Michigan. Lime consumed in southern Michigan is largely shipped in from Ohio and Indiana. Considerable lime is shipped from Michigan plants into Wisconsin and adjacent states.

Since 1921 the lime industry in Michigan has had a steady growth due to the increasing markets for chemical lime. The tendency has been for increase in production rather than in the number of plants.

The accompanying tables do not include a large amount of lime burned incidental to the manufacture of calcium carbide. Since this is not sold as lime, its value is simply that of the raw limestone purchased, hence it is included in the tables for limestone.

PRODUCTION AND VALUE OF LIME IN MICHIGAN, 1904-1926

Year.	Total lime		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	13
1917	135,920	892,682	6.72	7	7
1918	134,813	1,186,007	8.79	6	6
1919	145,783	1,381,534	9.48	7	6
1920	140,813	1,386,760	9.85	7	8
1921	48,164	445,386	9.24	6	15
1922	53,635	484,945	9.04	7	16
1923	59,629	612,369	10.27	7	18
1924	73,096	702,072	9.60	7	14
1925	95,036	909,952	9.57	8	14
1926	107,671	995,123	9.24	8	12

LIMESTONE†

HISTORY

The development of the limestone industry in Michigan began almost with its first settlers, the French. The strategic military points around the Straits of Mackinac and the mouth of St. Marys River were in the vicinity of extensive exposures of limestone rocks. The trails from Toledo to Detroit passed directly across the limestone exposures in Monroe County.

Quarrying limestone and burning lime for the construction of fortifications and buildings were logical industries in these localities. The slow settlement and development of the State, the limited markets, and poor interior transportation facilities tended, however, to retard the early development of the limestone industry except in a few favored localities. By 1850 burning lime and quarrying of building stone were flourishing

†For a more complete report on the limestone resources of the State, see Pub. 21, Geol. Ser. 17, Min. Res. of Mich. for 1915, pp. 103-312.

industries in Monroe County. The chief centers were in the vicinities of Monroe and Dundee, especially along Plum Creek and near the mouth of Macon River. Detroit was the principal market but Monroe lime, which enjoyed a reputation for good quality, was shipped to many other parts of the State. Other small centers of lime burning were in the vicinity of Bellevue, Eaton County; and Jackson, Jackson County. The great distance of the deposits in the northern part of the State from markets prevented their early development, but here and there quarries were operated for burning lime or producing building stone chiefly for local needs. Later with the settlement of the State and with improvement in lake and railroad transportation facilities lime burning became a thriving industry around Thunder and Little Traverse bays, where there are extensive deposits of limestone. Large quarries were opened on Drummond Island to furnish block stone for use in building the first locks of the present group at Sault Ste. Marie.

The production of limestone block for building purposes, however, has never become an important industry. This is due chiefly to the variable character and quality of the limestone beds, which make it difficult to produce a uniform product without excessive quarry waste.

The real growth of the limestone industry in Michigan followed the rapid growth of the cement industry, which occurred between 1899 and 1903. The growth of the limestone industry lagged behind that of the cement industry in Michigan because in the early days marl was used rather than limestone in the manufacture of cement. Gradually limestone was substituted for marl until the majority of the cement plants in Michigan now use limestone. A large amount of limestone is used in the manufacture of cement, and in concrete aggregates. The industry received another impetus from the discovery near cheap water transportation of large deposits of pure limestone especially adapted for blast furnace flux and other purposes requiring a pure limestone. A third impetus came from the initiation of a state-wide program of road building requiring large quantities of both cement and crushed stone. A steady growth in the chemical industries using large quantities of limestone products has also helped to increase the growth of the limestone industry.

In 1901 Michigan was twelfth among the states in value of its limestone output, but by 1910 it had climbed to ninth place, and in 1920 to fifth place.

In 1925 the maximum output was attained, a total of 11,460,000 tons valued at $6,327,634. Michigan was a close third in production for that year but ranked sixth in value of the output due to higher prices obtained in some of the rival states. In 1926 the production was slightly less, 10,788,740 tons, valued at $6,411,828 were produced.

CHARACTER AND OCCURRENCE

Most of the commercially important limestone deposits of Michigan occur in two belts, one extending around the northern part of the Southern Peninsula from Little Traverse Bay eastward to Thunder Bay, and the other in the Northern Peninsula extending from Menominee eastward along the north shores of lake Michigan and Lake Huron into Ontario. A large amount of siliceous and slaty magnesian limestone, partially marbleized, occurs in the iron bearing districts of the western part of the Northern Peninsula. South of the Little Traverse and Thunder Bay belt, deposits of limestone are relatively few and scattered, and only three or four are of any considerable commercial importance.

In Charlevoix, Emmet, Cheboygan, Presque Isle, and Alpena Counties of the Southern Peninsula, and in Menominee, Delta, Schoolcraft, Luce, Mackinac, and Chippewa Counties of the Northern Peninsula there are many exposures of pure limestone, and hundreds of exposures of pure dolomite, of commercial quality. The few commercially important deposits of limestone south of the Little Traverse-Thunder Bay belt are in Arenac, Huron, Wayne, Monroe, and Eaton Counties. There are several exposures of limestone in the vicinity of Jackson, but the deposits appear to be patchy and very thin and of little commercial importance.

The limestones in the Northern Peninsula are largely dolomite or high magnesian limestone, but there is one series of beds which is chiefly pure limestone. The exposures of magnesian limestones of the Northern Peninsula occupy a belt generally 10 to 15 miles wide along the northern shores of Lake Michigan and Lake Huron, from Green Bay to Marblehead, Drummond Island. The exposures of pure limestone are unfortunately inland, forming a narrow belt immediately north of the belt of high magnesian limestone deposits. The inland position of the deposits of pure limestone make them of much less economic importance than they would be were they near lake transportation.

The limestones of the Little Traverse-Thunder Bay belt are generally low in magnesia, though here and there high magnesian beds occur. Shales and shaly and siliceous limestones are associated with the pure limestones, especially at certain horizons. Many of the larger deposits of limestone are near lake transportation. The pure limestones are suitable for most purposes requiring high calcium limestone and most of the siliceous and argillaceous limestones are adapted for use in the manufacture of Portland Cement. The predominance and extent of low magnesian limestones, and the proximity of many of the deposits to lake transportation give great economic importance to this belt. These two factors account for the great development of the limestone industry in this part of the State and undoubtedly will continue to make this the principal limestone producing district in Michigan for an indefinitely long period.

DEVELOPMENT AND USE

The chief developments in the Southern Peninsula are near Rogers, Presque Isle County; Alpena and Rockport, Alpena County; Petoskey, Emmet County; Afton, Cheboygan County; Bayport, Huron County; Monroe, Monroe County, and Sibley, Wayne County; in the Northern Peninsula, at Fiborn and Ozark, Mackinac County, near Blaney, at Marblehead and Manistique, Schoolcraft County, Randville and Felch, Dickinson County. Important quarrying operations were formerly carried on at Charlevoix, Charlevoix County, and at Hendricks, Mackinac County.

Most of the important deposits near water have been developed or acquired by present operating companies or by limestone using concerns. Important undeveloped deposits near water transportation occur near Norwood and Charlevoix, Charlevoix County; Mackinaw City, Cheboygan County; and at El Cajon Beach about seven miles northeast of Alpena, Alpena County; on Adams Point and near Twin Lakes and Rogers, Presque Isle County.

Large undeveloped inland deposits of the Little Traverse-Thunder Bay belt occur near Afton, Cheboygan County. The purity of this limestone is shown by the following analysis which represents an average of all the different beds; $CaCO_3$, 96 per cent; $MgCO_3$, 1.25 per cent; SiO_2, Fe_2O_3, Al_2O_3, 1.50 per cent. Very extensive deposits of pure limestone also occur near Rogers, Presque Isle County. Most of the northeastern half of Alpena County has limestone at or near the surface. The interior deposits of undeveloped limestone in Alpena and Presque Isle Counties are practically inexhaustible. South of the Little Traverse-Thunder Bay belt undeveloped deposits of pure limestone occur near Omer, Arenac County; on Heisterman's Island, Huron County; and near Dundee, Monroe County.

Practically inexhaustible deposits of very pure high magnesian limestone or dolomite occur near the lake shore between Seul Choix Point, Schoolcraft County, and Drummond Island, Chippewa County. These dolomites, because of their purity and porosity, are especially adapted for paper manufacture by the sulphite process. They are also suitable for lining furnaces. The only development of this stone is at Ozark, Mackinac County. The limestone in Monroe County is largely impure dolomite, suitable chiefly for concrete, road material, and ballast.

The limestone in the vicinity of Rogers and Twin Lakes, Presque Isle County, averages 97.85 per cent of calcium carbonate, 1.26 per cent of magnesium carbonate and 0.34 per cent of silica. This exceptional purity especially adapts it for flux in smelting iron and other ores, for which it is extensively used. The limestone produced elsewhere is generally considerably higher in silica; therefore is not so well adapted for fluxing purposes. More than half of the total production of limestone in the State is sold for flux. A large part of the remainder of the output is used in the alkali industries, the manufacture of Portland cement, calcim carbide, the clarification of sugar, etc. Siliceous and shaly limestones and "fines" or screenings are used extensively in the manufacture of Portland cement. A large tonnage of the harder varieties of limestone are utilized for road building and concrete construction especially in localities deficient in gravel.

The Randville dolomite is quarried in the iron mining districts and sold for use as paint filler, stucco and in cast stone.

Because of the large amount of Michigan limestone sold as flux, the magnitude of production is dependent upon the condition of the iron industry.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, 1899-1926

Year.	Rank of state	Total.	
	Value.	Tons.	Value.
1899			$281,769
1900	12		330,847
1901	12		429,771
1902	13		413,148
1903	14		390,473
1904	10		501,708
1905	12		544,754
1906	10		656,269
1907	11		760,333
1908	9		669,017
1909	11		750,589
1910	9		842,126
1911	8		1,005,751
1912	8		1,139,560
1913	7		1,408,703
1914	8		1,457,961
1915	7		1,828,766
1916	6		2,389,763
1917	5		3,320,895
1918	3		5,186,867
1919	5		3,797,522
1920	5	7,186,760	5,943,229
1921	6	9,766,550	3,387,722
1922	6	5,395,780	4,533,998
1923	6	7,646,550	5,848,649
1924	6	10,589,070	5,578,642
1925	6	9,901,910	6,327,634
1926	7	11,460,000	6,411,828
		10,788,740	
Totals			$66,138,295

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1926.

	Tons.	Value.
Road Metal and Concrete	1,184,300	$1,115,335
Flux	6,627,090	3,443,921
Alkali Works	2,173,490	1,025,823
Paper Mills	72,370	97,597
Fertilizer	168,980	159,135
Other purposes*	562,510	570,017
Totals	10,788,740	$6,411,828

*Includes riprap, limestone for rough construction, glass and sugar factories, railroad ballast, calcium carbide, paint and asphalt filler, stucco, cast stone and refractory purposes; (Dolomite).

SAND AND GRAVEL

The sand and gravel resources of Michigan are practically inexhaustible. The various types of occurrence are as follows: in irregular hills called kames, in steep sided winding ridges or eskers, in broad plains known as outwash, in deltas, on beaches and in beach ridges now elevated above the present level of the lakes, in dunes and wind drifted sand ridges, in glacial drainage channels, rivers and lakes. From a commercial standpoint the last two types of occurrence, together with the outwash and kame deposits constitute the most important types. There are large deposits representing the other types of occurrence, but these

are not as regularly distributed over the State or sufficiently concentrated near the large markets. With the exception of some unimportant types of deposits the sand and gravel in Michigan has all resulted directly or indirectly from the action of the last ice sheet or glacier which covered a large part of North America and extended as far south as the Ohio and Missouri rivers.

The quality and composition of the sand and gravel vary greatly in different parts of the State. In localities where the glacial drift is thin, the gravel generally contains a large percentage of pebbles derived from the underlying rocks. If the underlying rock is soft sandstone, limestone, or shale, much of the gravel may be unfit for use in concrete aggregates and inferior for road surfacing. This is true in Jackson, Calhoun, and Kalamazoo counties, considerable portions of which are underlain by the Marshall formation. In Alpena, Presque Isle and Cheboygan counties there is a belt of gravel ridges along the shore of Lake Huron. Many of the beds of limestone underlying these counties are relatively soft and much of the gravel is of inferior grade. The most northern of these beaches, however, contain high grade material, as for instance along the straits in Cheboygan County. Soft limestone is practically absent in these beaches. Although the gravel is composed of from 65 to 70 per cent of carbonate rock, the material has been derived from the hard dolomitic beds to the north.

The large deposits of gravel along the north shores of Lake Huron and Lake Michigan are therefore generally of good grade for the same reason.

In the portions of the Upper Peninsula underlain by the Lake Superior sandstone the gravel contains large percentages of sandstone which is of an absorbent nature, and while the stone is firm and quite different from the Marshall, it is nevertheless not acceptable for use in concrete aggregates. The composition of the gravel in the iron bearing districts in the western part of the Northern Peninsula is strikingly different from the composition of gravel elsewhere in the State. Limestone is absent and dolomite is rarely observed, the gravel being made up of pebbles of amygdaloid, rhyolite, granite, quartzite and other crystalline rocks of the iron and copper districts. The sand is of like composition and as a result both sand and gravel are of a dark reddish color in contrast to the light colored gravels found elsewhere in the State. In some pits the pebbles are thoroughly coated with a film of iron oxide rendering them unfit for use in concrete.. Some sandstone is also present in the gravel of the western end of the Upper Peninsula, but it is the hard quartzite type which outcrops along the lake shore and is non-absorbing.

The most unfavorables areas for gravel in the State are those which were formerly occupied by lakes. The largest of these areas extends from Alcona County around Saginaw Bay, across the thumb and south to the State line. It varies from a few miles in width to more than forty miles in the region west of Saginaw Bay and represents the area formerly overlapped by Lake Huron and Lake Erie. There are similar large areas in the Northern Peninsula in Chippewa, Mackinac, Ontonagon, Gogebic, and Houghton Counties, and smaller areas in other counties. The old lake beds are composed chiefly of clay and sand, but may locally contain concentrations of gravel. These are, however, generally covered to considerable depth by the finer material washed in. There are good possibilities for gravel at the borders of the old lake basins in the form of delta and beach deposits. Several commercial pits are located in old deltas. The beach deposits of the Saginaw Bay district are suitable for gravel surfacing but generally unsatisfactory for concrete work because of large amounts of lime and iron oxide cementing. The beach deposits of the northern part of the State are referred to above. The sand plains typical of the northern half of the Lower Peninsula are also poor in gravel but are worth investigating because frequently small pits may be developed. The hills of the sand plains areas are generally characterized by a capping of two or three feet of gravel. The type of sand composing the sand plains and dunes is too fine for use in concrete aggregates but may be valuable for other purposes. The best building sand is generally found associated with gravel.

Some of the largest and highest grade gravel deposits in the State are found on the flats along the Grand and Maple Rivers, which represent an old glacial drainage channel, through which the waters of the earlier Lake Saginaw drained into Lake Chicago. There are enormous deposits of this type in Ottawa, Kent, Ionia, and Gratiot counties.

A type of gravel not resulting from glacial action is made use of in Keweenaw County and on Grand Island, Alger County. These are ancient gravels of marine origin which became cemented into conglomerate, but now when exposed at the surface have disintegrated and are easily broken up for use in road surfacing.

The sand and gravel resources of Michigan have a better opportunity for complete development than any of the other non-metallic mineral resources of the State. Because of the low cost of production and wide distribution of deposits gravel has an advantage over crushed stone for road making, railroad ballast and concrete construction. The sand and gravel deposits of the southern half of the Lower Peninsula have become highly developed due to the extensive road building program and huge demand in cities for construction purposes. There are commercial plants convenient to all of the larger cities. This road building program will be extended to the northern part of the State until all the main highways are paved. Since local material is used whenever possible many new pits will be developed in the northern part of the State. Better roads will stimulate construction in cities and villages and facilitate shipment with the result that millions of dollars worth of sand and gravel will be sold.

Sand and gravel constitute the mineral products of most interest and value in Michigan so far as the average land owner is concerned; hence numerous inquiries are received from farmers who have gravel on their property and desire to furnish material for state roads. The chief value of a gravel pit lies in its fitness for production of concrete aggregates. To be of value for such, the material should run up to 2½ inch screen size, and should not contain over two or three per cent of thin particles or soft rock unless the amount can be reduced by hand picking. Absorbent sandstone is also objectionable if present in amounts greater than five per cent. Clay, unless excessive, can be washed out. The objectionable features in sand consist chiefly of poor gradation and organic matter. For gravel surfacing, material over one inch screen size is not used and clay is desired as a binder. Sandstone is not objectionable but large amounts of non-durable particles will increase the cost of maintenance of the road.

The sand and gravel industry in Michigan has increased to such proportions that in 1926, of the non-metallic resources, it was exceeded in

value, excluding manufactured products, only by salt. Beginning with 1918 when the building trades were restricted, there was a steady growth until 1923 which year was marked by an increase of 60 per cent in quantity and 58 per cent in value. There was a further large increase in 1924, but a slight decrease in 1925. In 1926, however, Michigan produced 14,398,338 tons of sand and gravel valued at $7,265,161, an increase of 32 per cent in quantity and 28 per cent in value over the previous year. This huge production raised Michigan to third place in state production. The leading counties in order of their importance in 1926 are as follows: Oakland, Livingston, Kent, Kalamazoo, St. Clair, Wayne, Lenawee, Huron, Hillsdale, Washtenaw, Genesee. The production in Oakland County in 1926 was enormous and amounted to thirty-three per cent of the State total.

It should be borne in mind that in the case of products of universal distribution like sand and gravel that many thousands of tons are excavated and used for individual needs, for which there is no record obtainable. Likewise many producers fail to send in reports or are reluctant about submitting figures.

Because of the fact that the bulk of the sand produced is used for building or road making purposes, it has been treated from that standpoint in the above discussion. Sand having special uses is considered in following articles.

