unsightly yellow color. This is due to the fact that the cementing material, especially in the Marshall, contains a considerable amount of iron carbonate, which upon exposure to the weather is oxidized to limonite. The sandstone near Ionia, though soft and friable is streaked and mottled with red, orange, and yellow and makes a pleasing appearance in buildings. Some of the stone when first quarried is reported to be so soft that great care must be used in handling to prevent breakage. After seasoning for some time, the stone becomes sufficiently hard to work and strong enough for ordinary building purposes. The only quarries operating in the Marshall at the present time are at Grindstone City and Eagle Mills, Huron county, where the gritstones near the base of the formation are quarried for grindstones and scythestones. Some rubble and riprap are produced incidentally to the quarrying of gritstone, at Eagle Mills by the Wallace Company of Port Austin.

The only quarry producing sawed and rough building block is near Jacobsville, Houghton county. Extensive quarrying operations have been carried on near Portage Entry for many years but now the Portage Entry Redstone Co. is the only active operator. The sandstone is known as the Jacobsville and is apparently the

equivalent of the Lake Superior or Upper Cambrian sandstone. The "redstone" or "brownstone" of the Jacobsville is well cemented, permanent in color and pleasing in appearance, but the great distance from markets is a serious obstacle to development.

Formerly much sandstone was quarried for foundations but concrete has largly displaced stone for such purposes because of the cheapness of concrete and the rapidity and the ease of handling. Front and fancy brick are relatively cheap and a variety of artistic effects are possible through their use. Because of this they have largely displaced stone as a building material, except for foundations.

Artificial stone is now displacing natural stone for these, especially for outside work.

Apparently the sandstone industry will not soon regain its former importance.

*PRODUCTION AND VALUE OF SANDSTONE IN MICHIGAN, 1899-1916.

Year.	Rough building. Value.	Dressed building. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone. Road making. Value.	Crushed stone. Concrete. Value.	Other. Value.	Total. Value.
1899	$102,447	$51,682	$109	a					$23,800	$178,038
1900	73,850	58,800			$26,519					132,650
1901	128,909					b			19,000	174,428
1902	136,280	23,600			27,393	$800				188,073
1903	89,931	10,365			15,554		$2,050	$3,450		121,350
1904	47,593	14,818			10,657		1,400	400		74,868
1905	64,056	36,035			10,332				12,700	123,123
1906	35,272	18,950			10,403	770				65,395
1907	33,561	10,918		$528	7,900	96				53,003
1908	15,100	18,813			5,190					39,103
1909	12,985	16,805			6,294					36,084
1910	13,312	15,416			2,505					31,233
1911	5,682	2,809			3,068	1,140			286	12,985
1912	c	c			c	c			a	16,438
1913	c	c			c	3,127			c	19,224
1914	d	d			d	d				d
1915	d	d			d	d				d
1916	d	d			d	d				d
Totals			$109					$3,850		

a Included under curbing.
b Included under rubble.
c Included in total.
d Figures not given—less than three operators.
*Exclusive of sandstone made into grindstones and scythestones.

GRINDSTONES AND SCYTHESTONES.

Although Michigan ranks second to Ohio in the production of grindstones and scythestones, the latter state produces about eight times as much as Michigan. The "grit" or "grindstone" occurs in the lower part of the Marshall formation in Huron county. The Wallace Company of Port Austin and the Cleveland Stone Company operate quarries at Eagle Mills and Grindstone City respectively where the gritstone occurs in low-lying and thinly drift covered ledges near the shore of Lake Huron. The surface deposits are removed by stripping, and the stone is cut by channelling machines into square blocks eight feet or more in thickness. These are split with wedges along the bedding planes into thinner slabs which are loaded on cars by derricks, then carried to the mills for sawing into grindstones. The grindstones vary in size from very small ones a foot in diameter up to those seven feet in diameter with a 14-inch face. The broken stone is made into various grades of scythestones.

As there are but two producers no tables of production and value can be given.

SAND AND GRAVEL.

Michigan has very large sand and gravel resources. The most important deposits occur in the form of ridges known as "hog-backs" or eskers, in irregular hills, called kames, in out-wash plains and deltas, and in old beach ridges, features resulting from the last glacial invasion. Only a small portion of the sand and gravel resources have been developed. The chief developments are in the southern half of the Southern Peninsula and in the vicinity of cities, in river channels, and along the shores of the Great Lakes where means of transportation are favorable. Large pits are locally developed in building state award roads. The chief localities and counties in order of importance are: Detroit and St. Clair rivers and Kent, Washtenaw, Macomb, Ingham, Livingston, Manistee, Oakland, Berrien, Jackson, Kalamazoo, and Calhoun counties.