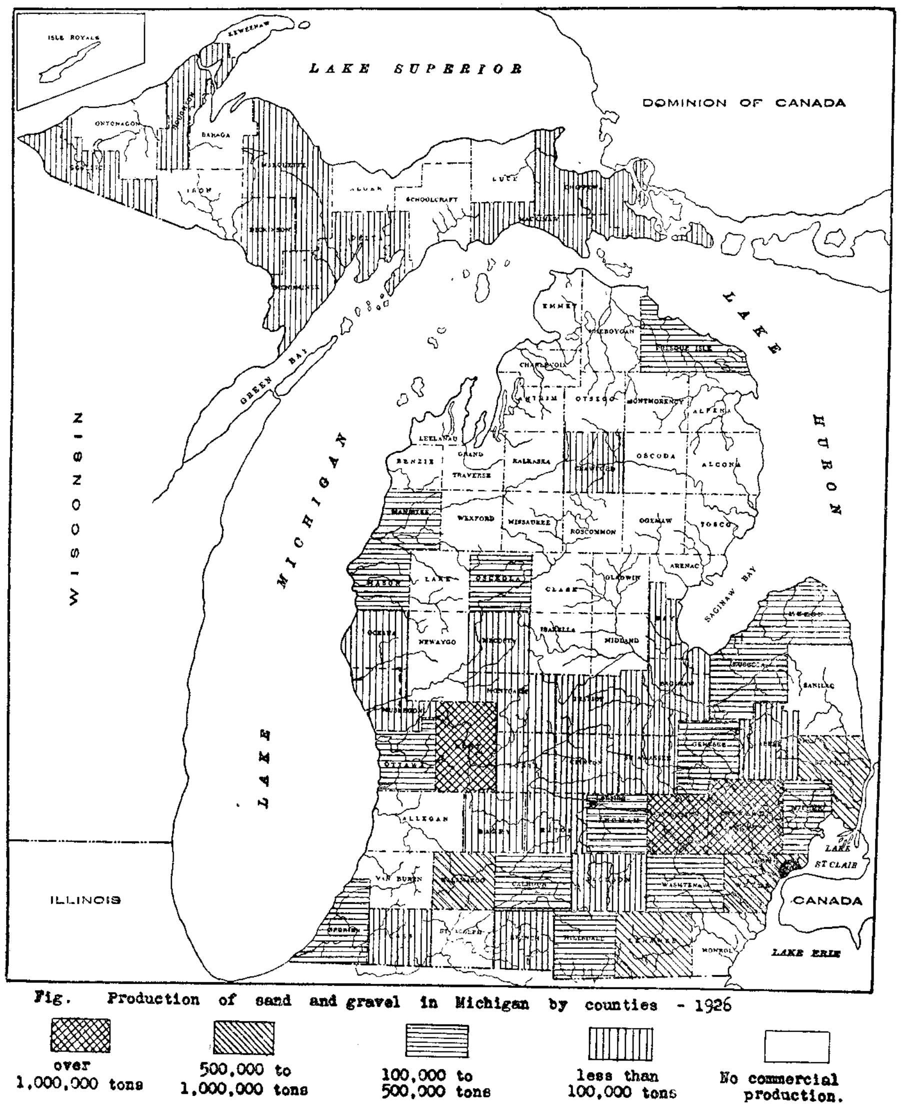

FIGURE 4.
Production of Sand and Gravel in Michigan by Counties—1926

PRODUCTION AND VALUE OF SAND AND GRAVEL IN MICHIGAN, 1905-1926.

Year.	Total Sand and Gravel		Rank.	
	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.	
1905	414,509	$210,609	10	11
1906	597,789	197,699	12	13
1907	1,024,641	289,595	10	11
1908	842,591	370,365	8	9
1909	2,219,757	685,632	8	8
1910	2,862,738	816,337	7	8
1911	2,185,165	565,969	9	10
1912	2,681,821	818,603	9	8
1913	6,422,818	1,528,892	4	5
1914	3,757,979	1,143,771	8	7
1915	3,776,726	1,036,739	8	7
1916	4,407,475	1,295,717	7	7
1917	3,814,445	1,641,748	7	6
1918	2,837,371	1,239,874	8	9
1919	3,772,535	1,944,143	6	7
1920	4,386,582	2,867,466	8	6
1921	5,515,253	2,916,917	4	6
1922	5,962,916	3,222,043	5	6
1923	9,601,562	5,096,071	5	5
1924	11,381,084	5,975,757	5	5
1925	10,878,375	5,684,474	6	5
1926	14,398,338	7,265,161	3	5
Totals	103,742,470	$46,153,681		

PRODUCTION AND VALUE OF SAND AND GRAVEL IN MICHIGAN, BY USES, 1926.

Sand.	Tons.	Value.
Molding Sand	695,172	$363,208
Building Sand	2,335,137	1,157,675
Paving Sand†	2,416,444	926,733
Railroad Ballast	206,591	80,420
Other Sand‡	624,992	362,247
Total Sand	6,278,336	$2,890,283
Gravel.		
Building Gravel	2,829,874	$1,900,090
Paving Gravel†	3,976,041	1,934,987
Railroad Ballast	1,233,654	438,347
Other Gravel	80,433	101,454
Total Gravel	8,120,002	$4,374,878
Total Sand and Gravel	14,398,338	$7,265,161

†Includes roadmaking.
‡Includes glass, cutting and grinding, engine, filter and furnace sand.

FOUNDRY SANDS

Sands for molding purposes in Michigan are largely imported from other states. There is, however, a large production of core sand, and Michigan ranked sixth in total foundry sands produced in 1925. Sand sold for making cores is chiefly dune or beach sand, which is produced in large quantities at Port Crescent, Huron County; Manistee, Manistee County; and Ludington, Mason County. The Burt Core Sand Company works a large deposit at Vassar, Tuscola County, which has the characteristics of a wind blown beach ridge formed when the lake stood at a higher level and since covered to a depth of several feet by other sand. These sands do not contain any natural bond, this being supplied at the foundry. A somewhat similar deposit to the one at Vassar is worked in sec. 24, T. 3 S., R. 18 W., Berrien County. This latter is a molding sand and is supplied with bond by mixing the white beach sand with a sandy clay which overlies it. Smaller deposits are worked in various places for local use.

Of late years there has been considerable interest manifested in research on molding sands. A number of states have undertaken surveys of molding sand resources upon the instigation of the Committee on Molding Sand Research of the American Foundrymen's Association. The work in Michigan has been carried on by Dr. G. G. Brown of the University of Michigan.

The manuscript is expected to be completed in time for publication during 1929. In addition to a report on localities and standard tests, this report will contain the results of an exhaustive study of the bond in foundry sands. The character of the bonding material and cause of the bonding property have been determined and a simple and cheap method for the manufacture of artificial bond devised. These discoveries may prove revolutionary in the use of foundry sands and may establish large resources of suitable sands in Michigan.

FELDSPAR

Feldspar is the most abundant constituent of the earth's crust constituting 60 per cent of the igneous rocks. These rocks, however, have been too deeply covered by sandstones, limestones, and shales to have any value except where the overlying sediments have been eroded away exposing the granitic masses below. Except in rare cases the feldspar is too intimately mixed with other minerals to have any value. For this reason the extensive granite areas in the western end of the Upper Peninsula are in great part valueless as regards feldspar content. There are, however, small areas which have been known for many years in Ontonagon, Marquette, and Gogebic counties where the feldspar occurs as dikes in granite and is relatively free from other minerals. Some sales were made from Ontonagon County but the material apparently was unsatisfactory as the workings were abandoned. No extensive investigations of the dikes in Gogebic County have been made, but those of Marquette County are better known, a quarry having been operated in Section 22, T. 47 N., R. 29 W., and feldspar sold for coating vitrified brick and certain kinds of tile. The extent of the feldspar deposit in this section has been investigated and a drill hole was put down to forty feet showing good material all the way.

Feldspar is used in large quantities in the manufacture of pottery, electrical porcelain, enameled wares and for other purposes. The following analysis of feldspar from near Republic shipped to East Liverpool, Ohio, shows the material to be low in iron, and containing but little free silica, hence suitable for porcelain.

Silica (SiO_2)	65.25	Lime (CaO)	0.38
Alumina (Al_2O_3)	18.60	Magnesia (MgO)	0.23
Iron oxide (Fe_2O_3)	0.40	Soda (Na_2O)	1.99
		Potash (K_2O)	13.40

The deposit in Sec. 22, T. 47 N., R. 29 W., contains about 18 per cent of potash and if a method should be devised for extracting potash from silicate minerals this material may have a value as fertilizer.

It is very probable that other feldspar dikes occur in the areas underlain by granite.

TRAP ROCK

Trap rock or basalt is quarried at Marquette, Ispheming, and Negaunee, Marquette County, near Crystal Falls, Iron County, and at Wakefield, Gogebic County. Since copper occurs in the amygdaloidal type of basalt, large amounts of amygdaloid are necessarily produced in the mining of copper. This material is finely granulated in the extraction of the copper and constitutes the major portion of the "stamp sand" used for road building in the copper district.

The quarry product is used for road material, in concrete aggregates and more recently in the form of roofing granules.

The much greater cost of this latter material accounts for the large increases in value of basalt for 1921, 1922, and 1923. The 1925 production was greater than that for 1923 in spite of fewer operators, but the value was considerably less due to lesser amounts of roofing granules and larger amounts of road material and concrete aggregates produced.

Michigan's resources in trap rock are enormous, but the higher cost of production is a handicap to its competition with gravel for road material and concrete construction.

PRODUCTION AND VALUE OF TRAP ROCK OR BASALT IN MICHIGAN, 1911–1926

Year.	No. of Producers.	Total Tons.	Total Value.	Rank Value.
1911	3	....	$51,000	8
1912	5	....	36,206	8
1913	5	....	92,201	10
1914	5	....	34,406	12
1915	6	....	105,855	12
1916	8	....	83,072	12
1917	4	....	70,197	11
1918	4	....	53,269	11
1919	1	....	36,186	11
1920	4	....	84,273	10
1921	6	....	173,620	12
1922	....	94,560	376,788	....
1923	12	109,810	420,524	10
1924	6	103,860	331,302	11
1925	6	110,400	323,991	10
1926	6	96,990	303,601	....
Total			$2,579,791	

GRAPHITE AND MINERAL PAINTS

The amount of graphite produced in the United States is small compared to that imported. Crystalline graphite was an important war material due to its use in the manufacture of crucibles for the steel industry and production in this country was greatly stimulated by the war. After the war, however, domestic producers found themselves unable to compete with the cheap foreign supply and as a result there appears to be no immediate future for graphite mining in the United States. Large amounts of artificial graphite are however produced at Niagara Falls, N. Y.

Graphite quarries have been operated in Michigan for some time in graphitic slate near L'Anse, Baraga County. The rock is reported to contain from 32 to 35 per cent of amorphous graphite which is ground and used in the manufacture of paint by the Detroit Graphite Company, which is the only producer at the present time. The production was intermittent for a time since enough graphite rock could be quarried in one year to supply manufacturing needs for several years. No production was reported for the years 1918 to 1922 inclusive, but since 1923 production has been steady. Due to the decline of the industry in Alabama and other states, Michigan now ranks third in the production of natural graphite.

A small amount of the iron ore produced in Michigan is of sufficient uniformity of color and freedom from grit to be ground and used for mineral paint.

CELESTITE—STRONTIANITE

Strontium salts are used chiefly in the manufacture of fireworks, signal lights and medicine. The market in the United States is not large and there has been no production since 1918 when 400 short tons valued at $20,000 were produced. The domestic demand at present amounts to about 2,000 short tons, most of which is imported from England. Strontium nitrate was much in demand during the war for signal lights and shells, hence a number of domestic deposits were opened up in the west. After the war, however, these could not compete in the eastern market with the English product.

Celestite and strontianite occur in Michigan at a number of different horizons of the Monroe formation in Monroe and Wayne Counties. Strontianite is more easily reduced than celestite, but is much less common. Celestite occurs in the Lower Monroe near Monroe, Monroe County, and in the Sylvania Sandstone, (Middle Monroe) at Rockwood, Wayne County. Near Gibraltar, Wayne County, and Maybee, Monroe County, the occurrence is in the Upper Monroe. Strontianite is found chiefly in the Monroe district and near Ida. At Maybee, native sulphur is associated with the celestite. The dolomites in which the strontium minerals occur contain many fissures and cavities in which the celestite and strontianite have been deposited by reaction of strontium bearing waters with limestone and gypsum.

Should larger concentrations of celestite and strontianite be discovered or methods of commercial recovery be devised for the known occurrences, these minerals could find a profitable use in the refining of beet sugar of Michigan and adjacent states.

SLATE*

Michigan has large deposits of high grade slate in northeastern Baraga County. The slate varies in color from black to blue-black and green, is fine grained, hard and firm, takes a good polish and has a perfect cleavage. It is said to compare favorably with that from the eastern quarries.

Quarries were opened in slate in the Huron Bay District near Arvon as early as 1876 and operated intermittently by different companies until 1888. The companies all failed, however, and the plants went to ruin.

The demand for roofing slate has generally decreased since 1902 due to keen competition from manufactured roofing. There are a number of other uses, however, for which the demand is good. Eastern producers have been meeting competition from manufactured roofing, by developing processes for surfacing structural and roofing slate in attractive colors and marketing it in various shapes to correspond to the architecture of the building and material used.

With efficient management, backed by the necessary capital, it seems logical that the Baraga County slate deposits could supply the cities of the Great Lakes at more attractive prices than could the eastern producers dependent upon rail shipment. The slate is suitable for most uses to which slate is put. Quarrying conditions are good and water power is available at some of the sites.

There are a number of other places in the Upper Peninsula where slate occurs but the quality is not comparable to that of Baraga County, nor are the deposits convenient to water transportation.

*A more detailed discussion is given in Pub. 16, Min. Res. of Mich. for 1913, pp. 92-95.

SANDSTONE

Previous to 1900 sandstone quarries were active in both the Lower and Upper Peninsulas. In 1899 the value of the stone quarried was $178,038 and in 1902 the maximum value, $188,073 was attained.

Large amounts of sandstone were formerly obtained from the Coal Measures near Ionia, Ionia County, near Grand Ledge in Eaton County, and at Parma, Jackson County. Many quarries were operated in the Marshall formation in Jackson, Calhoun, Hillsdale, Huron, and Ottawa Counties. The stone obtained from these quarries, however, was generally of too poor quality to compete with the Ohio sandstone and the Indiana limestone for structural purposes. Likewise, the growing use of concrete, brick and artificial stone lessened its demand for foundations and other rough construction purposes. At the present time only a very small amount of sandstone is produced for rough construction in lower Michigan and that only incidental to the manufacture of grindstones at Grindstone City, Huron County.

The Upper Peninsula has large resources of one of the finest sandstones in the country for building purposes. This stone is of Cambrian age and is known by a number of different trade names, Jacobsville "Redstone," Marquette "Brownstone," Portage "Redstone" and others. This stone has been quarried at Jacobsville, Portage Entry, Marquette, and elsewhere for years. There are many places along the lake shore where material suitable for building can be obtained. The industry has practically ceased in this part of the State also. In 1926, the only stone quarried was produced by the City of Marquette for concrete aggregate. The decline of the industry in Northern Michigan cannot be attributed to inferior qualities in the stone, but rather to changing styles in building stone, highly colored stone falling into disuse in favor of light colored limestone, marble, sandstone and granite. The competition from brick and other artificial rock products has also been an important factor in the decline of the sandstone quarrying industry.

Tests show that the Lake Superior sandstone will withstand a load of over 5,000 pounds per square inch which is far more than any modern structure is called on to bear. The stone works readily but soon hardens upon exposure to air. It does not disintegrate after long exposure and the color is constant. It has withstood severe tests in fire under circumstances where other stones have crumbled. The following analysis explains its desirability in the above respects: SiO_2—94.63, Fe_2O_3—2.74, Al_2O_3—0.36, $MgCO_3$—0.69.

Of recent date there have been some indications of a recurrence of taste for color in building stone. If such a trend develops, there should be a revival of the redstone activities in the Upper Peninsula.

GRINDSTONES AND OTHER ABRASIVES

The lower Marshall formation contains beds of sandstone or "grit" composed of sharp angular quartz grains and which are sufficiently hard and free from foreign substances to be of value for grindstones and whetstones. The quartz grains are imbedded in a softer cement of mica, siderite, and clay which wears away just fast enough to continually present fresh grains for cutting and to prevent the stone from acquiring a glaze. Thin beds composed of rounded quartz pebbles with an abundance of clay cement occur locally. When weathered, this rock resembles peanut candy, hence the term "peanut" conglomerate is assigned to these beds. These quartz pebbles also occur in the sandstone in places in such quantities as to entail considerable waste. The most uniform of the grindstone beds is about fifteen feet thick and blocks of stone weighing several tons can be secured. The stone is soft when first quarried but soon hardens upon exposure. The stone nearest the surface is softer than that lower down. The best stone is made into grindstones of various sizes and the smaller pieces are turned into scythestones.

Grindstones have been produced at Grindstone City since 1850, mainly by two companies, one of which was reorganized several times. Operations ceased during the war, but in 1923 the Cleveland Stone Company resumed its activities at Grindstone City. The Wallace Stone Company, however, has permanently abandoned its operations at Eagle Mills. Michigan is one of three states which produce grindstones but the value is small compared to that of Ohio and West Virginia.

A quartz conglomerate suitable for buhrstones has been found at several places in the Upper Peninsula. There is, however, very little demand for this sort of stone due to the development of modern grinding machinery.

Near Marquette a fine grained siliceous slate similar to novaculite was worked in 1849 and 1850. The stone is suitable for making hones.

Considerable amounts of sand are sold annually for cutting and grinding purposes. These figures are included under sand and gravel.

MARBLE

A dolomitic marble is present in the Menominee, Crystal Falls and Marquette iron bearing districts. In the Menominee and Crystal Falls districts it is known as the Randville dolomite, in the Marquette districts as the Kona dolomite.

A quarry was opened in Sec. 26, T. 42 N., R. 28 W., Dickinson County, in 1894 and operated in a small way sending out a few carloads for advertising purposes. The users were well pleased with the stone which is a very bright sparkling dolomitic marble, shading from pure white to pink, green, gray, and purple. The stone takes an excellent polish which stands up under the tests given New England marbles. Material was furnished for a number of large buildings but the difficulty of securing blocks free from fractures and suitable for building caused operations to be suspended in 1896.

Plans were made for reopening the quarry but nothing was done until 1916 when the Metronite Company of Milwaukee resumed operations at this quarry. In 1923 the Crystallite Reduction Company of Iron Mountain began operations at Randville. The stone is too badly shattered for the production of building stone. It is ground for paint filler, and crushed for stucco and cast stone. Large resources of this stone have been proved by drilling.

MARL

Marl is a term applied to a loose, earthy form of calcium carbonate containing more or less clay and other impurities. There are all gradations from a calcareous clay to a marl of high purity. Marl is chiefly a fresh water deposit and is found in lakes, swamps, and low lying areas which were formerly covered with water.

The exact processes by which marl is deposited have not been definitely established but it is likely that the explanation lies in a combination of factors rather than in a single process. Some of the theories of deposition are as follows:

1. In most marl deposits shells of fresh water animals are found. In a few instances this accumulation of shells represents a high percentage of the total calcium carbonate in the deposit. In general shells play but a minor role in the deposition of marl.

2. Some plants, notably chara, contain a relatively high percentage of calcium carbonate in their tissues. Upon the death and decomposition of the plant the lime remains to form marl.

3. All fresh water plants extract carbon dioxide from the water and by photo-synthetic processes build it into the tissues of the plant. The removal of the carbon dioxide from the water changes the calcium bicarbonate to the less soluble calcium carbonate which is then precipitated. This calcium carbonate is sometimes precipitated as a scale coating the leaves of the plant.

4. Calcium bicarbonate is carried in solution by most spring waters. Its solubility decreases rapidly with increase in temperature. Thus calcium carbonate may be precipitated by the warming of the cool spring waters when they reach the surface. This precipitation is aided by evaporation and the loss of carbon dioxide by agitation.

Michigan with its numerous lakes and swamps is rich in marl deposits. The majority of these deposits lie beneath the ground water level but many are now on dry land as a result of drainage.

The marl resources of the state, while they are known to be large, have been but partially investigated and no definite statements can be made as to the extent or character of the deposits in the different counties. Marl deposits are known to be present in the following counties: Alcona, Alger, Allegan, Alpena, Barry, Benzie, Berrien, Branch, Calhoun, Cass, Charlevoix, Chippewa, Clare, Clinton, Delta, Eaton, Genesee, Gladwin, Gratiot, Grand Traverse, Hillsdale, Ingham, Ionia, Isabella, Jackson, Kalamazoo, Kent, Lapeer, Lenawee, Livingston, Manistee, Mecosta, Missaukee, Montcalm, Newaygo, Oakland, Oceana, Ogemaw, Osceola, Ottawa, Presque Isle, Roscommon, Schoolcraft, St. Joseph, Tuscola, Van Buren, Washtenaw, Wexford. There are no doubt deposits in other counties. The marl situation in the northern portion of the Lower Peninsula and in the Upper Peninsula is less perfectly known than in the southern part of the state, because the availability of limestone in the northern part of the state has made marl of less significance in that section.

In 1925 an investigation of marl resources of the state by counties was undertaken with the co-operation of the State College and the following counties have been covered: Allegan, Barry, Chippewa, Clinton, Eaton, Hillsdale, Livingston, Mecosta, Menominee, Newaygo, Oceana, Ogemaw, Roscommon. The deposits are classified into three groups, those large enough to work by machine, those in which hand digging only is suitable, and those that are economically unavailable. The deposits vary greatly in extent, depth, and analysis. The depth varies from a few inches to more than thirty feet in the deposits recorded. The marl is usually covered with a layer of peat or muck except in the cases of some lakes where the shoreline and bottom of the lake consists of marl. When the

peat or muck cover exceeds four feet it is generally not practical to work the deposit. In most deposits the marl is underlain with soft clay although many times it rests upon sand or gravel. In Chippewa County some of the deposits lie directly upon limestone. The analysis of workable deposits show from 60-98% $CaCO_3$ with the average falling between 85% and 90%.

Marl is used chiefly for fertilizer and in the manufacture of Portland cement. The value of marl used for cement manufacture is expressed in terms of the value of the manufactured product and is to be found in the tables for cement. The use of marl for agricultural purposes has increased by leaps and bounds in the last few years. In 1924 approximately three thousand yards of marl were used in the state. In 1927, according to all available information, the production was about one hundred thousand yards. Although effective digging machinery has been developed the bulk of this was dug by hand. It is estimated that in the southern part of the state the use of marl instead of ground limestone for fertilizer effects a saving of $1.00 to $1.50 per yard.

SERPENTINE AND VERDE ANTIQUE

Outcropping at Presque Isle north of Marquette and extending west to Lake Michigamme there are a series of peridotite dike rocks cutting across diorite, diabase and felsites. These dikes have been largely altered to serpentine and serpentine with stringers of dolomite (verde antique) and appear as prominent ridges in Township 48 N., Range 27 W., and Township 48 N., Range 28 W. The stone is firm and hard and takes an excellent polish. It appears to be equal or superior to much of the serpentine and verde antique now on the market. The resources of verde antique are large and those of serpentine practically inexhaustible, the latter having been drilled into, in the course of explorations at the Ropes Gold Mine, to a depth of 500 feet from the surface. Quarrying and shipping conditions are favorable at several locations.

The Michigan Verde Antique Marble Company opened a quarry and began operations in 1914. Production, however, was intermittent due to lack of transportation facilities, labor shortage, etc. The material shipped consisted chiefly of stone for terrazzo and stucco. No shipments have been reported since 1923.

QUARTZ

Quartz was formerly mined near Ispheming, Marquette County, by the Michigan Quartz Silica Company of Milwaukee, and ground for wood filler, paint and polish. There has been no production since 1923.

PEAT

There are immense peat deposits in the eastern half of the Upper Peninsula and numerous smaller deposits in the Southern Peninsula. At one time peat was used for fuel in a blast furnace near Ispheming, but proved unsatisfactory. There have been many other attempts to utilize it for fuel. The chief use for peat at the present time is for filler in certain kinds of fertilizer.

Peat was produced in 1926 near Capac, Saint Clair County, and near Benton Harbor, Berrien County. The product is known as "humus."

SALT

The premier status which Michigan holds in the salt industry has been constantly maintained. An operation which was first developed as a byproduct of the lumber industry and later fostered by the chemical trades, ranks fairly as the State's most stable development of non-metallic mineral wealth. The position of Michigan in the most favorable lines of cheap transportation, and the location of unlimited thick beds of pure mineral salt at relatively shallow workable depths close to these lanes of commerce, will continue to be an influence of greatest importance. The salt and brine bearing formations are six in number which include the Salina, Detroit River Series (Upper Monroe), Dundee, Berea, Napoleon, (Upper Marshall) and Parma. Of these, the Salina easily leads in importance, for it represents an occurrence of extensive bedded rock salt with extreme purity. The other rock horizons are significant for their content of natural brine which is easily convertible by evaporation into salt products. From these, however, the more valuable minor salts found in the mother liquor or bittern become increasingly important. At an early date the greater part of the salt produced came from the Berea, Napoleon, and Parma. Only since 1895 with the beginning of operations in Wayne County has the major restriction of salt manufacture to the Salina deposit held sway. At the present time salt is produced from these other sources, simply as a byproduct during the recovery of other chemicals or in the limited instances where waste heat is still utilized.

The details of geology concerning the Salina are known only through the findings from shafts and deep well records. *Rominger has recorded outcrops in the vicinity of Point aux Chenes and St. Martin's Bay near St. Ignace but no salt beds or fossils were reported, and later observations do not give corroborating evidence. Outcrops are supposed to occur around the Straits of Mackinac and it is known that in this area beds containing salt are generally absent. The northernmost salt beds recorded at the Salina horizon were in the St. Ignace well No. 1 where four feet of salt was found. There is no record of salt being penetrated in the No. 2 well located two miles north of No. 1. The salt bearing beds at St. Ignace have not been determined as Salina, and they may belong to the Monroe, although there is no evidence either lithologically or from fossils. They are largely red, and blue shales which would seem to indicate the location of this area as near the border of both the Monroe and Salina basins. Examination of the Salina section from the mining operation at Oakwood, a suburb of Detroit, has given no fossil clues nor trace of organisms. Recent deep wells which have been drilled throw considerable light on the nature of the Salina, its extent, and the relations of the beds above and below. In addition to the two wells drilled by Henry Ford at Dearborn and Highland Park, Wayne County, and that of the Macomb County Oil and Gas Syndicate near Chesterfield, Macomb County, several new deep borings for oil and gas have completely penetrated the Salina. These wells of the Michigan Petroleum Company, Richardson No. 2, near Blaine, St. Clair County, the Diamond Crystal Salt Company, No. 9 and No. 12, St. Clair County, and the St. Clair Oil and Gas Company, Rosette No. 1, near Mt. Clemens in Chesterfield Township, Macomb County, have added considerable to the knowl-

*Rominger, Carl, Michigan Geological Survey, Vol. 1, Part 3, p. 30, 1873.

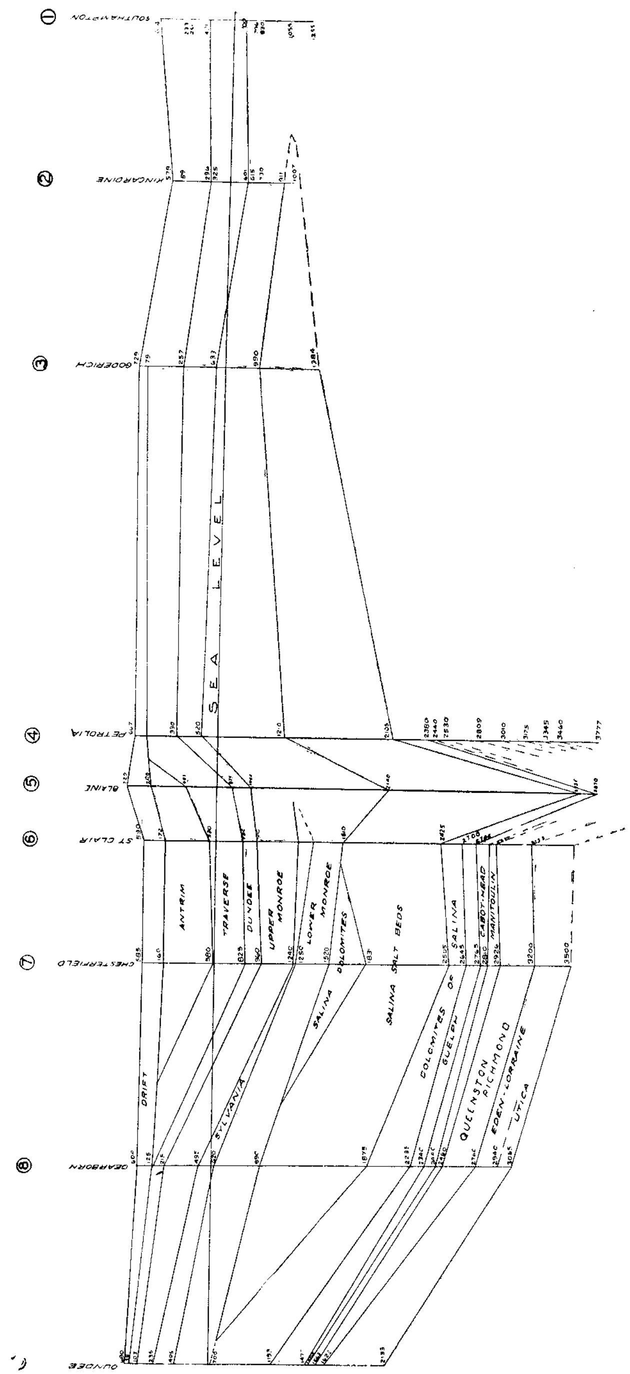

FIGURE 5.

A Cross Section from Dundee Michigan to Southhampton, Ontario, along the line A-B shown in Figure 6. Straight lines are used to emphasize the diagrammatic nature of the section.

edge of the Salina section. A graphical representation from these records together with some already known in Ontario and Michigan, aids to bring out the relation of the Salina to other beds and the northern and southern termination of the salt bearing rocks. This also shows the lenticular character of the salt bearing part of the Salina with both its deepest and thickest part represented near Blaine. The cross section shown in Figure 5 brings out effectively the fact that the salt bearing part of the Salina is a continuous deposit throughout almost the entire basin of deposition, and this is held to be an important feature when applied to the question of the extent of the salt beds.

The limits of the Michigan-Ontario salt basin are suggested in Figure 6.

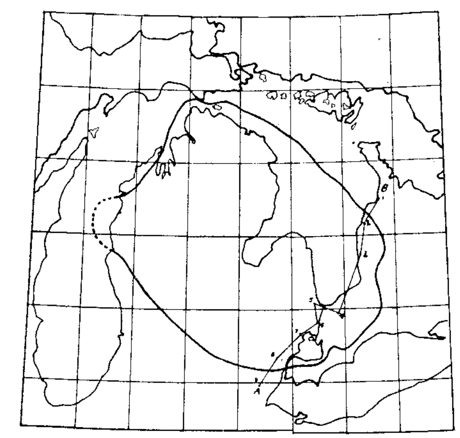

FIGURE 6.

Limits of the Michigan-Ontario Salt Basin. In Michigan the central part remains untested. Line A-B indicates the direction of the section shown in Figure 5.

Various writers and observers have postulated that the deposits in Michigan were of a distinct province from the New York basin. The contention has been that they were continental deposits of desert lakes and therefore apt to be found in restricted areas. However, the broad, regular, and continuous deposit of the Salina of Michigan, as it is shown, leads to the opposite conclusion. It is likely that the same regular and continuous deposit will prevail over the central and northern parts of the Michigan basin, although there is as yet no boring of sufficient depth in the central part of the basin to substantiate this statement. From the prevailing white and gray color of the salt beds, the absence of red except in the upper part, the lack of the more soluble salts and the absence of sands or grits, these beds are held to have had their origin in a large body of water, most probably with a connection with marine waters.

The records of recent wells lead to the conclusions also that potash salts do not exist in appreciable quantities in the Detroit-St. Clair area of Wayne and Macomb Counties. If the postulation is accepted from above, that shifting marine conditions with repeated influx of marine waters occurred in Salina time, then it is most probable that such salts do not occur anywhere in any quantity in Michigan Salina strata. At least it is certain that prospecting with intention of recovery of any of the more valuable salts of potash is not warranted on the basis of past experience.

Although there is considerable evidence for the continuity of the Salina under most of the Southern Peninsula, exploration has only been carried on along the outer margin near the shores of lakes Huron, Michigan, and St. Clair, and the Detroit river where the salt beds are not so deep as to make drilling operations unduly hazardous. In the southern part the Salina consists of shales and shaly dolomites and salt beds are not found. Productive Salina is found in an area bounded on the north by a line connecting Alpena, Onaway, and Manistee and on the south by a line joining Muskegon and Trenton. The southern line is a definite known limit of salt but the northern limit is only that beyond which there has not been further exploration. The salt beds continue north from Onaway and Alpena for some distance and this represents a very favorable area for exploration. Here the salt beds are thick and relatively close to the surface, being at a depth of 1284 feet at Grand Lake and 1630 feet at Onaway. The amount of salt imbedded in the Salina varies considerably over the productive area, although attempts in correlation of salt beds between wells have been successful in narrow limits. In the Detroit region five major salt beds have been proved to occur at similar positions in several of the deep wells. Although thick salt deposits probably occur throughout the Salina basin as limited, profitable exploitation in the central portion of the State is prohibited because of the great depth at which the salt beds occur. The area under which the Salina is practically out of reach is where Pennsylvanian and Upper Mississippian rocks occur underneath the drift cover as indicated on the Michigan Geological Map.*

Possible areas of exploitation for salt deposits in the Salina are available in the counties bordering Lake Michigan, from Ludington northward; those bordering Lake Huron from Oscoda north; those bordering Lake Huron from Grindstone City (Huron County) south; and those along the St. Clair river, Lake St. Clair, and the Detroit river as far south as Trenton in Wayne County.

The types of salt products are many and diversified as are the uses to which the commodity is put. A large division may be made between those which are derived from the evaporation of brines and those from the mined rock salt. It is in the former class that Michigan's leadership is most prominent as there is only one shaft salt mine located in the State. The evaporated salt is manufactured as open pan or grainer salt and vacuum pan salt. Grainer salt is coarse and flaky in texture whereas the vacuum pan product is fine and the crystals are cubical in form. Pressed blocks are prepared from the granular salt by a compacting process in enormous hydraulic presses. Some of the brine extracted is used as such, going into processes for the manufacture of soda, ash, bleaching powder, caustic, and allied products.

Michigan's salt production was somewhat less in 1924 than in 1923 and was slightly less than that of New York which was the largest producer for the year. In value of product, however, Michigan led all other states. An increase in production for the year 1925 placed Michigan again in the lead, both in amount and in value of production which foremost posi-

*Mich. Geol. Survey, Pub. 23, 1917.

tion was held, throughout the period of 1926. A total resume records Michigan as first in salt production from 1880 to 1892, in 1901, from 1905 to 1909, from 1912 to 1921, and in 1922, 1923, 1925 and 1926.

The variation in production and value from 1882 to 1926 is shown graphically in Figure 7. This clearly demonstrates the recent trend toward a marked sharp divergence between production and value.

After the slump which took place in 1924 there was a steady increase in the State's production, and a steady decrease in the value of the product. This reflected the general tendency for the United States which was characterized by keen competition, overproduction, and a

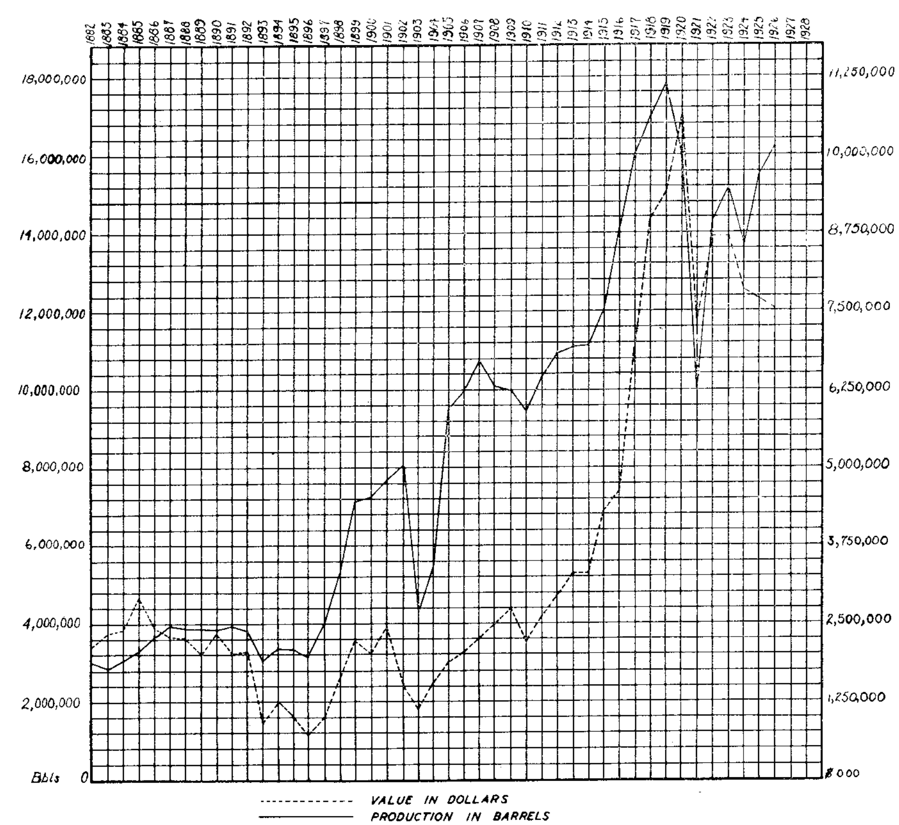

FIGURE 7.

Graphic Record of Salt Production from 1882 to 1926 showing Relation of Production and Value.

lowering of prices which resulted in the closing down of small plants or their absorption by larger operators. In 1924 the salt producers reported 1,918,463 short tons valued at $7,864,838; in 1925 2,172,600 short tons valued at $7,710,331; and in 1926, 2,260,320 short tons valued at $7,594,418. These figures refer to salt sold or used by the producers, no estimates being available for stocks held over from year to year.

After the decrease in production from 1923 to 1924 of 9.82 per cent, the yearly increase in production represented was 13.25 per cent in 1925 and 4.04 per cent in 1926. The decrease in value was 9.43 per cent in 1924, 5.09 per cent in 1925, and 1.50 per cent in 1926.

During the period from 1880 to 1890 the annual production of Michigan represented from 42 to over 49 per cent of the salt produced in the United States. Rapid growth of the salt industry in New York, Ohio, and other states caused the percentage to decline from 43.69 per cent in 1890 to only 22.89 per cent in 1896. Until 1924 Michigan continually produced about one-third of the total annual output, but that year there was a drop to 28.19 per cent of the limited State's production. In 1925 and 1926 its place was revived by showing 29.37 per cent and 30.66 per cent of that produced in the United States. A general decrease in United States salt production in 1924 was ascribed by the United States Department of Commerce to a price war in the East, the importation of low priced salt from Germany and the West Indies, drought, and a decreased demand from fish packing and other industries in the West.

The Salt Industry in Michigan has centered in three principal districts, located in the eastern part of the State along the Detroit-St. Clair rivers and the Saginaw Valley, with a western district situated in the vicinity of Ludington and Manistee. In the early days of Michigan salt production Saginaw Valley operators took the lead with their cheap fuel and easily available shallow brines from the Marshall sandstone at from 650 to 1000 feet. During more recent years the other two districts have had supremacy, their production and value being over 90 per cent of the total for the State. In these districts artificial brines are obtained by forcing water and compressed air or steam through casings down to the beds of rock salt and then back to the surface. One rock salt mining operation is carried on by the Detroit Rock Salt Company, at Oakwood, a suburb on the west side of Detroit. The salt is obtained from a 36 foot bed of which about 20 feet are mined at a depth of some 1040 feet. Electric shovels are used to excavate the salt which is crushed, screened, sized, and sold for pickling; curing fish, meats and hides; for the manufacture of ice cream; and for general refrigeration purposes.

Growth of the salt industry in Wayne County took place at a remarkable rate from 1895 to 1919. From the first production in 1895 of 13,077 barrels it increased to a maximum of 11,539,258 barrels in 1919 or 64.8 per cent of the total. The value was $2,324,164 or only 24.5 per cent of the total.