In 1916 Michigan produced 4,407,475 tons of sand and gravel valued at $1,295,717. This represents a gain of 630,749 tons or 16.7 per cent in quantity, or 24.9 per cent in value. The chief increases in quantity were in moulding sand, building sand and gravel. There were but two producers of glass sand (See Glass-Sand) in 1915, hence figures of production and value are not given.

PRODUCTION AND VALUE OF SAND AND GRAVEL IN MICHIGAN, 1904-1916.

Year.	Glass sand.		Molding sand.		Building sand.		Fire sand.		Engine sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1904	.....	.....	167,147	$76,299	69,656	$30,898	.....	.....	.....	.....
1905	.....	.....	19,382	13,247	263,315	148,065	5,000	$2,500	.....	.....
1906	600	$3,000	61,387	26,108	403,199	127,937	.....	.....	4,000	$400
1907	4,300	8,600	54,172	24,190	451,646	157,150	6,000	3,000	1,534	153
1908	17,000	34,000	4,584	2,892	474,238	228,395	.....	.....	1,991	319
1909	65,000	79,000	53,226	20,756	1,090,419	327,247	4,000	2,000	12,415	1,493
1910	16,212	25,675	93,812	24,004	1,151,588	334,336	5,000	3,000	22,270	2,172
1911	*	*	68,878	17,901	833,729	247,997	*	*	25,392	4,447
1912	*	*	152,433	40,145	902,556	294,115	.....	.....	18,575	4,774
1913	*	*	50,763	17,493	1,326,016	415,737	4,542	4,542	4,447	647
1914	26,035	32,593	53,400	36,583	1,088,650	360,152	.....	.....	6,357	1,066
1915	*	*	82,666	25,998	843,887	236,956	4,601	5,751	70,077	2,794
1916	*	*	117,200	31,978	1,234,280	350,138	*	*	*	*
Totals	.....	.....	979,051	$357,595	10,133,179	$3,269,123	.....	.....	167,058	$18,265

Year.	Furnace sand.		Paving sand.		Other sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.	
1904	.....	.....	.....	.....	.....	.....
1905	.....	.....	.....	.....	50,187	$14,476
1906	5,000	$2,500	.....	.....	51,005	12,140
1907	3,858	3,133	.....	.....	173,724	12,187
1908	3,329	3,828	.....	.....	29,187	6,850
1909	3,183	3,660	.....	.....	295,612	50,953
1910	3,185	4,924	.....	.....	372,880	57,385
1911	*	*	152,144	$29,650	114,801	52,005
1912	.....	.....	68,453	16,898	130,624	54,746
1913	†	†	533,261	108,328	113,318	20,342
1914	†	†	320,322	74,866	115,291	107,392
1915	.....	.....	131,466	14,021	111,105	12,248
1916	*	*	154,413	38,068	228,003	103,722
Totals	.....	.....	1,360,059	$287,831	.....	.....

Year.	Railroad ballast.		Gravel.		Total.		Rank.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1904	.....	.....	.....	.....	236,803	$107,197	.....	.....
1905	.....	.....	76,625	$32,321	414,509	210,609	10	11
1906	.....	.....	72,598	25,614	597,789	197,699	12	13
1907	.....	.....	329,407	81,182	1,024,641	289,595	10	11
1908	.....	.....	312,262	94,081	842,591	370,365	8	9
1909	.....	.....	695,902	200,523	2,219,757	685,632	8	8
1910	.....	.....	1,197,791	364,841	2,862,738	816,337	7	8
1911	.....	.....	935,072	203,218	2,185,165	565,969	9	10
1912	.....	.....	1,409,180	407,925	2,681,821	818,603	9	8
1913	.....	.....	3,928,874	915,205	6,422,818	1,528,892	4	5
1914	7,565	$781	2,140,359	530,338	3,757,979	1,143,771	8	7
1915	.....	.....	2,457,094	671,970	3,776,726	1,036,739	.....	.....
1916	.....	.....	2,226,878	726,033	4,407,475	1,295,717	.....	.....
Totals	.....	.....	15,782,042	$4,298,251	31,530,812	$9,067,125	.....	.....

*Included under other sand. †Included under fire sand.

GLASS SAND.