The industry began to decline in 1920, production being 9,713,564.3 barrels valued at $2,510,789, a decrease of 1,925,694 barrels or 16.6 per cent in production but an increase of $186,625 or 8 per cent in value. Production continued to decrease in 1921, being only 5,950,521.4 barrels valued at $2,052,596, a decrease of 3,763,043 barrels or 38.7 per cent in quantity (a decrease of 48.4 per cent from the maximum of 1919) and of $458,193 or 17.1 per cent in value. In 1922 Wayne County produced 9,363,564 barrels valued at $2,437,710; in 1923, 10,457,185 barrels valued at $2,873,664; in 1924, 8,942,707 barrels valued at $2,377,395; in 1925, 10,574,375 barrels valued at $2,308,378 and in 1926, 11,264,732 barrels valued at $2,293,738.

The manufacturers of bleach, caustic, soda ash, etc., cause considerable demand in Wayne County for salt in the form of brine, and this is the governing factor for the low relative value of the product in comparison to other counties. The Solvay Process Company at Delray, the Michigan Alkali Company at Ford City and Wyandotte, and the Pennsylvania Salt Company at Wyandotte, use great quantities of brine in their manufacturing processes.

St. Clair County, although classed in the same district, is treated separately because of the exceptionally high grade of the trade products manufactured. During 1923, St. Clair County showed an output of 2,604,607 barrels or 17.1 per cent of the State total, but the valuation of $4,097,427 represents 47.2 per cent of the total value for Michigan. Practically 50 per cent of the county's output consists of table and dairy salt. In 1924 St. Clair County produced 2,691,993 barrels valued at $3,859,155; in 1925, 2,643,733 barrels valued at $3,714,729; and in 1926, 2,569,497 barrels valued at $3,579,162. It is at once noticeable that for the three year period there was a continual decline in both production and value.

Pressed blocks were first placed on the market in 1917 and have been utilized as a substitute for the large lumps of rock salt formerly used for cattle licks in field and stable. The blocks are formed in hydraulic presses, and make use of refined salt spilled around machines in evaporating and packing departments. Although these blocks are prepared from both rock salt and the evaporated salt, Michigan production comes largely from the latter. Depending on the demand there has been a recent tendency to use straight run evaporated salt in preparation of the blocks. In 1926 a decrease of 7 per cent in block salt made from evaporated products took place for the United States as a whole. The dropping off of block salt production in Michigan for that year was 13.83 per cent. These figures may be misleading somewhat, as certain firms are making pressed blocks from salt bought in the open market.

The few concerns still producing salt in the Saginaw Valley represent a small output of open pan product. This salt, together with that derived as byproduct from the Dow Chemical Company at Midland, Midland County, comes from the natural brines of the Marshall formation located at depths from 650 to 1200 feet.

PRODUCTION AND VALUE OF SALT IN MICHIGAN AND UNITED STATES, 1880–1926.††

Year.	U. S. production quantity bbls.	Michigan production. State Salt Inspectors† Quantity, bbls.	Michigan production. U. S. G. S.= Quantity, bbls.	Per cent of total Michigan.	Rank quantity.	Value Michigan.	Michigan Rank value.	Michigan Price bbl.
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	3,036,317	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	......	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‡	5,097,276	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	45,449,329‡	....	14,918,278	32.84	1	4,612,567	1	0.309
1917	49,844,125*	....	16,078,136	32.25	1	6,817,202	1	0.421
1918	51,705,317*	....	17,165,178	33.19	1	9,048,650	1	0.520
1919	49,157,686‡	....	17,800,564	36.21	1	9,456,138	1	0.531
1920	49,745,373‡	....	16,163,679	32.49	1	10,698,674	1	0.662
1921	35,579,672	....	10,196,179	28.66	2	7,439,445	1	0.729
1922	48,520,350	....	14,322,057	29.52	1	8,693,604	1	0.607
1923	50,933,664	....	15,195,800	29.83	1	8,684,148	1	0.571
1924	48,593,678	....	13,703,307	28.19	2	7,864,838	1	0.574
1925	52,839,286	....	15,518,571	29.37	1	7,710,331	1	0.497
1926	52,654,387	....	16,145,174	30.66	1	7,594,418	1	0.470
Totals	1,192,156,476	....	389,010,582	......	......	$182,882,509	......	......

†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 1914-1917-8 and 1922.
††For the State total 1865-1879 see Pub. 29, G. S. 24, Michigan Geological Survey.
*Includes production of Porto Rico.

PRODUCTION AND VALUE OF SALT IN MICHIGAN BY METHODS OF MANUFACTURE, 1906-1926

Year	Evaporated. Quantity	Evaporated. Value	Pressed blocks. Quantity Tons.	Pressed blocks. Value.	Other rock. Quantity. Bbls.	Other rock. Value.	Brine and other.† Quantity. Bbls.	Brine and other.† Value.	Total. Quantity. Bbls.	Total. Value.
1906–1910	29,278,297	$10,302,732	....	....	....	....	20,796,007	$1,083,643	50,336,468	$11,503,238
1911	5,355,707	232,046	....	....	576,695	$181,865	4,387,772	219,244	10,320,074	2,633,155
1912	5,441,288	2,486,785	....	....	763,908	250,680	4,737,038	236,852	10,946,739	2,974,429
1913	6,042,657	2,811,429	....	....	727,364	244,172	4,756,779	237,431	11,528,800	3,293,032
1914	6,141,711	2,806,895	....	....	712,530	252,024	4,816,735	240,086	11,670,976	3,299,005
1915	6,595,113	3,602,886	....	....	919,735	321,354	5,073,940	380,491	12,588,788	4,304,731
1916	6,549,407	3,747,695	....	....	1,012,942	368,022	7,365,927	506,850	14,918,278	4,612,567
1917	6,233,793	5,729,911	....	....	1,204,543	568,717	8,639,800	578,574	16,078,136	6,877,202
1918	7,307,928	7,679,927	....	....	1,405,671	827,348	8,451,578	541,375	17,165,178	9,048,650
1919‡	7,021,800	8,004,713	....	....	1,350,634	972,517	9,430,264	660,119	17,800,564	9,456,138
1920	6,452,785	8,677,108	....	....	1,511,050	1,186,682	8,199,843	549,824	16,163,678	10,698,674

Year	Evaporated. Open pans or grainers. Quantity Bbls.	Evaporated. Open pans or grainers. Value	Evaporated. Vacuum pans. Quantity Bbls.	Evaporated. Vacuum pans. Value	Pressed blocks. Quantity Tons.	Pressed blocks. Value.	Other rock. Quantity. Bbls.	Other rock. Value.	Brine and other.† Quantity. Bbls.	Brine and other.† Value.	Total. Quantity. Bbls.	Total. Value.
1921	2,349,893	$3,557,177	2,482,693	$2,449,417	29,657	$273,187	1,367,643	$868,348	3,784,122	$201,316	10,196,179	$7,439,445
1922	2,987,250	4,543,626	2,786,443	2,471,455	‡‡	‡‡	‡‡	‡‡	6,600,543	430,154	14,322,057	8,693,604
1923	2,747,835	4,221,764	2,708,664	2,688,779	‡‡	‡‡	‡‡	‡‡	7,708,528	452,838	15,195,800	8,684,148
1924	2,608,671	3,890,908	2,775,650	2,267,171	50,580	429,689	‡‡	‡‡	6,247,486	468,394	13,703,307	7,864,838
1925	2,778,879	3,757,779	2,862,771	2,367,621	52,145	387,352	‡‡	‡‡	7,560,207	457,417	15,518,571	7,710,331
1926	2,679,926	3,736,338	2,913,440	2,176,346	44,930	374,655	‡‡	‡‡	8,504,991	525,952	16,145,174	7,594,418

†Brine only after 1910.
‡1919 computed from census returns and subject to revisions and corrections.
‡‡Included in total.

CEMENT

The early history of Michigan cement industry deals with a venture made by the Eagle Portland Cement Company of Chicago, to establish a plant about two miles northeast of Kalamazoo. This was one of the first attempts to manufacture cement in the United States, and marl and surface clay constituted the raw materials. These were mixed, air dried, cut into bricks, further dried on a wood fire and then calcined with burning coke in two vertical kilns of beehive shape. The clinker was ground with millstones and some 100 barrels a day of the product was sold from 1872 to 1882.

The industry was definitely established in 1896 with the building of a vertical kiln plant by the Peerless Portland Cement Co. at Union City. In 1902 rotary kilns replaced those of vertical type, but the raw material of marl and shale continued in use.

Although the manufacture of cement as an industry has continued to expand ever since, there have been two periods of particular marked growth. The first was from 1895 to 1907 when the introduction of rotary kilns and the location of new plants close to cheap marl supply were dominating factors. The second period came from 1920 to 1926, when increased uses, larger plant capacity, and location of new plants close to markets and lanes of commerce stimulated the increase. This period was also one in which earlier companies using marl exclusively were prompted by advantages in fuel consumption and kiln capacity to a more general use of limestone where it was available.

The raw materials used for the manufacture of Portland cement are governed by varying conditions. Those ingredients essential are calcium carbonate, usually in the form of limestone or marl but sometimes in the form of waste lime from chemical plants, and either clay, shale, or blast furnace slag. As freight on the finished product is a large item in the industry, the location of marl near a strategic shipping point may favor its use as the lime constituent. Of the sixteen plants reporting operation in 1926 in Michigan, five used marl exclusively while two others used both limestone and marl. Because of the few exposures of shale within the State, it is more rarely used than clay, only two producers reporting an exclusive use of shale and two others reporting a use of both shale and clay. The sources of raw materials useful in cement manufacture are discussed under the headings of "Limestone" and "Shale," and more detailed accounts may be found in other reports.*

Besides the cement materials proper, fuels, fluxes, and retarders enter intimately into the manufacturing process. The separate stages leading up to a finished product are mixing, burning, and grinding and these demand extremely exact control. In the "wet" process of manufacture the mixture is introduced into the kilns as a thin slurry mud containing up to about 40 per cent water. This enables a greater ease of producing a uniform product, but more heat to evaporate the moisture is required.

*Bulletin 522, United States Geological Survey.
D. G. Hale, Michigan Geol. Survey VIII, Part III, Marl and its Application to the Manufacture of Portland Cement. (1903).
R. A. Smith, Pub. 24, Geol. Series 20, Mich. Geol. and Biol. Survey, pp. 117-151, 1916.
G. G. Brown, Pub. 36, Geol. Series 30, Mich. Geol. and Biol. Survey. The Clays and Shales of Michigan 1926, pp. 181-186 and other citations.
Cook, C. W., Michigan Cement, Mich. Geol. & Biol. Survey, Pub. 8, Geol. Series 6, 1912, pp. 337-354.

In the "dry" process the pulverized materials are mixed dry and are fed into the kilns entirely free from moisture. By this process a greater kiln capacity is possible and fuel consumption is reduced although preliminary heating may be necessary.

During 1924 the total United States production was 148,859,000 barrels and according to "Rock Products," the total capacity of plants was approximately 165,000,000 barrels or between 10 and 12 per cent in excess of actual production. Sixteen plants were in operation in Michigan during 1925 with a daily capacity of more than 47,000 barrels. In 1924 the plants ran at 80.5 per cent capacity, but in 1925 production was only 71.5 per cent of capacity. No figures were available for 1926. It is evident, therefore, that the construction of cement plants is increasing at a greater rate than the demand for cement and there is a widening margin between actual production and possible production. Too many plants, poorly located, using poor material, cause an oversupply and result in many failures. Nevertheless in some localities plants have been pushed to utmost capacity, which was especially true in the East, South, and Central West sections.

The general increase of Portland Cement production for the United States during the 1924, 1925, 1926 period was augmented in Michigan by the establishment of two new plants. These were the Ford Motor Company's plant in Detroit in 1924, and the Peerless Portland Cement Company plant also in Detroit in 1925. All but two of Michigan's plants are in the southern half of the lower peninsula. The two plants in the northern part, one at Petoskey and one at Alpena, are so situated that cheap water transportation is available to carry their product to Chicago and Detroit markets. One Michigan plant has increased its loading capacity, and various improvements in technology are under way throughout nearly all the cement industry in the State.

The location of the various cement plants throughout Michigan are indicated on the map in Figure 8.

LOCATION OF CEMENT PLANTS -1925

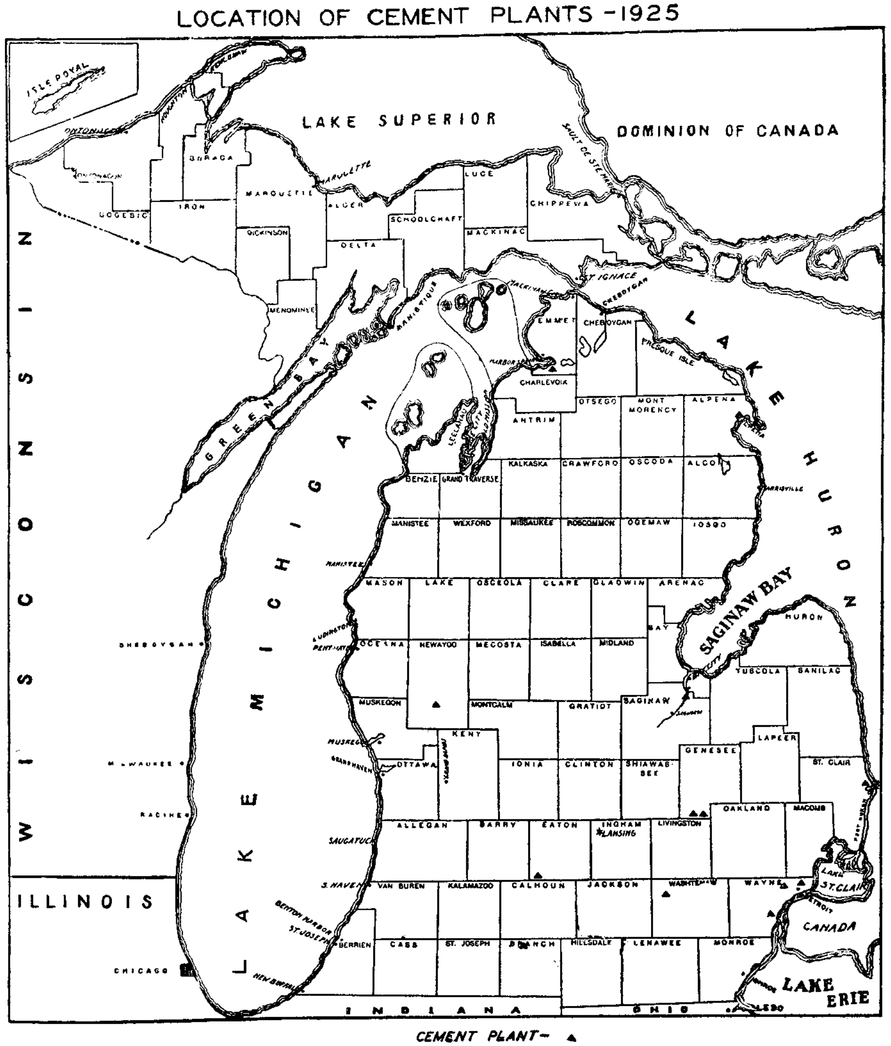

FIGURE 8.

Map Showing Location of Cement Plants in 1925.

In 1924 Michigan produced 9,259,781 barrels of cement and shipped 8,991,270 barrels valued at $16,405,761 or an avearge price of $1.82 per barrel. During 1925 the total amount of cement produced in the State increased 18.1 per cent with 10,936,181 barrels of which 10,073,453 barrels valued at $17,511,908 were shipped. The year showed a decrease in the average price per barrel to $1.74, but in 1926 this came back to $1.82 or the same as for 1924. Production increased 7.81 per cent in 1926 with a total of 12,037,400 barrels for the State. Of this, 11,959,447 barrels were shipped valued at $19,449,788. For the three year period from 1924 to 1926 Michigan showed both a production and value from 6 to 7 per cent

of that for the United States and ranked continually in third place as to comparative state production. In 1926 there was a smaller stock left on hand than at the end of either of the two preceding years.

In 1924 cement products had a larger year in every line except drain tile. Largest increases were noticeable in cast building stone and concrete block. Continuous large increases took place also in concrete building tile, roofing tile, sewer pipe, and cement stucco. For the first time the wall volume of concrete masonry exceeded that of common burned brick. This use together with the ever increasing amount of concrete highway construction has contributed to enormous volume of Portland cement output for the past three years.

PRODUCTION, VALUE, ETC., OF PORTLAND CEMENT IN MICHIGAN AND UNITED STATES, 1896-1926.

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	$2,244,011	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	8,482,020	7.8	93.4	....	830,990	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	2,342,973	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	....	2,556,215	43,547,679	5.8	....	0.883	0.85
1909	12	7	......	....	3,212,751	64,991,431	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	1.891
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	4,228,879	4,228,879	89,106,975	4.74	473,563	1.035	1.005
1914	11	7	77	19,100	4,285,345	88,230,170	4.85	2.27	4,218,429	4,064,781	80,118,475	5.07	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	74,756,674	5.95	569,919	.942	0.86
1916	11	6	68	20,650	4,919,023	91,521,198	5.37	3.2	5,151,818	6,017,911	104,258,216	5.77	338,035	1.168	1.103
[illegible]	11	6	68	20,550	4,688,899	92,814,202	5.03	—4.47	4,313,771	6,122 887	122,775,088	4.98	701,919	1.419	1.354
1918	10	6	49	22,160	3,554,872	71,081,663	5.00	—24.2	3,618,088	6,078,167	113,153,513	5.37	635,447	1.680	1.596
1919	11	4	58	20,425	4,675,244	80,777,935	5.78	32.00	4,990,308	8,468,196	146,734,844	5.77	219,641	1.70	1.71
1920	11	7	58	22,700	4,891,457	100,023,245	4.89	5.00	4,442,455	10,939,633	194,439,025	5.62	666,389	2.46	2.02
1921	11	3	53	23,600	5,777,533	98,293,000	5.78	18.1	5,680,156	10,300,289	180,778,415	5.69	760,503	1.815	1.89
1922	12	5	60	25,550	6,243,805	115,679,412	5.39	11.8	6,349,751	11,145,573	207,170,430	5.38	759,703	1.76	1.76
1923	14	5	62	29,400	7,619,792	137,460,238	5.54	22.	7,466,283	14,038,322	257,684,424	5.44	738,892	1.88	1.76
1924	15	3	66	34,950	9,259,781	148,859,000	6.22	21.5	8,991,270	16,405,761	267,319,000	6.13	782,377	1.82	1.81
1925	16	3	84	47,405	10,936,181	161,658,901	6.78	18.1	10,073,453	17,511,908	278,524,108	6.18	1,060,047	1.74	1.77
1926	16	3	*	*	12,037,400	164,520,168	7.31	7.81	11,959,447	19,499,788	277,963,432	7.02	1,897,474	1.82	1.71

*Information not furnished.
†Minus sign indicates decrease.

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GRAPHS SHOWING PORTLAND CEMENT—VALUE, PRODUCTION & SHIPMENTS

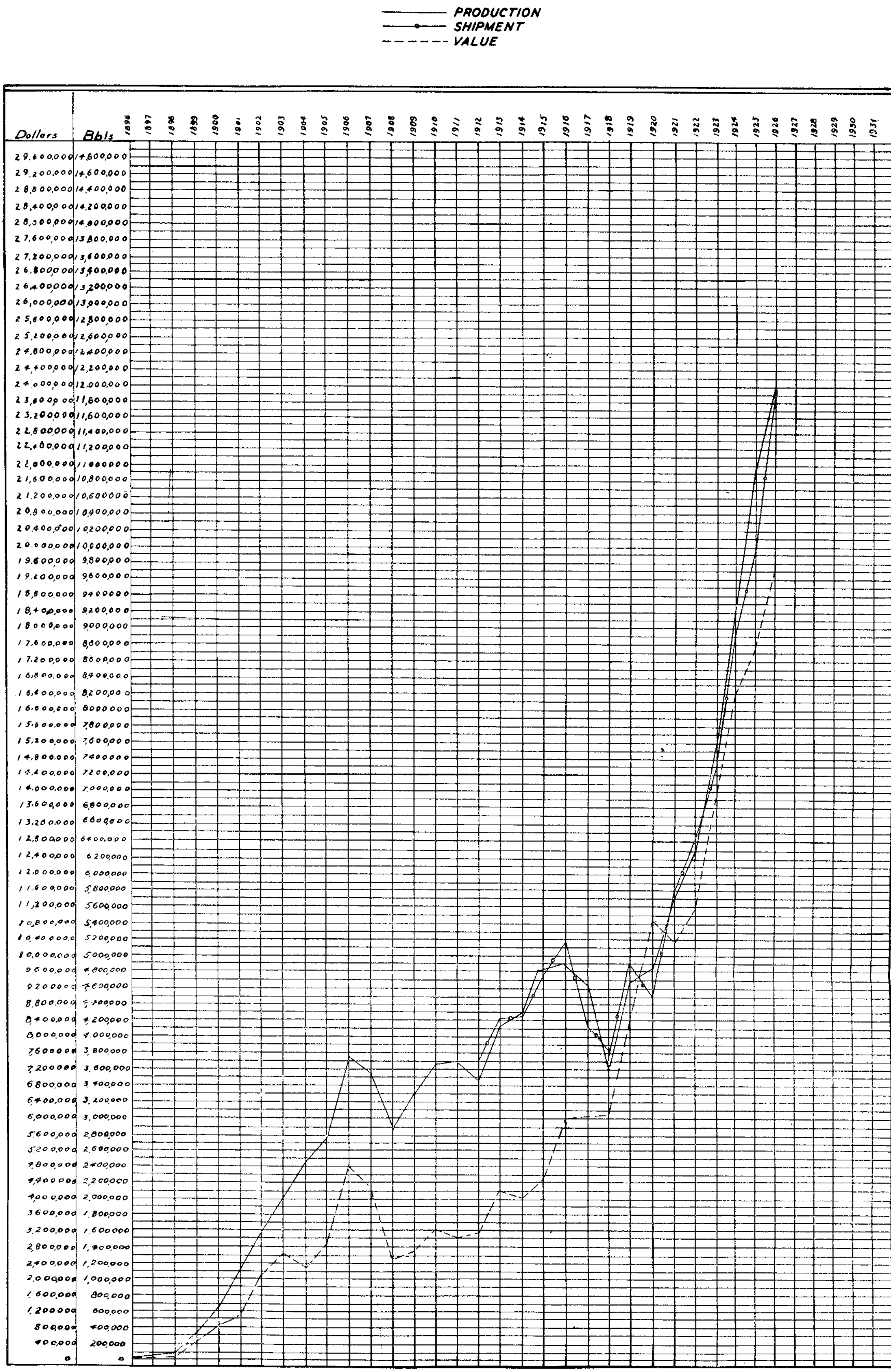

FIGURE 9.

Graph Comparing Production,
Shipments, and Value of Portland Cement Manufactured
in Michigan from 1896 to 1926.

PRODUCTION, VALUE, ETC., OF PORTLAND CEMENT IN MICHIGAN AND UNITED STATES, 1896–1926.

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	$2,244,011	0.29	....	$1.75	$1.57
1897	2	......	......	....	15,000	2,677,775	0.56	275.0	....	26,250	4,315,891	[illegible]	....	[illegible]	[illegible]

GYPSUM*

Michigan was one of the pioneers in the gypsum industry and has continually held a prominent place in its production. Since 1827 when the first traces of the mineral were discovered along Plaster Creek, which flows into Grand River in the southwestern part of Grand Rapids, the total gypsum mined has increased until in 1926 it amounted to nearly 660,000 tons. The areas of importance around which this growth has centered are the Grand Rapids-Grandville district in Kent County and the Alabaster district in Iosco County. The former furnishes the greater bulk of the State's production, but the latter is known for especial purity of raw material and the size of its open pit workings. The foundation of the United States Gypsum Company, the largest producer of gypsum products in the United States, was laid in the exploitation of the Alabaster property.

Geologically, the occurrence of commercial gypsum in Michigan is confined to the lower part of the Michigan formation of Mississippian age and to a formation somewhat indefinitely correlated as Salina of Silurian age. At the present time only those of the Michigan formation are worked, as water difficulties caused an early abandonment of the older Silurian deposits. At least three and possibly four gypsum beds are worked in Kent County where there are drift entries down the dip known as "caves" and shafts from 75 to 95 feet deep. In former days quarrying was carried on, but large quantities of water and overburden encountered have caused all the operators to revert to mining methods.

The upper beds of the series at Grand Rapids are 6 and 12 feet thick respectively and occur near the surface. The third bed in the western part of Grand Rapids averages about 22 feet in thickness with a parting bed of one foot of shale near the middle, and is found at a depth of 60 feet below the surface. At Grandville the quarry exposes an upper bed 11 feet in thickness which is separated from a lower 14 foot bed by four feet of hard limestone and blue to green shale that checks on exposure to the weather. Above the gypsum are beds of blue-gray fissile shale, intercalated thin beds of blocky gray sandy shales, and the overburden of about 25 feet consisting of sand and gravel. Fluted weathering effects are well displayed on the surface of the upper bed. The two beds are supposed to be equivalent to the 22 foot "split" in the West Grand Rapids district. Another bed is located at some 50 feet below these and numerous explorations have recorded the presence of other mineable beds in the Grand Rapids area.

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 from 5 to 25 feet thick. Extensive prospecting by the National Gypsum Company in the vicinity south of Emery Junction, some eight miles to the west of Alabaster, has proven a property of considerable promise. From 8 to 30 feet of very pure white gypsum exist under a covering of about 8 feet of clayey loam. The company has built a modern wallboard plant and opened a quarry.

Whether or not this is the same bed as that worked at Alabaster can not be determined without more detailed correlation.

South of this gypsum belt in the vicinity of Turner, Twining, and the deserted village of Harmon City, Arenac County, another prominent gypsum bed is found. This is known as the Turner bed and occurs from 50 to 100 feet above the Alabaster bed. Locally, in the vicinity of Turner it attains a mineable thickness, but is not worked on a large scale.

In the Upper Peninsula gypsum beds of Silurian age occur near St. Ignace at Pt. aux Chenes, and on St. Martins and other nearby islands. The gypsum compares favorably in quality with that at Grand Rapids, but locally water would cause difficulty in quarrying. The total thickness of gypsum beds in the vicinity of St. Ignace are reported to aggregate 60 feet, three of the beds showing a thickness of 9, 13, and 21 feet respectively. According to available data there are seven beds of gypsum quarryable in the immediate area.

Deep drilling in the southern part of the State in which the Salina has been penetrated, show large quantities of anhydrous calcium sulphate, or anhydrite. Any gypsum that might occur associated would be at a prohibitive depth for commercial exploitation. In the central part of the Michigan basin gypsum and anhydrite have been found in appreciable quantities in many wells that have gone through the Michigan formation. There is every indication from these findings that there are plenty of reserves and the supply of gypsum is nearly inexhaustible.

In the Grand Rapids district the gypsum is variable in color and purity. The colors range through grays and creams to various shades of pink and red, with often mottled effects that may be due to brecciation. Most of the rock is massive and granular, but some is crystalline and often shows "cone in cone" structure which is termed "needle" or "pencil" rock depending on the relative size of the cones. Anhydrite is rarely associated, but small amounts of salt may cause difficulty with the calcined product, quantities of more than 0.3% being objectionable for plaster making. At Alabaster a granular white gypsum predominates, and high purity is more generally prevalent throughout the district. There are occasional light pink or gray shadings and clay stringers to be found in the bed.

From 1868 to 1889 the annual production of gypsum in Michigan never reached 70,000 tons. The production in 1890, however, attained a maximum of 74,877 tons. The maximum value of gypsum and gypsum products for the period was attained in 1883, the value being $377,567. The growth of the industry began in 1890. In 1892 the output reached 139,557 tons but the financial depression throughout the country during 1892-3 disorganized the industry, the production in 1895 decreasing to only 66,519 tons, or less than half that in 1892. From 1896 to 1916 the growth was almost uninterrupted, reaching the maximum production of 457,375 tons in that year, valued at $1,066,588.

The increased production in 1916 was due to the general activity and prosperity in industrial lines, particularly in the building trade. After the entry of the United States in the War in 1917 building operations excepting for War purposes, were greatly curtailed. This is reflected in the marked decrease in the production of gypsum and gypsum products for 1917 and 1918, although the same year shows a 65.11 per cent increase in value over pre-war production.

In the early days of the industry four-fifths of the raw gypsum was ground into land plaster and from 1860 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 more or less gradually decreased, so that the production in 1918 was only 5,892 tons as

compared with the maximum of 49,570 tons in 1880, and in 1919 had further decreased to 1,597 tons. In 1919 the Gypsum Industries Association of Chicago, Illinois, launched a campaign to induce greater use of gypsum as land plaster, as a deodorizer and fixative of ammonia in manure about stables, as a soil stimulant, and as a specific for black alkali. That the campaign was effective is shown by the fact that the production of agricultural gypsum for the United States increased from 40,000 to 107,000 tons. In Michigan the increase was from the minimum production of 1,597 tons in 1919 to 12,092 in 1920, and 26,558 tons in 1921. The 1922 production was 13,054 tons, but in 1923 and 1924 the total re-

PRODUCTION AND VALUE OF GYPSUM AND GYPSUM PRODUCTS
1868 – 1926

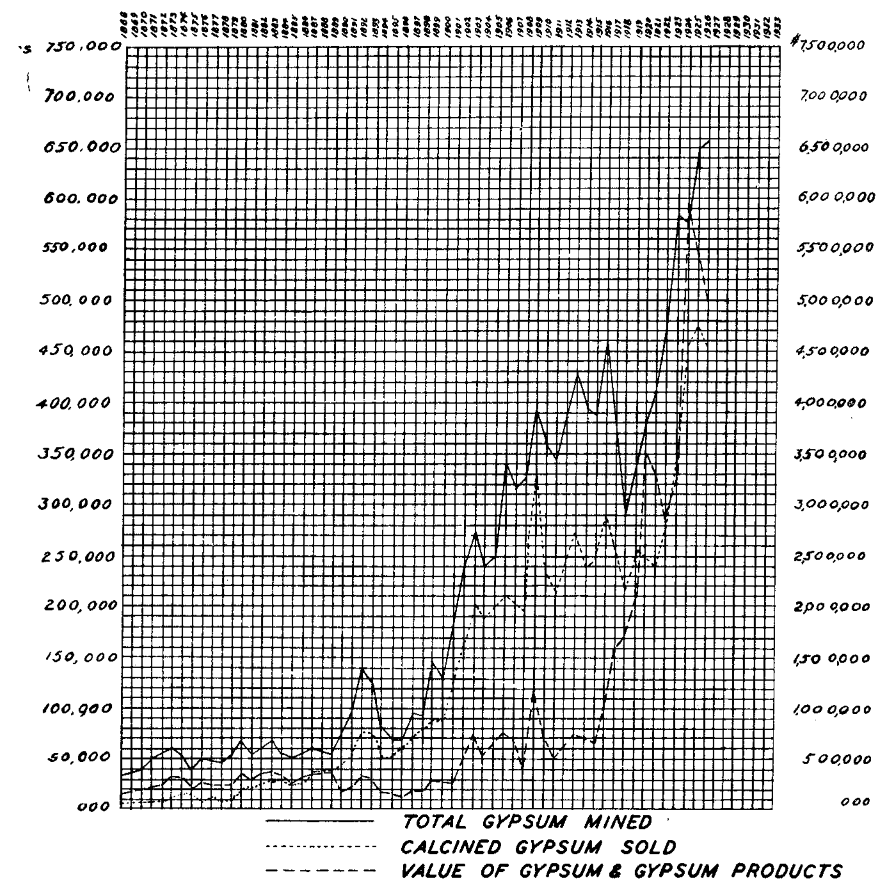

FIGURE 10.

Graph Showing Relation Between
Production and Value of Gypsum and Gypsum Products

ported was greatly reduced, the figures being withheld from publication because of the small number of producers.

During 1925 the production was only 566 tons valued at $3,344 and in 1926 there were 609 tons produced valued at $3,324.

The production of gypsum and gypsum products for the three year period of 1924, 1925, and 1926 showed a continual increase although there was a slight decrease from 1923 to 1924. After 1924 the total value of the products showed a slight decline each year from that preceding. The production increased from 577,526 tons in 1924 to 659,685 tons in 1926, but the value decreased from $5,950,822 to $5,021,465 for the corresponding years. Michigan's rank in production was maintained in third position for the three years, being only exceeded by New York and Iowa in first and second place. The position in value held by Michigan fluctuated somewhat, being second in 1924, and fourth in 1925 and 1926.

Most of the gypsum which is sold crude is used as a retarder in the manufacture of Portland cement. The quantity for this use increased each year from 1924 to 1926 and in the latter year 157,178 tons were shipped to cement plants, which was valued at $376,524. This was far less than the quantity sold as the calcined product, which amounted in 1926 to 455,616 tons valued at $4,641,617. The peak production of all time for calcined product in Michigan was 477,076 tons in 1926, and the calcined product attracted the greatest value of $5,626,682 during 1924. The relation between production and value of gypsum and gypsum products is shown in Fig. 10.

A recent innovation has been the use of crude gypsum because of its thermal properties, as an insulator between walls.

Calcined gypsum is used largely in construction. Development of new ways of using gypsum in the building trades has been rapid and it is now employed in pre-cast block, tile, and wall board and poured into place as partitions. A form of gypsum concrete called "structolite" has also been put on the market, which has the advantages of lighter weight and better thermal insulation than Portland cement concrete. It is pressed into slabs of various shapes and sizes as a gypsum lumber, which may be planed, nailed, sawed, etc., in the same way as wooden lumber. The increased demand for stucco as an exterior finish and improvements in the art of applying it and rendering it frost-resistant point to an increase in the production of gypsum for that purpose.

The great expansion of building activity from 1919 to 1924 is reflected in the amount of prepared gypsum that was sold. By far the greatest increase took place in 1924. However, the general decrease in value of the product for the industry in 1925 and 1926 is entirely involved in the decrease in value of that part which was calcined.

*For a more detailed discussion of "Gypsum" the following publications are suggested:
Adams, Geo. I. and others.—Bull. 223, U. S. Geol. Surv.—Gypsum Deposits of the United States.
Grimsley, G. P., Vol. IX, Part II, Geol. Survey of Mich.—The Gypsum of Michigan and the Plaster Industry.
Smith, R. A.—Pub. 19, Geol. Series 16, Min. Res of Mich., for 1914, Michigan Geol. & Biol. Surv.
Smith, R. A.—Pub. 8, Geol. Series 6, Min. Res. of Mich. for 1910, 11, and prior years, Michigan Geol. & Biol. Surv.

PRODUCTION OF GYPSUM IN MICHIGAN, 1868-1926.*

Year.	Ground into land plaster. Tons.	Calcined sold. Tons.	Sold Crude Tons.	Total mined. Tons.	Gypsum and gypsum products. 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	284,054	....	....
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	18,920	....	68,499	349,710	....	....
1881	33,178	20,145	....	53,323	298,872	....	....
1882	37,821	24,136	....	61,957	344,374	....	....
1883	40,082	28,410	....	68,492	377,567	....	....
1884	27,888	27,950	....	55,847	335,382	....	....
1885	28,184	25,281	....	53,465	286,892	....	....
1886	20,373	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	67,633	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	10,304	86,972	33,328	129,654	285,119	2	2
1901	9,808	120,256	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	24,289	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	401,928	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	68,819	384,227	621,547	2	3
1913	9,604	278,368	60,706	423,896	721,325	3	3
1914	9,322	240,648	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	3	4
1917	7,090	257,588	68,155	375,803	1,568,655	3	3
1918	5,892	207,059	46,608	286,768	1,761,149	4	4
1919	1,597	250,687	58,754	339,125	2,390,367	3	3
1920	12,092	261,499	73,842	382,212	3,521,028	3	3
1921	26,558	240,648	110,677	408,224	3,312,096	2	2
1922	13,054	275,885	107,708	471,355	2,843,117	3	4
1923	†	341,746	†	587,987	3,252,993	3	4
1924	†	453,135	†	577,526	5,950,822	3	2
1925	†	477,076	†	649,053	5,447,294	3	4
1926	†	455,616	†	659,685	5,021,465	3	4

†Included in total.

PRODUCTION OF GYPSUM IN MICHIGAN, 1913-1926.

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.	
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
1917	375,803	60,846	$92,874	7,090	22,903	††	††	68,155	116,653
1918	286,768	40,314	105,621	5,892	23,876	††	††	46,608	131,438
1919	339,125	48,798	138,611	1,597	10,422	††	††	58,754	174,110
1920	382,212	52,705	188,591	12,092	54,050	††	††	73,842	268,968
1921	408,224	74,672	245,593	26,558	98,139	9,447	25,453	110,677	369,185
1922	471,355	85,275	228,982	13,054	40,583	26,120	164,198	107,708	291,295
1923	586,987	120,539	324,582	††	††	††	††	135,616	355,067
1924	577,526	123,641	321,049	††	††	††	††	124,134	324,140
1925	649,053	155,395	387,749	566	3,344	††	††	155,961	391,095
1926	659,685	157,178	376,524	609	3,324	††	††	157,787	379,848

Year.	Gypsum sold calcined.								Total. Value.	No. mines. and quarries.	No. mills.
	As mixed wall plaster		As stucco.		As boards, tile, etc.		Total sold calcined.†				
	Quantity	Value	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.			
	Tons.		Tons.		Tons.		Tons.				
1913	166,711	$437,720	95,402	$202,675	....	....	278,368	$665,356	$721,325	7	8
1914	163,972	475,638	83,780	173,172	....	....	249,648	654,599	705,841	8	8
1915	155,861	426,432	80,172	177,317	....	....	245,484	623,073	686,309	8	8
1916	193,816	668,795	87,405	279,597	....	....	292,109	975,626	1,066,599	7	8
1917	147,371	949,511	85,426	384,661	19,158	$67,741	257,588	1,452,002	1,568,655	7	8
1918	117,902	931,725	52,132	330,761	33,253	339,901	207,059	1,629,711	1,761,149	7	8
1919	152,162	1,460,572	48,039	315,516	46,377	415,972	250,687	2,216,257	2,390,367	7	8
1920	133,289	1,499,226	62,458	446,381	60,986	1,266,659	261,499	3,252,060	3,521,028	7	8
1921	169,809	1,662,343	37,968	298,538	22,809	807,519	240,648	2,442,911	3,312,096	7	8
1922	160,109	1,453,458	72,157	501,595	12,713	245,302	275,885	2,551,822	2,843,117	7	8
1923	††	††	††	††	††	††	341,746	2,897,926	3,252,993	7	8
1924	††	††	125,302	830,520	††	††	453,135	5,626,682	5,950,822	7	8
1925	††	††	128,053	777,087	††	††	477,076	5,056,201	5,447,294	7	8
1926	††	††	125,253	734,018	††	††	455,616	4,641,617	5,021,465	7	8

†Included in the total are values for sanded plaster, plaster of Paris, Keene's cement, dental plaster, gypsum for plate glass works and for other purposes.
††Included in totals.