Glass sand is extensively quarried near Rockwood, Wayne county and near Steiner, Monroe county. The glass sand rock occurs in the Sylvania sandstone or Middle Monroe of the Silurian. The Sylvania underlies a belt extending west from the mouth of Detroit river, then curving to the southwest across the southeast corner of Wayne county and through Monroe county, leaving it near the southwest corner. The belt is from three to five miles wide except in the southwest corner of Monroe county where it narrows to about one-half mile. The Sylvania is exceedingly variable in thickness. In Wayne county, along Detroit river it is from 70 to 165 feet in thickness and here as elsewhere contains horizons of sandy dolomite. To the southwest it thins irregularly until near the Ohio line it is about 35 feet thick.

The sandstone is exposed or is near the surface in three localities, viz.: in the southwestern part of Whiteford township (T. 8 S., R. 6 E.) and in the vicinity of Steiner, Monroe county, and Rockwood, Wayne county. In section 28 of the Whiteford township area the overburden is locally ten feet or less in depth. It is exposed for a considerable distance in the bed of Raisin river near Steiner in the southwest quarter of sec. 2, T. 6 S., R. 8 E. At this place the rock is exposed* or covered by a few inches of soil on an area of 8 to 10 acres and on an area of 60 acres the overburden is reported to be nowhere more than two or three feet thick.

There are no natural exposures of the Sylvania in Wayne county but east of Rockwood in section 16, in the vicinity of the pits of the American Silica Company, the overburden is only from five to eight feet deep. Apparently there is an area of several hundred acres in the vicinity of Rockwood where the overburden does not exceed twenty feet.

Typically the sandstone is a remarkably pure, sparkling, snow-white aggregation of fine incoherent quartz grains of very uniform size and resembling granulated sugar. Lumps of it may be readily crumbled in the hands and when placed in water they literally fall to pieces. At the pits of the American Silica Co. east of Rockwood, Wayne county and of the National Silica Co. near Steiner, Monroe county, the sandstone is washed down by a small stream of water from a hose. At the Rockwood pit there is a stratum of hard dolomitic sandstone which requires blasting. The material after being crushed and washed is pumped into bins where it is allowed to drain.

Some years ago the Rockwood Silica Sand Co. drilled a well just

*W. H. Sherzer, Vol. VII, pt. 1, p. 54, Geology of Monroe County, Mich. Geol. Surv.

east of Rockwood (SE ¼ SW ¼, Sec. 10) to the depth of 122 feet penetrating 15 feet of clay, 15 feet of dolomite, and 92 feet of glass sand rock without reaching the bottom of it. A six-inch casing was used to rock and below this a four-inch casing, through which steam under a pressure of 60 pounds per square inch was injected, forcing out water and sand. About a car-load of sand per day was obtained in this way.

Glass sand pits known at "Tolls Pits" were opened many years ago near Steiner, Monroe county. These properties later were taken over by the National Silica Co. which operated them up to 1916 when its plant was burned down. The property has been recently sold to the Ford Plate Glass Co. of Toledo, Ohio. The Whiteford area is undeveloped.

Immediately beneath the drift, the sandstone is more or less colored to a depth varying from a few inches to several feet, by iron from percolating surface waters. Elsewhere the sandstone is remarkably free from iron. In the pit of the American Silica Co. at Rockwood, there are numerous masses of celestite, or strontium sulphate, and native sulphur. The masses appear to be most numerous near the horizon of dolomitic sandstone. Washing removes practically all of the small amount of dolomitic cement in the incoherent sandstone, and most of it from the dolomitic sandstone. The sand as marketed is said to average over 99 per cent silica and is adapted for making the highest grades of glass.

The following analyses are of the crude unwashed sand from the pits of the National Silica Co. at Steiner, Monroe county, and of the washed product from the pit of the American Silica Co. at Rockwood, Wayne county.

ANALYSIS OF GLASS SAND.

	Crude Percent.	*Washed Percent.
Silica	96.50	99.70
Calcium carbonate	1.50	0.08
Magnesium carbonate	1.04	0.22
Iron oxide	0.00	....
Surphuric acid loss and undetermined	0.76	....
Loss on ignition	0.20	....

A large amount of glass sand is produced from these pits and sold to plate glass factories in Michigan, Ohio, and other states. The washed sludge containing the fine grit is used for the ignition sur-

*Analyst Dr. J. E. Clark, Detroit.

face on match boxes. Since there are but two producers, no figures of production can be given, the output being included in the state totals of sand and gravel.

NATURAL GAS.