BRICK AND TILE PRODUCTS

Brick and tile are the finished product from the grinding, molding, shaping, and burning of a plastic mass obtained from clays and shales. They vary widely in character and properties as do the raw material from which they are derived. The larger part of the brick and tile are manufactured in close proximity to the deposit, thus increasing efficiency by limiting the handling of bulky raw materials. A discussion of the different kinds of raw materials may be found under the headings of Clay and Shale in more detailed* publications on the subject. Because of the great variety of clays and shales and their wide distribution, production is scattered in many independent units throughout the State. On this account the industry is not adapted to central control of manufacture or marketing, and the ease of starting development has caused many projects with unforeseen adverse economic conditions to be abandoned. These abandoned brick plants bear mute testimony of the hazards of the industry, especially when it is undertaken without a careful investigation of the raw materials. The neglect of such factors as extent and uniformity of deposit, difficulties in burning the material, market, transportation, and labor together with that of insufficient capital to take care of unexpected difficulties has been the downfall of many such enterprises.

The greater production of common brick in Michigan comes from such low grade deposits as (1) morainic clays or drift clays (2) lake clays and (3) river silts. There is a concentration of suitable lake clay deposits in the vicinity of Springwells and West Detroit, and the largest part of the common brick produced in the State comes from this vicinity. Inflation of land values by the growth of Detroit westward has been gradually forcing the brick companies to move into other localities. One of the large companies has recently purchased two hundred acres of clay property in Dearborn for future development.

The more refined ceramic products as tile, pipe, and face brick are manufactured from the Coal Measures shales of the Saginaw Formation where they outcrop or occur close to the surface. Vitrified drain tile is the most important of these in the point of value and Grand Ledge, Eaton County, is the chief center for its manufacture, although significant production also is located at Flat Rock, Wayne County; Ashley, Gratiot County; and Morenci, Lenawee County. Sewer pipe is made in large quantities at Grand Ledge and Jackson. In the past few years the manufacture of face brick has been constantly increasing with plants in operation at Grand Ledge, Corunna, and Williamston. During 1925 there was 14.89 per cent more face brick produced than in 1924, and in 1926 an increase in production of 18.71 per cent took place over the preceding year.

Other brick and tile products are hollow building tile, faience tile, sewer tile, sewer pipe, fire brick, conduits, flue lining and wall coping. A plant projected in 1917 at Williamston, Ingham County, is now producing and a second plant of more recent construction is one of the most modern in the State. Some difficulty has been encountered in burning because of the occasional high carbon content due to local coal seams but this is being overcome by careful selection and mixing.

Ries, H.—Mich. Geol. Survey VIII, Pt. I, 1903.—Clays and Shales of Mich.
Brown, G. G.,—Pub. 36, Geol. Series 30, Mich. Geol. and Biol. Surv., 1926.—Clays and Shales of Michigan.

The trend of the brick and tile industry has been in recent years toward an increasing use of machine methods and more accurate sampling of raw material with consequent burning tests. Kiln development has brought about burning conditions which give a more uniform product and less waste. Other steps have been taken to eliminate breakage from handling.

After the War slump a recovery took place in the brick and tile industry with an increase in 1919 over 1918 of 116.5 per cent in value of the total production. This increase involved nearly every type of product. During 1920 the rise in production was not maintained although the value of the brick and tile products was the greatest in the history of the industry up to that time. In only one instance was there normal business reported for the year; some recorded business as dull and others stated that sales were better but they were unable to meet demand on account of coal and labor scarcity.

In 1921 there was another decrease in the total value of brick and tile products over that of the year preceding. This was due largely to the decrease in average price per thousand for brick which fell from $16.42 (in 1920) to $12.47, together with a 44.7% decrease for drain tile and a falling off of 67.7 per cent in the value of hollow building tile. During 1922 the total value again increased but was a little less than that reached in 1920. There was a gain in production and average price per thousand of brick, but the value of drain tile decreased 44.4 per cent, continuing a steady decline which began in 1919.

In 1923 the total value of brick and tile products showed a decrease of $192,292. This decrease was due to a decrease in the amount and value of brick with other items showing an increase in amount and value. The average price per thousand decreased from $14.53 to $14.36 or 17 cents. In 1922 the value of drain tile decreased sharply and in 1923 it increased again by $168,414, reaching a value of $337,833. This figure approximates an average figure for drain tile since 1902 and shows that the marked decrease in 1922 was not caused by permanent factors.

A review of the three year period from 1924 to 1926 reveals a striking change in production along all lines from 1923 to 1924, with comparative uniformity following in the succeeding years. Only under the heading of miscellaneous products would this statement need modification, in which case the immense figure of $3,603,601 for value of production in 1924 is attributed largely to completeness of data collected in that year. It is undoubtedly true, however, that large increases in production did actually take place, especially in sewer pipe. In 1924 the 261,614,000 common brick produced were valued at $2,927,123, representing an increase over 1923 of 35.31 per cent in quantity and 5.45 per cent in value. The average price per thousand decreased from $14.36 to $11.18 or 22.14 per cent. The total value for brick and tile products of $16,912,135 was the largest ever recorded and was an increase of 85.62 per cent over that for 1923.

The quantity of common brick produced was maintained with the slight decrease to 260,280,000 in 1925 and an increase to 275,294,000 in 1926. The value was practically constant at about three million dollars with the average price per thousand holding at about eleven dlolars. The years 1915 and 1916 were the only ones showing a greater production of common brick than 1926, and the value of the product in 1925 and 1926 was only exceeded in 1920 and 1922 when the average price per thousand was extremely high.

The value of drain tile produced did not fluctuate much but displayed a small decrease in each year from the preceding. The value of $361,130 in 1925 was 5.28 per cent less than $381,411 in 1924 and the decrease to $360,593 in 1926 was less than one per cent from 1925. The miscellaneous products decreased in the value of their production to $895,483 or 75.15 per cent less than 1924, and decreased to $809,549 or 9.6 per cent less than 1925. In spite of this decrease the value was higher than any years previous to 1924.

There was a decrease to thirty-one in number of firms operating in 1924, but the total was brought up to thirty-seven in 1925. The number was one less, or thirty-six, in 1926. The total value of brick and tile production decreased 37.97 per cent in 1925 to $4,287,422, and there was but little change in 1926 when the value of production totalled $4,227,731. These values are highest ever recorded with the exception of 1924.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899–1926.

Year.	Common brick.‡ Quantity.	Common brick.‡ Value.	Average price per M.	Drain tile. Value.	Miscellaneous† Value.	No. of firms operating.	Total value.
1899	200,144,000	$933,176	$4.66	$140,171	$180,909	196	$1,254,256
1900	180,892,000	863,250	4.77	114,747	169,381	189	1,147,378
1901	215,836,000	1,095,254	5.07	98,972	302,943	180	1,497,169
1902	237,254,000	1,331,752	5.61	96,645	232,545	182	1,660,942
1903	215,791,000	1,251,572	5.80	129,028	281,814	178	1,662,414
1904	205,196,000	1,116,714	5.44	208,088	346,090	168	1,670,892
1905	211,558,000	1,152,505	5.45	205,445	361,796	154	1,719,746
1906	206,583,000	1,178,202	5.70	314,098	301,067	142	1,793,367
1907	200,817,000	1,181,015	5.88	289,868	315,307	136	1,786,190
1908	181,049,000	994,525	5.49	327,630	344,226	132	1,666,381
1909	219,820,000	1,250,787	5.69	364,006	332,266	122	1,947,059
1910	232,551,000	1,363,316	5.86	348,205	372,004	118	2,083,525
1911	252,465,000	1,301,998	5.16	313,072	338,372	111	1,953,442
1912	271,189,000	1,592,283	5.87	387,945	370,378	101	2,350,606
1913	273,571,000	1,626,287	5.94	415,543	409,412	95	2,451,242
1914	269,154,000	1,633,216	6.07	421,941	379,715	90	2,434,872
1915	277,399,000	1,461,188	5.23	305,156	481,724	82	2,248,068
1916	279,175,000	1,856,587	6.65	548,795	299,672	73	2,705,054
1917	236,612,000	1,882,042	7.95	734,042	230,180	69	2,846,264
1918	94,746,000	915,599	9.65	565,398	227,739	61	1,708,736
1919	200,352,000	2,734,503	13.64	737,124	228,302	52	3,699,929
1920	186,526,000	3,062,660	16.42	690,816	226,215	49	3,979,691
1921	193,730,000	2,417,809	12.47	381,507	116,603	31	2,915,919
1922	248,608,890	3,613,542	14.53	169,419	132,349	27	3,915,310
1923	193,350,663	2,775,925	14.36	337,833	609,260	33	3,723,018
1924	261,614,000	2,927,123	11.18	381,411	3,603,601	31	6,912,135
1925	260,280,000	3,030,809	11.64	361,130	895,483	37	4,287,422
1926	275,294,000	3,057,589	11.11	360,593	809,549	36	4,227,731

†Includes hollow tile, block, fire-proofing, sewer pipe, face brick, floor tile, faience tile, wall tile and fire brick.
‡ For 1922 includes face brick.

COAL

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COAL

COAL DEPOSITS IN MICHIGAN

AREAL EXTENT

The area of coal bearing rocks in Michigan is commonly known as the Northern Interior Coal Field or sometimes simply the Michigan Coal Basin. It is so called because of the complete isolation from any other region of coal measures, and the basin shaped structure of the rocks involved. Although quite definitely established from fossil evidence that the period of coal formation is nearly equivalent to that in part of Ohio and Illinois, there is no apparent proof of connection at any time. The Michigan coal area is the only one in the drainage basin of the St. Lawrence River. According to various estimates it includes from 6,500 to 11,000 square miles of territory covering the central part of the Southern Peninsula. It is slightly wider north and south than east and west, and extends from the vicinity of Houghton Lake in Roscommon County to near Jackson, Jackson County, and from White Cloud, Newaygo County, to the vicinity of Caro, Tuscola County. To the south and east development and drilling has fairly well outlined the limits of the coal basin and has shown it to be somewhat irregular. The boundaries to the northwest and west are less well defined because of thick mantle of drift deposits which prohibit most drilling operations from going to the bed rock surface. The limit in this direction is rather one of exploration than of actual occurrence.

GEOLOGY

GENERAL FEATURES

The surface deposits are derivative of the several periods of Pleistocene Glaciation and the associated stages of the Great Lakes with their respective drainage systems. The region is low and flat in the eastern part where Saginaw Bay is the salient feature, and more generally rolling in other sections except locally such as in the valley of the Grand River. Surface materials are those characteristic of glacial deposits such as clay, boulder clay, sand, and gravel with minor bog and swamp occurrences of peat and marl. Elevations vary from 580 to 800 feet above sea level in the lower flat portion included by the Saginaw Valley and between 800 and 1000 above sea level in the higher undulating portions. The still higher broken tracts vary from 1000 feet to over 1200 feet above sea level on the north to between 1200 and 1600 feet above sea level on the northwest where the highest surface elevations in the Southern Peninsula are encountered. The rock surface below the drift sheet has also been proven to be highly irregular where extensive borings have outlined it, and this is considered quite generally the case.

Considerable surface control has been effected by the more resistant rim of the Upper Mississippian Bayport Limestone and Marshall Sandstone, which underlie the higher portions of land. A piling up of glacial material was concentrated along this area and accentuated the topography. This rim is broken into by Saginaw Bay and an old pre-glacial channel which extends southwest through northern Gratiot County, then turns westward and finally west through Montcalm and Newaygo Counties.

The section of the Coal Measures is extremely variable in thickness but in general there is from 300 to 400 feet in the series. About the margin there may be less than 100 feet of strata, and over 500 feet have been found in a few instances. Specifically in the vicinity of Saginaw the thickness is from 260 to about 325 feet, near Bay City, about 350 feet, and nearer the center of the coal basin at Midland, 410 and 525 feet, respectively. These figures are obtained from drill records, but exposures are known along the Rifle River in Arenac County; the Cass and some of its tributaries, near Tuscola, Tuscola County; the Flint near Flushing, Genesee County; the Shiawassee from Corunna, Shiawassee County, north to the Saginaw County line; the Cedar and Grand from Williamston, Ingham County, to six miles below Grand Ledge, Eaton County; and the Grand and its tributaries around Dimondale and Eaton Rapids, Eaton County; Ionia, Ionia County; and Jackson, Jackson County.Correlation of the strata is made with the Upper Carboniferous or Pennsylvanian age and equivalent to the Lower Barren Measures or Pottsville of the Pennsylvania classification. The series is divided into the Parma sandstone, or lower barren portion; the Saginaw formation, which is found above and carries the coal seams; and at the top the barren Woodville sandstone, which occurs locally and is of disputable age.

The Parma formation is a white sandstone and often somewhat conglomeratic. Locally, a black shale underlies it, provisionally classified with the Parma, but which is probably an unnamed member. The pebbles of the sandstone are usually white quartz and somewhat rounded, although occasionally they take on grays or yellowish shades. The Parma sandstone is considered as a basal or shoreward phase of the Saginaw formation above, so that a definite age cannot be assigned. It is a very persistent and continuous member and varies throughout the Coal Basin from about 170 feet to a mere parting. Locally it has been found absent or replaced by some other type of rock. Where present as a sandstone, it yields either fresh water or brines high in sulphates depending upon relative depth from the surface.

The Saginaw formation is a group of various thin beds including white, gray, and black shales; white to gray fine grained sandstones, and coal seams. Limestone is very infrequent, but there are local occurrences of pyrite nodules, zinc blende, and blackband (siderite). The beds are often lenticular and vary over short distances, although there is usually an orderly arrangement with the coals and their underclays below.

The Woodville sandstone is only locally present where it has been deposited in depressions or channels in the underlying Saginaw formation. The rock is pink to red and feldspathic in character. Association with gypsum has led to a belief in possible Permian age, but the gypsum may have been carried in with the drift or might be due to unconformable relations. No corroborative fossil evidence has been found to support the above contention.

The Coal Measures rocks rest unconformably upon the eroded surfaces of the Michigan formation of Upper Mississippian age. This discordance reaches considerable proportions in Michigan, for the erosion period which followed the continental uplift in North America at the close of the Mississippian was so severe that deep valleys were cut into the land surface and in places engraved through the Bayport limestone, and into or even through the Michigan Series below. Much rougher topography than the present land surface is thus indicated. As a result of the absence of the Bayport limestone and the Michigan Series

which were probably eroded away along much of the southeastern side of the Coal Basin, the Parma sandstone rests directly but unconformably upon the Napoleon sandstone of the Marshall formation and even the Coldwater shale. Since these two sandstones are rather similar in lithologic character, they are often distinguished only with difficulty in well records. Tracing out the Coal Measures in northern Jackson and northeastern Calhoun counties, it is found that in a number of places they were deposited in the bottom of valleys between hills and ridges which are capped with the Bayport limestone and other Michigan Series rocks.

STRUCTURE.

The major structure of the Michigan Coal Basin is a very flat synclinorium which although quaquaversal has a longer north-south axis. The minor wrinkles or folds are considered to be more or less radial to the center and recent oil exploration has shown some of them to be more pretentious than heretofore thought. The strata in general are not conformable to the basinlike structure of the pre-coal measure formations, but are nearly flat with the exception of the local undulations. According to *Robinson the general effect is one of a central basin surrounded by a flattened rim or terrace. He states that after the deposition of the Parma, the Michigan basin continued to receive sediments which were deposited under water and accumulated mostly in the deeper central part. The rocks formed in the deeper parts at this time reduced the gradient of the surface until it became a nearly perfect plain. The surface upon which the coal bearing rocks were laid down was probably as nearly a plain as would ever be developed in a filled basin. Faults have been noticed locally in the strata, but the displacements are usually only of small dimensions. Recently several faults of considerable size have been found and one near Bay City has a displacement of over 50 feet. Whether these movements have been due to settling or actual horizontal stresses has not been worked out, but indications are that the causative forces were probably the former. Further observations may show that faults are more prevalent in the coal series than formerly supposed.

RELATION OF COAL BEDS

Coal beds are not everywhere present in the basin, for deep wells completely penetrating the coal bearing series near the center of the area have found the Saginaw formation devoid of both coal and black shale, consisting only of sandstones and gray shales. *Lane estimates that sixty-one per cent of the basin is underlain with coal, but only about one-third of the basin with workable coal. The coal beds are apparently thicker and more numerous toward the margin of the Basin and tend to thin and disappear toward the center. In different districts a varying number of coal seams have been recognized. Of these †Lane makes the provisional series in ascending order: Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne, Upper Verne, and Upper Rider. Cooper‡ divides the series for Bay County into twelve recognizable seams, named from the bottom upwards: Bangor Coal, Bangor Rider, Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne, and

*Robinson, W. I.—Unpublished manuscript.
*Lane, A. C.—Mich. Geol. Surv., Vol. VIII, Pt. II, pp. 143-144.
†Loc. cit.—p. 46.
‡Cooper, W. F.,—Mich. Geol. Surv.—Ann. Report 1905, Bay County Report, p. 174.

Lower Verne Rider, Upper Verne and Upper Verne Rider, Salzburg Coal, and Salzburg Rider. Such divisions can only hold for very limited districts, however, as there is no continuity over broad areas. It is definitely established that the Michigan coals are the product of concentration in local basins or connecting channels on the borders of the larger basin. This leads to extreme local thickenings, but uncertainty for any distance. A single coal bed may rise or fall from 30 to 50 feet in a quarter of a mile, thicken, thin, or pinch out entirely in a few hundred feet, or split into two or more separate seams. The term "rider" is applied to a coal that may or may not occur above a specially prominent seam, and some beds may have several lenses that exist above them in the deeper troughs or valleys. The importance of various seams changes from one locality to another, and that which may be the main seam in one district corresponds to a rider in another. All these things witness to the transfer of favorable coal forming conditions from one part of the basin to another.

The equivalence of the series to the Appalachian Pottsville being fairly well established, various efforts have been made to correlate the beds with well known seams in other districts. The Verne coals and the Saginaw Seam have been most generally locally correlated upon the basis of physical and chemical properties and the overlying and underlying associated rock. The Saginaw coal is supposed to be of about the same age as the Sharon or Massilon coal of Ohio and the Upper and Lower Verne beds should correspond somewhat closely to the Upper and Lower Mercer seams. It must be born in mind that such correlations may be entirely inadequate, as the basis for them is rather unsatisfactory because of the isolation and uncertainty of Michigan seams. However, it serves of some value as a basis for checking, comparison, and a beginning for other hypotheses.

LOCAL FEATURES

The occurrence of coal in basins and channels already alluded to is one of the distinctive features of the Michigan area. The deposits, where workable, are similar in form to concave lenses, much thicker toward the center. The general outline is usually decidedly irregular and maps of mine workings where the channels have been followed are spider web like in their various radiations. Thickness of the seams in varying from place to place averages scarcely more than three feet for any of the deposits worked. In a few cases they average only about thirty inches which is the economic limit of workability in Michigan, unless other controlling conditions are exceptionally favorable.

Certain beds that occur with some regularity above the coal seams have been thought to be diagnostic. A thin layer of dark shale carrying the fossil *Lingula*, often overlies the Upper Verne bed and a distinctly calcareous bed is not infrequently found above the Lower Verne seam. Besides the undulating character of the floor, serving the base of the seams, occasional "horse backs" occur cutting up into them. *Lane has also described clay seams, sulphur partings, and spar seams.

He classifies the different types of channels into (1) open channels (2) gravel channels (washouts) (3) and sandstone channels. A "want" is any place where coal is lacking in a continuity of seam where it should

*Lane, A. C.—Geol. Surv. of Michigan—Vol. VIII, Pt. 2—Coal of Mich.—Chap. V—pp. 121-128.

occur. Open channels are those results of recent erosion which cut through the coal seams and either expose them at the surface or eliminate them entirely. Gravel channels are a similar phenomena caused from erosion of coal formation during the glacial epoch and contemporaneous or subsequent filling with glacial debris. In the case of sandstone channels, the stream courses which cut into the coal were of the same relative age and their subsequent fillings were indurated as the rest of the coal measures rocks.

PROPERTIES OF THE COAL

The physical properties of Michigan coals are largely similar to other bituminous coals suitable for domestic use. Certain seams are more dull than others and pyrite partings vary from place to place. The alternating bands of shiny and dull coal depending upon varying coaly matter as mineral charcoal, anthraxylon, spores, resins, etc., is the common occurrence, and so-called "block coals" are frequent. Some of the Michigan coals are coking, but the coke is usually inferior from sulphur content and thus derived friability. Nearly all are highly gaseous but this use is also generally prohibited by sulphur content. That which is called cannel coal in Michigan is a bone coal high in ash that burns with a great deal of smoke. Most of the coals of Michigan are weak and friable and this property causes them to slack readily, and is a detriment to shipment and storing. In general they are poorer and of lower grade than the Appalachian coals from Pennsylvania, West Virginia, and Ohio.

Chemical properties of coals are expressed in both proximate and ultimate analyses. These results must be examined closely for relative amounts of fixed carbon and volatile combustible matter, moisture content, and with special attention to ash and sulphur. The former type of analysis derives the constituents as compounds or mixtures above stated; the latter gives a complete division into the various elements making up the coal. Extreme care should be taken in the sampling of coal for analysis, and uniformity of method should be employed throughout. Reference is made to this by *Moore and it is extensively treated in publications of the ‡U. S. Bureau of Mines. The analyses of Michigan coals vary in moisture content from 2 per cent to 11 per cent in volatile combustible matter from 30 per cent to 46 per cent; in fixed carbon from 41 per cent to 58 per cent; ash content 1 per cent to 12 per cent; in sulphur content from 1 per cent to 7 per cent. The heating values range between 12,500 and 13,700 B. T. U. Saginaw and St. Charles coals from Saginaw County are higher grade than the average, the ash varying from 1 per cent to 7 per cent, the sulphur from 0.5 per cent to 2 per cent, and the fixed carbon from 50 per cent to 58 per cent. The moisture content for Bay County coals averages from 3 to 8 per cent and for Saginaw County from 6 per cent to over 12 per cent. Much of the coal mined in Bay County is similar in being high in ash and low in fixed carbon.

HISTORICAL ACCOUNT

COAL INDUSTRY IN MICHIGAN

Various accounts differ in the earliest coal mined, but this operation probably took place at Jackson, Jackson County in 1835. Certainly

*Moore, E. S.—Coal. Jno. Wiley & Sons 1922—Chap. III, p. 40.
‡Holmes, Jas. A.—Tech. Pap. No. 1, U. S. Bur. of Mines, 1918.
Pope, Geo. S.—Tech. Pap. No. 133, U. S. Bur. of Mines, 1919.

there was active mining on a small scale near Grand Ledge, Eaton County, in 1838 to 1839. Up to about 1910 the small shallow trough-like deposits of coal were operated by a few small mines in Jackson County. A similar deposit has been worked intermittently in recent years near Spring Arbor, Jackson County, and a larger development took place just across the county line in Calhoun County four miles north of Albion. According to reports this latter deposit opened in 1913 has not been operated in the past several years. Outcroppings of coal seams 18 to 26 inches thick occurred in the bed and along the banks of Grand River at Grand Ledge for more than a mile. The accessible coal here has been largely mined out, although some is still obtained from clay pits in connection with brick workings and one wagon mine is occasionally operated. In the years prior to 1860 coal was mined near Corunna and Owosso, Shiawassee County, and some mining has been carried on more recently. The occurrence of coal in this vicinity is pockety and of uncertain quality with the result that operations have been rather intermittent. At present there is no activity in this district.

Other developments of historical note took place in the vicinity of Millets, Eaton County, during 1858-59 and later successful mining was carried on at Williamston, Ingham County, near the site of the present Michigan Clay Products pit. Several shafts were put down at what was called Pinnacle Hill, on the Rifle River, Arenac County, in about 1875, but the deposits were only of local importance. They were largely cannel coal, had a very poor roof, and because of water difficulties and poor transportation facilities, extensive mining never took place.

The discovery of coal in Bay County has been attributed to William Walker when he drilled a salt well in 1861. Saginaw County coal was found in a like manner from well drilling associated with the lumber and salt industry. However cheap wood fuel retarded development until 1897, when mining of coal sprung into a real growth. The sinking of shafts centered around Saginaw, St. Charles and Bay City where numerous good mines were opened. A few years afterward coal deposits were discovered and mining began in Huron, Tuscola, and Genesee Counties. These mines have been mostly discontinued but one mine in Genesee County was operated in comparatively recent years. The maximum production of Michigan coal mining was reached in 1907 when more than 2,000,000 tons were mined.

A systematic subdivision of Michigan coal fields made by Lane* was based on the order of their historical development. Their growth spread from the different centers of exploration which usually owed their beginning to accidental discovery of coal. In the way of summary, this grouping includes:

1. Jackson field including mines around Jackson.
2. The Cedar-Grand field grouped 20 miles each way from Lansing and covering those small coal banks at Grand Ledge and that which was mined at Williamston.
3. The Owosso district includes all the region surrounding Corunna and Owosso with those mines near Flushing and Elk, Genesee County.
4. The Saginaw district embodies the mines operated around Saginaw and St. Charles and also the Verne mine.

*Lane, A. C.—22nd Ann. Rept., U. S. G. S., p. 313.

5. The Bay field includes the counties bordering on Saginaw Bay—Arenac, Tuscola and Bay counties, and the Sebewaing field of Huron County.

MINING METHODS

Since only in two areas does the Michigan coal appear at the surface, shaft mining is the general rule. The cardinal principle in the location of a shaft to be sunk, is to so place it in respect to the low part of the individual basin that it may receive the maximum amount of drainage. Even with this precaution, water difficulties are continually encountered and auxiliary pumps are often necessary to carry the water over local rises. The drifts follow the channels and troughs in the coal bed as closely as possible, and every advantage is taken of gravity for haulage. Often expensive cuts must be taken through poor coal or lean portions of the seam, and considerable waste areas must be left entirely. Artesian conditions cause water to enter the mine through the roof, the foot wall, or even the seam itself and practically all the mines are wet. The presence of channels contributes greatly to this difficulty.

Mining is carried on by the double entry system with room and pillar. Attempts at long wall methods proved futile because of the low coal and uncertain roof conditions. Early practice was to mine the coal by hand and "shoot off solid," but this was later replaced by machine cutting due to numerous difficulties encountered. The heavy charges of dynamite required breaks the coal, makes a great deal of fine slack, and renders the lump coal altogether too friable for easy transportation without crumbling. Moreover there is constant danger from falling of weak roofs shattered by the charge. The percentage of machine cutting is now about 70 per cent of the total although the number of machines used decreased somewhat with recent decline in production. Three types of machines are used, including the pick or puncher type, the chain breast machine, and the short wall machine. Pick or puncher machines require compressed air for operation and have become less popular on account of the objectionable feature of cumbersome hose or having to lay air pipes. The other types are electrically operated and the necessary wires for electric power are much more portable. Because of their compactness and ease of manipulation, and the advantages found in mining thin seams with lack of room and narrow openings, the short wall machine stands head and shoulders above all other types for efficiency of operation.

ECONOMIC FACTORS

The cost of developing a coal property before any actual mining is begun involves a number of hazards and considerable expense. No estimates of mineable coal can be made without thorough and accurate prospecting, and this prospecting requires extensive holdings. The Michigan coal beds are so uncertain and they vary so much over such a short distance that many more drill holes are required to prove up and outline an area than in most other coal regions. To make certain of having enough coal to mine it is also necessary to acquire a much larger piece of property than can actually be used.

Mining costs are abnormally large for the product obtained. In the first place the sinking of a shaft through a thick covering of glacial drift materials involves water difficulties and extra heavy timbering to keep back the sand and gravel. The cost of a shaft, power mine plant and equipment is about twice in Michigan to that in Ohio for similar depth and capacity. The amount of dead work-entry driving, timbering, track laying, cutting through bars and areas of unmineable coal, is greater than in competitive fields. Water conditions require excessive pumping expense, and the mines must be kept in order during the idle season, for they operate only part time. Besides the wage scale is higher and the mines work but six eight hour shifts per week. All this makes the mining costs several times as high as in Ohio or West Virginia, whereas the product must sell at a lower price because of inferior quality and friable nature of the coal.

The difficulties of transportation on account of the nature of the coal have already been mentioned. Some of this has been eliminated by the installation of a washery to wash the slack from the Consolidated Coal Company mines in the Saginaw area. This leaves an improved product which is easily moved and in great demand by companies using powdered coal and mechanical stokers. The matter of differential freight rates has been a natural protection for the Michigan coal market north of a line from Port Huron to Lansing. However, higher costs of mining in Michigan somewhat counterbalances this, so that the larger part of the market except at certain times is confined to the northern part of the state and the coal basin proper. On various occasions difficulties have been encountered because of the scarcity of cars, but this may be experienced in any coal field. The chief railroads that serve the Michigan mines are the Pere Marquette and the Michigan Central. Principal demand for the coal is derived from domestic uses although it has found its way into some industrial pursuits.

Any estimation of reserves always involves variables that leave the estimate open to question. In 1902 Lane* estimated the area of the coal basin as 7,500 square miles. Allowing 1000 tons to the acre yield and taking into account only coal two feet thick or over, his estimate of the reserve indicated would be 8,025,600,000 tons, nearly half of which would be in workable seams. Those areas which may be considered as proven are Bay and Saginaw counties with Tuscola and Genesee County possessing workable coal reserves. The undeveloped coal areas of importance are between (1) Midland and Bay City, just outside of which a mine was recently opened three miles west of Midland, (2) between Saginaw and St. Charles, (3) in the northern part of Bay County, (4) and in the vicinity of Flint, Genesee County. Many probable reserves exist in the southern part of the coal basin where beds from three to five feet thick have been struck in places around the margin. A coal bed 4 feet thick was recently penetrated in drilling for oil 10 miles east of Mt. Pleasant and seams probably reach mineable thickness in the northwest corner of the basin. The great thickness of drift and the abundance of water and quicksand have proved effective barriers to exploration and development in this region.

CURRENT PRODUCTION

The output of Michigan coal reached its peak in 1907 when 2,035,858 tons were reported to have been mined. In the following year production broke off rather sharply to 1,835,019 tons and a gradual decline then took place until 1912. For a period of years after this coal production continued rather steady, showing only slight decreases in 1915 and 1916 and slight increases in 1917 and 1918. These fluctuations were attributed to car shortage and changing labor conditions. During 1919 the output fell off about 500,000 tons, largely because of the closing of many mines by strike conditions and the erratic operation of many others from the same cause. The strike being abated and two new shafts opened two miles east of Corunna, Shiawassee County, and three miles west of Jackson, Jackson County, brought more nearly normal times in 1920 and 1921. In these years 1,489,765 tons and 1,141,715 tons were produced, respectively, and 1920 with a figure of $7,346,000, showed the highest total value for annual output in the history of Michigan coal production. The highest average price per ton of $5.05 was reached in 1922, but the total production of that year decreased to 822,441 tons. Mining costs were reported as an average of $3.85 per ton for 1922, which would show a profit for the year of $1.20 per ton. These figures represent the largest margin of profit at any time, but may prove misleading because of neglecting such factors as depreciation, interest on investment, etc.

*Lane, A. C., Vol. VIII, Pt. II, Coal of Michigan, p. 144.

Since the increase in 1923 which ran up to 1,172,075 tons of coal valued at $5,545,000 or an average of $4.23 per ton, the trend of production has been continually downward. The number of active mines producing fell off to nine in 1924, and this did not change for the ensuing three year period. However, the units represented varied somewhat from year to year. In 1924 the output was 831,020 tons valued at $3,602,000 or an average ton price of $4.33, which was a drop of *29.09* per cent from the preceding year. The 1925 production declined 2.7 per cent and totalled 808,233 tons representing a value of $3,391,000 or an average price of $4.20 per ton. The year 1926 witnessed a decrease of *15.03* per cent to 686,707 tons produced, valued at $2,829,000 or $4.49 for the average price per ton. This was the smallest yearly production since 1899.

At present, with one exception in Midland County, the only coal mining activity is centered in Bay and Saginaw counties. For 1924 and 1925 the production of Saginaw County exceeded that of Bay County by over twice and during 1926 the Saginaw County output reached three times that of Bay County. Over a period of years the quantity of coal produced from these two counties was very nearly the same. Evidently a large part of the decline of production in Michigan since 1920 took place in Bay County, although the suspension of activities in other parts of the State where overdevelopment had occurred also contributed.

PRODUCTION OF COAL IN MICHIGAN, 1860-1926 IN SHORT TONS.

Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.
1860	2,320	1874	58,000	1888	81,407	1902	964,718	1916	1,180,360
1861	3,000	1875	62,500	1889	67,431	1903	1,367,619	1917	1,374,805
1862	5,000	1876	66,000	1890	74,977	1904	1,342,840	1918	1,464,818
1863	8,000	1877	69,197	1891	80,307	1905	1,473,211	1919	996,545
1864	12,000	1878	85,322	1892	77,990	1906	1,346,338	1920	1,489,765
1865	15,000	1879	82,015	1893	45,979	1907	2,035,858	1921	1,141,715
1866	20,000	1880	100,800	1894	70,022	1908	1,835,019	1922	929,390
1867	25,000	1881	112,000	1895	112,322	1909	1,784,692	1923	1,172,075
1868	28,000	1882	135,339	1896	92,882	1910	1,534,967	1924	831,020
1869	29,980	1883	71,296	1897	223,592	1911	1,476,074	1925	808,233
1870	28,150	1884	36,712	1898	315,722	1912	1,164,973	1926	686,707
1871	32,000	1885	45,178	1899	624,708	1913	1,138,639		
1872	33,600	1886	60,434	1900	849,475	1914	1,283,030		
1873	56,000	1887	71,461	1901	1,241,241	1915	1,156,138		

†PRODUCTION AND VALUE OF COAL IN MICHIGAN, 1900–1926.

Year.	Number active mines.	Total tons of coal mined. Excluding that used for steam and heat.	Total tons of coal mined.	Total value of coal mined.	Average price received per ton.
1900	31	871,388	849,475	$1,259,683	$1.483
1901	30	1,016,496	1,241,241	1,753,064	1.412
1902	32	899,967	964,718	1,653,192	1.714
1903	34	1,601,984	1,367,619	2,707,527	1.979
1904	33	1,408,375	1,342,840	2,424,935	1.806
1905	38	1,413,307	1,473,211	2,512,697	1.705
1906	38	1,367,385	1,346,338	2,427,404	1.803
1907	37	1,911,201	2,035,858	3,660,833	1.798
1908	38	1,842,778	1,835,019	3,322,904	1.811
1909	36	1,736,573	1,784,692	3,199,351	1.793
1910	34	1,462,276	1,534,967	2,930,771	1.909
1911	32	1,389,585	1,476,074	2,791,461	1.891
1912	26	1,160,768	1,201,230	2,399,451	1.989
1913	24	1,138,163	1,231,786	2,455,227	1.993
1914	23	1,153,869	1,283,030	2,559,786	1.99
1915	20	1,069,798	1,156,138	2,372,797	2.05
1916	18	1,076,215	1,180,360	2,653,182	2.25
1917	22	1,393,180	1,374,805	4,426,314	3.22
1918	25	1,520,883	1,468,818	5,615,097	3.83
1919	22	971,603	996,545	3,864,228	3.87
1920	18	1,373,616	1,489,765	7,346,000	4.93
1921	15	1,125,156	1,141,715	5,555,000	4.87
1922	14	822,441	929,390	4,693,376	5.05
1923	15	1,086,198	1,172,075	5,545,000	4.73
1924	9	773,792	831,020	3,602,000	4.33
1925	9	741,449	808,233	3,391,000	4.20
1926	9	630,060	686,707	2,829,000	4.49

†From Mineral Resources. U. S. Geological Survey.

SAND LIME BRICK

Sand lime brick making was introduced into this country from Germany where it had become somewhat perfected and reached much favor. The pioneer plant was established in 1901 at Michigan City, Indiana, by the Ohlemacher Brick Company. The "boom" nature of the industry was evidenced by the fact that within three years' time nine plants were in operation. Popularity of the new industry sprang from the opinion that sand lime brick which was satisfactory for most purposes could be made more cheaply than clay brick. Later many failures occurred and the sand lime brick industry suffered the consequence from insufficient investigation of the character and supply of raw material, methods of manufacture, competition from clay brick transportation facilities and market conditions. Oftentimes the bricks made were of poor quality and would not sell. The sand-lime brick industry finds its greatest adaptability in parts of the country where good face sand is abundant and workable brick clay is rare. Constant improvements in the quality of this type of brick now made by many companies is overcoming the early prejudice of contractors and clay brick does not offer the overwhelming competition which it did in the past.

"Kalksandstein" or lime sandstone, as the Germans call sand-lime brick, is simply a form of sand rock which has been indurated by artificial means. Chemically the binding material is a calcium or calcium-magnesium hydro-silicate produced by the action of high pressure steam on a mixture of caustic lime (slacked) and sand. The sand and lime is thoroughly mixed in a proportion of about 10 per cent lime to sand and pressed into bricks under high pressure on a rotating table press. The bricks are loaded on cars and pushed into steel cylinders or hardening boilers where they are steamed for 10 to 12 hours under pressure. Sometimes the bricks are allowed to season a time, but usually they can be loaded directly for shipment.

The raw materials required for sand lime brick manufacture are sand, burned lime, and a source of fuel and power. Labor requirements are very small except for loading. The sand should be relatively free from clay although 10 to 12 per cent would probably not prove injurious. A fine sand is better than a course one but the important factor is to have a ratio of fine to coarse grains so that they will pack. In some instances various waste siliceous ingredients have been used instead of sand. Lime can either be prepared from pure calcium or dolomitic stone, and although some prefer the latter its advantages are disputed. Various patents are in vogue for the slacking process but in nearly all of these the practice is to slack to a dry powder by adding only a little more water than will be chemically combined. In this way the excess water is removed by the heat generated on the hydration of the oxides.

Experiments* have shown that good sand lime brick have a strength comparing very closely with hard rock sandstone. It has been found to have a particularly high resistance to weathering agents. Freezing temperatures, in spite of the high porosity of the product, are supposed to increase rather than reduce the strength of the brick. Resistance to chemical agents is also known to be high.

Most of the early sand-lime brick plants in Michigan were established in widely separated parts of the State, and far from clay working industries, or were located near large cities which furnish a ready market for a limited output. Consequently the industry in the State did not suffer from nearly so many failures as in some other localities and has maintained a relatively steady growth. Very shortly after the development of sand-lime brick making, Michigan attained first rank as a producer and with the exception of one year has held that rank since 1904.