In Michigan natural gas* is obtained both from the drift and from the underlying bed rocks. The supply in Macomb and Oakland counties is entirely from the drift, but in St. Clair county it is chiefly from the oil wells (See Petroleum), where it occurs in association with the oil. Gas also occurs in considerable quantities in the drift around Portage Lake, Manistee county, and in Alcona and Montmorency counties.

The surface gas is most abundant in the belts underlain by the bituminous and petroliferous Devonian formations and presumably is the result of leakage from these formations. At many places in these belts, gas is given off in springs and shallow wells, sufficient in some cases to be lighted. Many explorations have been made upon the basis of such evidence but no gas of commercial importance was found in any of the borings. In general such signs are of little significance in Michigan, particularly as they are most frequent along the line of exposures of the oil and gas bearing formations, therefore are in the zone of leakage, rather than accumulation.

The gas generally occurs in small volume and under low pressure, the pressure generally varying from a few pounds to forty pounds or more. Most of the wells yield gas sufficient only for the needs of a family or two. Generally they last for a number of years but some of them "play out" in a few days or weeks. In Oakland and Macomb counties, 25 or 30 drift gas wells are or have been utilized by farmers for heating and lighting purposes. According to the reports of the owners many of the wells have been declining rapidly in pressure and volume during the past three years.

Many artesian wells around Portage Lake, Manistee county, yield some gas. In 1913 gas was struck in a well in drift west of Onekama near the shore of the lake. The gas was under a pressure of about 190 pounds per square inch. At last reports, the gas from only a few of the wells has been utilized. Small drift gas wells also occur and are utilized to a limited extent in Benzie, Monroe, and Washtenaw counties.

At Port Huron, some of the May and Gillette oil wells about two miles west of Port Huron are reported to yield from 20,000 to 40,000 cubic feet per day, when allowed to flow freely. The gas pressure is said to vary from 125 to over 250 pounds per square inch. In 1915,

*Pub. 14, Geol. Ser. 11, Occurrence of Oil and Gas in Michigan, 1912.

a project was under way for utilizing the excess gas for lighting a small suburb of Port Huron, but apparently nothing came of it. Several other wells drilled for oil in various parts of the city yield sufficient gas to be utilized for domestic and industrial purposes.

At Mt. Clemens, some of the wells, from which the mineral water for the bathing establishments is obtained, also yield gas nearly sufficient for heating the boilers used for pumping.

The total production of natural gas in the state however, is relatively insignificant, the average value for the past six years being less than $1,500 annually.

PRODUCTION OF NATURAL GAS IN MICHIGAN, 1911-1916.

Year.	No. of producers.	Domestic.		Industrial.		Other.		Total.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
		M. cu. ft.		M. cu. ft.		M. cu. ft.		M. cu. ft.	
1911...	22	930	$930	.....	.....	800	$400	1,730	$1,330
1912...	17	.....	1,020	900	$450	.....	.....	900	1,470
1913...	.....	.....	.....	.....	.....	.....	.....	1,805	1,405
1914...	.....	.....	.....	.....	.....	.....	.....	2,442	1,442
1915...	16	960	960	.....	.....	1,100	550	2,060	1,510
1916...	12	598	598	.....	.....	700	350	1,298	948
Total..	.....	.....	.....	.....	.....	.....	.....	.....	.....

PETROLEUM.

Oil* has been found in small quantities at many places in Michigan, notably at Port Huron, Allegan, and Saginaw. At Port Huron† there are two principal groups of productive wells and several scattered wells. All of the wells are very small, the average yield per day probably being about one-half barrel. Some of the wells when first drilled are said to have yielded as much as seven barrels per day, but the production gradually fell off to less than a barrel. Most of the wells yield gas and some of them, considerable quantities. Their shallow depth, 500 to 600 feet, and the presence of sufficient gas for motive power in pumping the wells and drilling new ones, make possible profitable operation. The G. B. Stock Xylite Grease and Oil Company operates a group of eighteen wells and uses the oil in the manufacture of lubricants for which it is adapted. A group of eleven wells has been drilled on the Henry May and Lawrence Gillette farms near the "Oxbow" bend of Black

*Pub. 14, Geol. Ser. 11, Occurrence in Oil and Gas in Michigan, 1912.
†See Publication 19, Geol. Ser. 16, Mineral Resources of Michigan for 1914 for a more complete discussion of the Port Huron field.

River about two miles west of North Port Huron. Drilling is now (June, 1917) in progress on the Henry May farm. The average yield of oil from these wells, when pumped, is said to be similar to that of the Stock wells. It is probable that a few more small wells will be sufficient to make the operation of this group profitable, especially as some of the wells yield significant quantities of gas, more than sufficient to furnish power for operating the wells and drilling new ones.

There was but one operator reporting a production in 1916, hence figures of production and value are omitted.

MINERAL AND SPRING WATERS.

There has been a persistent decline of the mineral water industry in Michigan since 1902, though the amount and value of mineral and spring waters produced in Michigan fluctuate greatly from year to year.

PRODUCTION AND VALUE OF MINERAL WATERS IN MICHIGAN, 1900-1916.

Year.	Rank.		No. of Springs active.	Total.		Medicinal. Value.	Table. Value.	Average price per gal.
	Quantity.	Value.		Quantity. Gals.	Value.			
1900.....	6	4	28	3,398,996	$411,935	.....	.....	$0.121
1901.....	2	1	28	7,019,168	1,195,614	.....	.....	0.170
1902.....	1	9	28	8,653,690	275,763	.....	.....	0.032
1903.....	1	9	19	6,919,107	200,668	.....	.....	0.029
1904.....	7	13	19	3,385,675	118,422	.....	.....	0.035
1905.....	4	4	17	2,684,800	277,188	$38,900	$238,288	0.100
1906.....	13	23	19	902,528	73,357	.....	.....	0.081
1907.....	8	15	19	1,472,679	127,133	35,091	92,042	0.086
1908.....	8	16	24	2,004,433	88,910	5,995	82,915	0.044
1909.....	5	16	19	2,760,604	104,454	6,099	98,355	0.035
1910.....	9	17	17	1,454,020	69,538	100	69,438	0.048
1911.....	11	24	23	1,713,401	72,253	12,156	60,097	0.042
1912.....	12	19	17	1,420,465	75,611	777	74,834	0.053
1913.....	17	24	20	884,893	52,642	3,605	49,037	0.059
1914.....	16	20	22	931,343	70,310	12,252	58,058	0.075
1915.....	16	18	19	913,765	72,711	5,165	67,546	0.080
1916.....	.....	.....	18	996,875	108,867	.....	.....	0.109
Total...	.....	.....	.....	47,516,442	$3,397,376	$114,140	$890,610	$0.09

The principal factors affecting the production are (1) general business conditions, (2) local conditions affecting municipal supplies. The largest decreases in production in Michigan occurred in the general business depressions of 1906, and 1907, and of 1914. The municipal water supplies in certain cities are unsafe or unpalatable and consequently a thriving business of vending spring waters has grown up in these cities. During the past few years, the quality of the supplies in some of these cities has been greatly improved through the installation of filtration plants or the development of new sources. The production in 1902 was 8,653,690 gallons valued at $275,763. In 1916 only 996,875 gallons, valued at $108,867, were produced, as compared with 913,765 gallons valued at $72,711 in 1915. This was a gain of 83,110 gallons and $36,156 or .091 per cent in quantity and 50 per cent in value. The large gain in value was due chiefly to the larger average price which was 10.9 cents per gallon as compared with 8 cents in 1915.

MARBLE.

The Kona dolomite in the Marquette iron bearing district, the Randville dolomite in the Menominee and Crystal Falls districts locally have been more or less completely metamorphosed into dolomitic marble. The marble varies in texture from coarse to fine, and in color from white to various tones of pink, blue, green, and brown. The marble generally contains so much interbedded impurities such as slate and quartzite, or grades into these rocks, that few of the deposits offer commercial possibilities. Attempts have been made to quarry the marble in several places, but according to reports the large amount of waste made operations unprofitable. An old marble quarry in Sec. 26 T. 42 N., R. 28 W., Dickinson county, is now operated for the manufacture of whiting and paint filler.

Verde Antique Marble. A belt of altered peridotitic rocks about 4½ miles in length occurs northwest of Ishpeming, Marquette county. These rocks have been altered largely to serpentine and dolomite, or so-called *verde antique marble.* In some places the rock is almost wholly dolomite but generally it is a dolomitic serpentine, the dolomite investing the rock by an intricate system of veins and stringers of dolomite. The serpentine varies from light to dark green with tones of olive, but the dolomite is generally white. The rock takes a high polish and the intricate veining produces very beautiful effects. Polished slabs exhibited in the office of the Survey indicate that the stone, locally at least, is equal or superior to much of the verde antique now on the market.

For the past two years the Michigan Verde Antique Marble Co. of Ishpeming has been opening a quarry about five miles northwest of the city in section 30, T. 48 N., R. 27 W., and began limited shipments early in 1917. The marble was hauled in winter on sleds to the railroad, pending the building of a railroad spur. The Marquette Green Marble Co. made an attempt to open a quarry east of the old Michigan gold mine but become financially involved and suspended operations in the summer of 1917.

Apparently there is a large amount of easily available *verde an-*

tique marble in the belt, and with careful development, the marble industry in this district probably will become of considerable or even large importance.

SHALE.

Shale is quarried near Coldwater, Branch county, at Paxton, Alpena county, one mile south of Ellsworth, Antrim county, and at Bellevue, Eaton county for use in the manufacture of Portland cement; at Grand Ledge, Eaton county, for vitrified sewer-pipe, tile and conduit and front brick; six miles north of Jackson near the mouth of Portage River, Jackson county, for vitrified sewer-pipe and tile; at Flushing, Genesee county, and near Corunna, Shiawassee county, for vitrified brick.

The Michigan Vitrified Brick Company of Bay City formerly mined shale from an abandoned coal mine for the manufacture of vitrified brick but this company ceased operating in 1916.

For the past two years a project has been under way to develop shale beds at Williamston for the manufacture of front brick. Although a large area of shale land was explored and burning tests were made of the shale, the project has not materialized.

The shale beds at Grand Ledge, Jackson, Flushing and Corunna belong to the Coal Measures. The beds vary from soft white, or light gray clay shale to compact, dark or black bituminous shale. Probably further tests will show that some of the beds are suitable for other products than those now made. The beds at Paxton belong to the lower portion of the Antrim formation of the Upper Devonian. The extent of the easily quarryable shale near Paxton is unknown but propably exploration would reveal the presence of a number of quarryable areas. Most of the shale exposed is dark brown and very bituminous but locally there are streaks of bluish to greenish gray shale and huge balls of iron carbonate and dolomite. The shale beds at Ellsworth belong to the upper part of the Antrim and are largely of soft blue gritless shale, with a few thin dark bituminous beds. The extent of the easily quarryable areas is uncertain but apparently large. Tests probably will show that this shale is suitable for a variety of purposes. Other exposures of the Antrim shale occur in Charlevoix, Cheboygan, and Alpena counties, notably along the shore of Lake Michigan at Norwood, Charlevoix county.

Excellent exposures of shale belonging to the Coldwater formation occur at Richmondville, Sanilac county, and along the shore of Lake Huron from Forestville in the same county to Whiterock, Huron county. The Coldwater shale is also exposed or is at shallow depth in a number of places in the vicinity of Coldwater, Union City, Quincy, and Bronson, Branch county, but it is utilized only at Coldwater.

Exposures of the Bell shale, the base of the Traverse formation, occur near Bell, Presque Isle county. At Rockport, Alpena county, it forms the floor of the quarry of the Great Lakes Stone & Lime Company. The shale is soft, bluish, and generally highly calcareous. Probably most of it will be found suitable for use in the manufacture of Portland cement. At Charlevoix, a bed of shale about 10 feet thick occurring in the upper Traverse limestones, forms the floor of the quarry of the Charlevoix Rock Products Company. This shale is reported to have been tested and found suitable for the manufacture of vitrified products.

Unfortunately most of the deposits of good shale occur in the northern part of the Southern Peninsula, far from large markets, or at some distance from means of cheap transportation.

SLATE.*

Extensive deposits of black slate suitable for roofing occur in Baraga county chiefly on the northwest side of Huron Mountains in the vicinity of Huron Bay. From 1875 to 1878 and 1883 to 1888 slate was quarried in a number of quarries at Arvon. All of the attempts to develop the slate industry in the state failed chiefly because of the poor methods of quarrying, though many natural difficulties were important contributing factors. The slate at Arvon is of fine texture, pleasing black color, and uniform quality and compares favorably with the product from eastern quarries.

TRAP ROCK.

There are inexhaustible resources of trap rock in the western half of the Northern Peninsula, chiefly in the iron and copper bearing districts. Trap rock is quarried at Marquette and Negaunee, Marquette county. Large quantities of amygdaloidal trap are produced incidentally to the mining of copper. The trap rock from Marquette county is harder, tougher, and less altered than that from the copper mines. The inferior wearing qualities of the amygdaloidal trap, however, is partially compensated by superior cementing power.

Most of the quarry product is crushed for road material and concrete. In some years, a small amount has been sold for rip-rap. The great distance from markets is a serious obstacle to the development of the trap rock industry of the state.

*For a more complete report see Pub. 16, Min. Res. of Mich. for 1913, pp. 92-95, Mich. Geol. & Biol. Surv.

PRODUCTION AND VALUE OF TRAP ROCK IN MICHIGAN, 1911-1916.

Year.	No. of producers.	Crushed stone.				Riprap, Rubble. Value.	Total. Value.	Rank. Value.
		Road making.		Concrete.				
		Quantity.	Value.	Quantity.	Value.			
		Tons.		Tons.				
1911...	3	.....	.....	45,250	$38,429	.....	$51,000	8
1912...	5	21,805	$18,366	11,355	9,340	$8,500	36,206	8
1913...	5	24,920	23,369	*	*	*	92,201	10
1914...	5	25,690	24,863	4,448	4,771	.....	34,406	12
1915...	6	28,262	29,764	18,775	22,047	*	105,855	12
1916...	.....	38,193	37,475	9,601	9,715	.....	83,072	.....
Total...	.....	138,870	$133,837	.....	.....	.....	$402,440	.....

*Included in total.

GRAPHITE.

Graphite slate occurs southeast of L'Anse, Baraga county. Quarries have been opened about 9 miles southeast of L'Anse by the Detroit Graphite Company, Detroit, and by the Northern Graphite Company of L'Anse. The graphite material is ground for paint.

The quarries are operated only intermittently, enough material being taken out in one year to supply the needs of the companies for a number of years. The Detroit Graphite Company was the only operator in 1916.

MINERAL PAINTS.

Certain iron ores were formerly mined in Iron county by the Pickands Mather Company of Cleveland, Ohio, for the manufacture of paint. Last year operations ceased and the only manufacture of mineral paints from the crude material are the Detroit Graphite Company and the Acme White Lead & Color Works, Detroit. The former (See Graphite) utilizes graphitic slate for the manufacture of graphite paint. The latter manufactures a large amount and a great variety of mineral paints. The two above are the only producers, hence figures of production and value cannot be given.

QUARTZ.

Vein quartz is mined near Ishpeming by the Michigan Quartz Silica Company of Milwaukee and ground chiefly for wood filler and paint. Some of the product is used in the manufacture of scouring polishes. According to an analysis submitted by the company the quartz rock is practically pure silica, there being only a trace of impurities. The mills are located at Ishpeming, Michigan, and Milwaukee, Wisconsin.

There is but one producer of quartz hence figures are not given.

FELDSPAR.

Deposits of potash feldspar are reported to occur about one-quarter mile from Republic and in section 22, T. 47 N., R. 29 W., Marquette county. Pegmatitic granite occurs in sections 7 and 18, T. 46 N., R. 41 W., Gogebic county and a pegmatitic dike is exposed near the south quarter corner of section 8.

According to the reports of the Commissioner of Mineral Statistics of Michigan for 1902 and 1903, the Republic deposit is of red potash feldspar. A carload of spar from this deposit was shipped to East Liverpool, Ohio, for use in the manufacture of porcelain. An analysis made of this by an Ohio chemist, is as follows:

	Per cent		Per cent
Silica (SiO_2)	65.25	Magnesia (MgO)	0.23
Alumina Al_2O_3	18.60	Sodium oxide	1.99
Iron Oxide Fe_2O_3.....	0.40	Potassium oxide	13.40
Lime CaCO	0.38		

According to the chemist there is but little free quartz present in the sample. An attempt was made to develop the property in section 22, T. 47 N., R. 29 W., but apparently without success.

The pegmatite dike in section 8, T. 46 N., R. 41 W. is very coarse, the crystals of orthoclase attaining a maximum of 14 inches in length. The exposure is very small, being a rock knob 20 to 25 paces across and 15 to 20 feet high. More or less exploration would be required to determine the extent of the dike. It is probable that other dikes exist in this and other localities.

CELESTITE.

Celestite or strontium sulphate ($SrSO_4$) occurs in various strata of the Monroe formation in southeastern Michigan. Near Maybee, Monroe county it is found as scattered masses associated with native sulphur in the lower part of the Upper Monroe. At Rockwood, Wayne county, it exists similarly in the Sylvania sandstone. Near Gibralter it occurs as disseminated crystals in the Upper Monroe dolomites. In the glass sand quarry of the American Silica Co., Rockwood, the masses are very numerous in places and some of them are very large. The commercial possibilities of the recovery of the celestite in connection with the quarrying of the glass sand is now being investigated. The masses are imbedded in the friable sandstone and can be readily separated from it.

SUMMARY TABLE OF THE PRODUCTION AND VALUE OF MINERAL PRODUCTS IN MICHIGAN, 1912-1916.

Mineral Products.	1912		1913		1914		1915		1916	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Brick and tile products, number of brick	281,741,000	$2,350,606	282,664,000	$2,451,242	278,384,000	$2,434,872	281,819,000	$2,248,068	288,391,000	$2,705,054
Brick, sand-lime, number of brick	49,292,000	316,732	50,065,000	321,245	42,465,000	255,784	47,285,000	286,948	72,004,000	499,711
Bromine	(a)	(a)	(a)	(a)	(a)	(a)	600,325	494,271	.....	(a)
Calcium chloride	(a)	(a)	(a)	(a)	(a)	(a)	10,558	74,670	.....	(a)
Cement, Portland; bbls. made, value cement shipped	3,651,094	3,145,001	4,081,281	4,228,879	4,218,429	4,064,781	4,765,294	4,454,608	4,919,023	6,017,911
Clay, tons	2,043	6,173	1,710	6,504	1,463	4,572	3,142	5,605	3,454	11,153
Coal, tons	1,206,230	2,399,451	1,231,786	2,455,227	1,231,786	2,559,786	1,156,138	(c) 2,139,596	1,076,215	2,695,557
Copper, lbs	218,138,408	35,992,837	183,853,409	28,442,806	158,009,748	21,426,122	238,956,410	(d)41,775,296	339,599,198	61,831,805
Glass sand	.....	(e)	.....	(e)	.....	(e)	.....	(e)	.....	(e)
Graphite	.....	(a)	.....	.....	.....	.....	.....	(a)	.....	(a)
Grindstones, tons	.....	(a)	.....	(a)	.....	(a)	.....	(a)	.....	(a)
Gypsum and gypsum products, tons mined	384,297	621,547	423,896	721,325	393,006	705,841	389,791	686,309	457,375	1,066,599
*Iron ore, long tons	12,649,296	29,003,163	12,677,466	31,947,214	8,835,274	18,965,058	13,151,612	26,574,168	18,626,051	45,884,330
Iron, pig; long tons made; value pig iron shipped	459,975	(b)6,579,048	447,188	(b)6,568,920	379,619	(b)5,229,948	(b) 486,106	6,624,559	505,646	8,851,361
Lime, tons made	74,720	311,448	77,088	331,852	66,507	287,648	81,359	349,979	86,447	385,341
Limestone	.....	1,139,560	.....	1,408,708	.....	1,457,961	.....	1,828,766	.....	2,389,763
Mineral paints	.....	(a)	.....	(a)	.....	(a)	.....	(a)	.....	(a)
Mineral and spring waters, gallons sold	1,420,465	75,611	884,893	52,642	931,343	70,310	913,765	72,711	996,875	108,867
Natural gas, M. cu. ft	900	1,470	1,805	1,405	2,442	1,442	2,060	1,510	1,298	948
Petroleum	.....	(a)	.....	(a)	.....	(a)	.....	(a)	.....	(a)
Pottery	.....	194,892	.....	222,883	.....	265,194	.....	521,989	.....	792,716
Precious stones	.....	.....	.....	.....	.....	(a)	.....	(a)	.....	(a)
Quartz	.....	(a)	.....	(a)	.....	(a)	.....	(a)	.....	(a)
†Salt, bbls	10,946,739	2,974,429	11,528,800	3,293,032	11,670,976	3,299,005	12,588,788	4,304,731	14,918,278	4,612,567
Sand and gravel, tons	2,681,821	818,603	6,424,168	1,529,142	3,647,790	1,118,978	3,776,726	1,036,739	4,407,475	1,295,717
Sandstone	.....	16,438	.....	19,224	.....	(a)	.....	(a)	.....	(a)
Silver, fine oz. Troy	528,453	324,999	295,173	178,284	413,500	228,665	585,933	297,068	.....	247,485
Trap rock	.....	36,206	.....	92,201	.....	34,406	.....	105,855	.....	83,072
Miscellaneous	.....	522,141	.....	540,626	.....	565,147	.....	119,905	.....	971,263
Total	.....	$79,931,757	.....	$77,860,192	.....	$57,641,013	.....	$94,003,349	.....	$140,446,220

*Figures from Iron Trade Review.
†Exclusive of bromine and calcium chloride.
(a) Included under miscellaneous.
(b) Excluded from total, covered by iron ore.
(c) Estimated.
(d) Copper sales.
(e) Included under sand and gravel.