The growth of the industry has been in increased production rather than in the number of plants. In 1904 ten plants were in operation and produced only 10,440,000 bricks of all grades, valued at $69,765. In 1905, twelve plants produced 26,421,000 bricks, valued at $169,302. After 1905 the number of operating plants fluctuated between ten and thirteen but production and value greatly increased, until the maximum production of 72,004,000 bricks valued at $499,711 was reached in 1916. A sharp decline began in August of 1917, due to the car shortage, and because of war-time conditions was continued during 1918, production dropping to 47, 998,000 bricks of all classes in 1917 and to 22,564,000 bricks in 1918, the lowest production since 1904.

In 1919 the industry rallied and increased 88.6 per cent in quantity and 158 per cent in value. The increase in quantity was from 22,564,000 to 42,570,000 or 20,006,000 bricks and in value from $198,633 to $513,094. The increase in quantity was due to the resumption of building operations and relatively larger increase in value was due to the increased demand and to increased cost of production. The production of 1919 was less than the maximum of 1916 by 29,434,000 bricks. Michigan continued the leading State in marketing sand-lime brick and produced 29 per cent of the quantity at 30 per cent of the value for the United States.

*Peppel, S. V.—The Manufacture of Artificial Sandstone or Sand Lime Brick—Geol. Surv. of Ohio, 4th Series, Vol. V, p. 48.

Although in 1920 the total production of sand-lime brick for the United States increased, the production in Michigan decreased to 39,280,000 bricks of all classes, a decrease of 3,290,000 bricks or 7.7 per cent. The value of $670,744 was an increase of $127,650 or 24.8 per cent and is the highest value recorded. The industry in 1920 was handicapped by the shortage and inefficiency of labor and difficulties of transportation and in securing raw material. Despite the decreased production Michigan continued in first rank and produced 23 per cent of the total United States production at 26 per cent of the total value.

Since statistics for sand-lime brick were collected by the Bureau of the Census there has been considerable delay in securing production figures and details of the industry. In 1921 a production of 33,658,000 bricks of all classes valued at $403,929 was reported. The production value shows a decrease of $236,815 or 36.9 per cent when compared with the 1920 reports. In 1922 a production of 46,558,000 at $557,647 shows a gain of 38 per cent in value over the 1921 figure. In 1923, 64,650,000 valued at $777,693 shows a gain of 39 per cent.

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 in 1908 to about 900,000. The maximum production of 3,255,000 was attained in 1910. From 1911 to 1916 the production of front brick did not exceed 1,000,000 annually, falling off in 1916 to 888,000. Evidently front and fancy sand-lime brick as manufactured were not as satisfactory for outside work or could not be produced as cheaply as clay front brick. In 1917, however, the production of front brick increased to 1,019,000 valued at $8,477. Either new methods of molding, producing a more shapely brick, or better methods of manufacture, producing a less easily crumbled brick, accounted for the increased demand, but the output quickly declined and at present no bricks other than the common bricks are made by the sand-lime process.

The years from 1924 to 1926 were represented by increase in every phase of the sand-lime brick industry in Michigan. The number of plants operating increased from 9 to 13 and the quantity of bricks produced increased *38.03* per cent to 89,239,000 in 1924, *9.62* per cent to 97,828,000 in 1925, and *10.84* per cent to 108,434,000 in 1926. Value of the product amounted to $1,052,435 in 1924 which was an increase of *35.32* per cent over 1923. In 1925 the value jumped to $1,175,776 or an increase of *11.71* per cent over 1924 and in 1926 the value was $1,341,284 or an increase of 14.07 per cent over 1925. The average price per thousand also increased for 1924, 1925, and 1926, the figures being $11.79, $12.02, and $12.36 respectively. In comparison the increases in production for the United States over the three year period 1924-1926 were 35.32 per cent, 16.6 per cent, and 4.8 per cent while the yearly value increases were 34.51 per cent, 19.4 per cent, and 5.3 per cent. For the year 1926 these figures show that the gain in Michigan production more than compensated for the falling off in other states.

With the exception of 1906 when New York assumed first position, Michigan has held first rank among the states both in the number of plants and in the value of the output of sand-lime brick. For a number of years Michigan has produced about twice as many sand-lime brick as any other state, being most nearly approached by New Jersey in 1926. The decided depression suffered by the sand lime brick industry in common with other building industries in 1918 prompted many operators to close their plants, so that of the eleven firms reporting in 1917, but seven operated in 1918. The increase in building operations caused one plant to be reopened and in 1919 and 1920 eight operators reported production. This number increased to nine in 1923, eleven in 1924, and thirteen in 1926. According to 1924 reports operating plants are located at Detroit, Grand Rapids, Flint, Saginaw, Jackson, Rochester, Menominee, and Sebewaing.

ANNUAL PRODUCTION AND VALUE OF SAND-LIME BRICK IN MICHIGAN AND UNITED STATES, 1904-1926.

Year	No. of operating firms reporting—Mich.	No. of operating firms reporting—U. S.	Michigan production.									Total value Michigan.	Total value United States.	Rank.	
			Common brick.		Average price per thousand.	Front brick.		Average price per thousand.	Fancy brick.						
			Quantity (thousands).	Value.		Quantity (thousands).	Value.		Quantity (thousands).	Value.				Production.	Value.
1904	10	57	9,886	$64,034	$6.64	580	$5,234	$9.02	19	$497		$69,765	$463,128	1	1
1905	12	84	24,841	155,883	6.28	1,577	12,898	8.17	24	526		169,302	972,064	1	1
1906	11	87	27,281	162,879	5.97	1,796	12,022	6.69	7	20		174,921	1,170,005	1	2
1907	13	94	25,488	158,606	6.22	†2,000	14,284	7.17	....	....		172,840	1,225,769	1	1
1908	10	87	21,997	131,827	5.99	†900	6,982	7.76	....	....		138,809	1,029,699	1	1
1909	11	74	34,217	207,082	6.05	†1,600	11,144	6.97	....	....		218,226	1,150,580	1	1
1910	10	76	37,648	218,627	5.81	3,256	22,022	6.76	....	....		240,649	1,169,153	1	1
1911	10	66	32,889	192,224	5.84	2,726	17,777	6.52	....	....		210,001	897,664	1	1
1912	11	71	48,129	307,106	6.38	1,163	9,926	8.27	....	....		316,732	1,200,228	1	1
1913	12	68	49,373	315,882	6.40	‡	‡	....	‡	‡		321,245	1,238,325	1	1
1914	12	62	41,456	248,113	5.98	‡	‡	....	‡	‡		255,784	1,058,512	1	1
1915	11	56	46,513	281,009	6.04	‡	‡	....	‡	‡		286,948	1,135,104	1	1
1916	12	53	71,116	491,866	6.92	888	7,845	8.83	....	....		499,711	1,474,073	1	1
1917	11	47	46,979	362,246	7.71	1,019	8,477	8.31	....	....		370,723	1,420,330	1	1
1918	7	42	22,248	195,636	8.79	‡	‡	9.48	....	....		198,633	883,929	1	1
1919	8	35	42,063	507,010	12.05	‡	‡	12.00	....	....		513,094	1,705,163	1	1
1920	8	37	38,810	632,112	16.80	‡	‡	18.36	....	....		640,744	2,490,283	1	1
1921	....	26	*33,658	....	....	....	....	....	....	....		403,929	1,268,502	....	....
1922	8	....	*46,558	557,647	11.97	....	....	....	....	....		557,647	....	....	....
1923	9	33	*64,650	777,693	12.03	....	....	....	....	....		777,693	2,471,536	....	....
1924	11	37	*89,239	1,052,435	11.79	....	....	....	....	....		1,052,435	3,334,503	1	1
1925	....	42	*97,828	1,175,776	12.02	....	....	....	....	....		1,175,776	3,780,639	1	1
1926	13	42	*108,434	1,341,284	12.36	....	....	....	....	....		1,341,284	3,981,492	1	1
TOTALS	....	....	1,534,407	$9,536,977	....	....	....	....	....	....		$10,106,890	$35,439,681	....	....

†Estimated.
‡Included in total.
*Includes common and front brick.

The glass sand belt of Michigan extends in a curving band westward across Wayne County from the mouth of the Detroit River and then southwestward across Monroe County, where it leaves the state in the southwest corner. This strip of land underlain by the outcrop of glass sand rock beneath the drift averages from three to five miles in width except in the far southwest corner of Monroe County. The age of the glass sand bed is Middle Monroe of the Silurian and it has been assigned the name of Sylvania from the occurrence at Sylvania, Ohio, just across the state line. Thickness of the Sylvania sandstone varies considerably which can be attributed largely to its probable manner of formation as a windblown deposit. Along the Detroit River where penetrated by wells in Wayne County it is from 70 to 165 feet thick and usually is divided into two or more separate beds by layers of siliceous dolomite. When the sand grains in this dolomite are separated from the limerock by the use of acid they cannot be distinguished from the Sylvania grains themselves. The thinnest section of Sylvania sandstone in this outcrop belt is found near the Ohio line where it is only about 35 feet thick. This accounts for the narrowing of the width of sandstone outcrop beneath the drift cover to about one-half mile for a short distance in southwest Monroe County.

Areas where the glass sand is exposed or is so near the surface as to be quarryable are located in Whiteford, Township (T. 8 S. R. 6 E.) and in the vicinity of Steiner, Monroe County, and close to Rockwood, Wayne County. In Section 28 of the Whiteford Township area the overburden is locally ten feet or less in depth. At a quarry in Section 2 the Sylvania is exposed in the bottom where a very small amount of dolomite has been removed. In the bed of the Raisin River near Steiner it is exposed for a considerable distance in the southwest quarter of Section 2, T. 6 S. R. 8 E. Previous to developments in this vicinity it reported that the rock was exposed* or covered by a few inches of soil over an area of 8 to 10 acres and over an area of 60 acres the overburden was in no place more than two or three feet thick. No natural exposures of the Sylvania Formation occur in Wayne County, but east of Rockwood in the vicinity of the pits of the Rockwood Silica Company, the overburden ranges only from five to eight feet deep. According to all evidence an area exists in the vicinity of Rockwood where overburden will not amount to more than twenty feet in thickness.

Present quarrying activities are confined to this Rockwood locality. The only operator reporting any production in the past three years is the Michigan Silica Company. This concern located south and east of Rockwood has a large pit, plenty of reserves, and abundant storage. The rock is blasted and loaded on cars which are hauled up a steep incline to the crusher by means of a cable and drum hoist. After crushing and washing the material is pumped into bins where it is allowed to drain.

The typical Sylvania sandstone is noted for its uniform character and purity, as well as the more or less complete rounding of the frosted grains. It has been described as a remarkably pure, sparkling, snow-white aggregation of incoherent quartz grain lumps which may be crumbled in the hands and when placed in water simply fall to pieces like some varieties of clay. By drillers it has been compared with snow,

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*W. H. Sherzer, Geology of Monroe County; Mich. Geol. Survey, Vol. VII, Pt. I, p. 54.

MECHANICAL ANALYSIS OF SYLVANIA SANDSTONE

No.	Sand No. 10 Sieve 1.80 mm. mesh.	On No. 20 .80 mm. mesh.	On No. 30 .50 mm. mesh.	On No. 40 .42 mm. mesh.	On No. 50 .35 mm. mesh.	On No. 80 .18 mm. mesh.	On No. 100 .16 mm. mesh.	On No. 200 .08 mm. mesh.	Through a No. 200 .08 mm. mesh.	Average size of grain determined by the aspirator method.
	Toll's pit.	%	%	%	%	%	%	%	%	mm.
1	1 ft. down	0.05	0.40	3.50	9.05	58.78	16.52	9.80	1.90	0.2454
2	6 ft. down	0.00	1.55	9.42	19.98	51.70	6.25	6.25	4.85	0.2385
3	11 ft. down	0.00	0.55	2.10	18.18	65.72	7.05	4.65	1.75	0.2841
4	16 ft. down	0.00	0.00	3.40	29.03	61.52	1.95	2.10	2.00	0.2967
5	21 ft. down	0.00	0.00	2.85	6.31	76.83	8.36	4.20	1.45	0.2660
6	26 ft. down	0.00	1.80	1.95	4.05	42.46	31.92	13.37	4.45	0.1810
	Rockwood									
7	4 ft. down	0.00	0.40	7.65	40.50	50.60	0.50	0.25	0.10	0.3950
8	15 ft. down	0.00	0.60	0.60	2.35	70.45	16.60	9.10	0.30	0.2392
9	20 ft. down	0.00	0.35	6.65	34.10	53.70	2.30	2.25	0.65	0.3497
	Detroit salt shaft									
10	Near top	0.00	1.00	7.51	11.51	43.20	19.52	16.11	1.15	0.2448
11	440 ft. down	0.00	0.10	3.00	15.35	64.93	8.35	6.85	1.40	0.2513
12	450 ft. down	0.00	0.65	6.90	15.95	59.70	11.10	5.30	0.40	0.3071
13	460 ft. down (a)	0.00	0.85	7.55	14.45	44.90	18.70	12.20	1.35	0.2766
14	460 ft. down (b)	0.00	0.75	7.23	16.00	47.35	16.16	11.65	0.82	0.2760

flour, salt, and granulated sugar. The range of its fineness and uniformity is shown in the table which indicates that the bulk of the grains passed a No. 40 (.42 mm. mesh) screen and were caught on No. 50 and No. 80 respectively. (.35 mm. and .18 mm. mesh)

Aside from the uniformity and fineness of the grains a noteworthy characteristic is the practical absence of any original material of the nature of clay or dust.

At the old pits of the American Silica Company east of Rockwood, Wayne County, and of the Ford Plate Glass Company, near Steiner, Monroe County, the sandstone formerly was washed down by a stream of water from a hose. Another extraction process was tried some years ago similar to that used for sulphur and salt. The Rockwood Silica Sand Company drilled a well just east of Rockwood (SE¼ SW¼ Sec. 10) to a 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 set on the rock and below this a four inch casing was placed. The injection of steam under a pressure of 60 pounds per square inch forced water and sand out to the surface. For some time about a carload of sand per day was obtained in this manner.

Glass sand pits known as "Toll Pits" were opened many years ago near Steiner, Monroe County. These properties were taken over later by the National Silica Company, which operated them up to 1916 when the plant was burned down. The property was then sold to the Ford Plate Glass Company of Toledo, and a new plant was built. At the present time the quarry is full of water, the equipment is rusting away, and many of the buildings are in ruins. The Whiteford area is still undeveloped.

According to the careful work of Grabau and Sherzer† the Sylvania is for the most part a deposit of wind blown sand upon which partial reworking by the sea has taken place. Evidence for this stated by them includes the irregular stratification, highly inclined lamination, absence of original binding material, absence of fossils, uniformity in size of grain, the rounding of the finer granules, and the pitted character of their surfaces. The source of the material very likely came from the northwest and probably in the main from the St. Peter formation of Wisconsin to which the Sylvania bears a striking resemblance. The contention concerning the history of the Sylvania is that the basal layers were sedimentary in origin, the body of the bed derived by eolian means, and the upper eolian deposits reworked by a transgressing sea.

Immediately beneath the drift the sandstone is more or less colored by iron from percolating surface water, to a depth varying from a few inches to several hundred feet. However, most of the standstone is free from iron and the washed product from some horizons contains only about .001 of one per cent of iron. In the quarry of the Rockwood Silica Company near Rockwood there are numerous masses of celestite (strontium sulphate) together with native sulphur produced by the reduction of the celestite. The masses of celestite are most numerous near the horizon of the dolomitic sandstone. Washing removes practically all of the small amount of dolomitic cement in the incoherent sandstone and also removes most of the cement from the dolomitic portions. The sand as marketed is stated to contain over 99 per cent of silica.

†A. W. Grabau & W. H. Sherzer. The Monroe Formation. Mich. Geol. & Biol. Survey, Pub. 2, Geol. Series 1, 1910.

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

ANALYSES OF GLASS SAND

	Crude Per Cent	+Washed Per Cent
Silica	96.50	99.70
Calcium carbonate	1.50	0.08
Magnesium carbonate	1.04	0.22
Iron oxide	0.00	
Sulphuric acid, loss and undetermined	0.76	
Loss on ignition	0.20	

The very low percentage of iron makes the sand especially adapted for glass making, particularly for glass of the higher grades, such as plate and optical glass. Large quantities are used in the manufacture of plate glass. Experiments by the United States Bureau of Standards show that the purest grade of the Sylvania sand of Michigan is suitable for making optical glass and now all the sand used by the Government for this purpose comes from this State. It was found that from the deposits near Rockwood it is possible under careful supervision to obtain carload lots of glass sand which average 0.015 per cent iron oxide, and some analyses running as low as 0.001 per cent in iron are reported. Glass sand for optical purposes is also obtained at Ottawa, Illinois, and Hancock, Maryland, but analyses from the best of these deposits averaged 0.02 per cent iron oxide.

The washed sludge containing the fine grit is used for the ignition surfaces on match boxes.

MINERAL WATERS

The mineral waters of Michigan fall into a number of distinct classes. In a broad sense all natural waters are mineralized and aside from their varying concentrations and chemical characteristics, a division according to use is most helpful in separating them. Those available under such a concentration as to be considered as brines and valuable as a source of salts are treated under other headings. The common conception of mineral waters includes that water reputed to have medicinal value and any water which has value from its purity and local scarcity of potable water and can be sold as a bottled product for drinking purposes. In most works on mineral springs a mineral water is defined as any water that has an effect upon the human system, no matter how feebly mineralized it may be; that is, it is any water that possesses medicinal virtues, whether they be due to the presence of organic, inorganic, or gaseous contents, or to the principle of heat. From the standpoint of the dealer in bottled mineral waters the definition of course has a much wider range. From his point of view all waters put upon the market for sale in bottles or barrels or in any other way, come under the head of mineral waters.

Common practice in the development of a mineral water project is the drilling of a well and the establishment of a hotel or sanitorium adjacent. Patients are treated both internally with the water as a drink and externally in the form of baths and accompanying attention from a masseur. This hygienic manner of living together with abundant rest has

*J. E. Clark, Analyst.

proven curative for a number of neuratic, rheumatic, and skin diseases, although distinctly contested by a great number of the medical profession. Peale* states that some very pure waters have an undoubted therapeutical effect, and chemical analysis, which is absolutely reliable only in the estimates of basic salts and acids, will not always explain the medicinal effect of a water, and small quantities of some constituents are often more effective as remedial agents than others that are present in larger quantities.

Although in some states natural mineral springs have furnished the bulk of the mineral water output, the chief production of Michigan has come from drilled wells. Often so-called mineral springs are simply flowing water wells. The chief mineral water horizons are the Marshall formation of Mississippian age and the Dundee formation of Devonian age. The Marshall gives origin to potable water where found at reasonably shallow depths, whereas the Dundee water is characteristically sulphurated. Production from the Marshall horizon occurs chiefly in the central part of the state with centers at Alma and St. Louis. The Dundee mineral water is used at Mt. Clemens in the southeastern part of the Southern Peninsula and at Benton Harbor in the southwestern part, together with a few other scattered localities close by. Two new wells are proposed to be drilled at South Haven, Van Buren County, for the purpose of developing mineral water in connection with the Edgemere Beach and Janis Hotels. A limited production of mineral water comes from shallow wells in the drift material, of which the Ponce de Leon water of Grand Rapids is most prominent. Some chalybeate water containing CO_2 gas and a high percentage of carbonates is obtained mainly within the Coal Basin.

An objection raised in regard to important mineral water centers of the state, is that the waters from different depths mix and consequently a water of constant composition is not obtained. This may be due to insufficient casing in the well when first drilled, corrosion of the pipe by the sulphur water, or neglect in cleaning out the well at frequent intervals during operation. Many years ago Lane† raised the criticism on the exploitation of the undoubtedly valuable medicinal bitterns of Michigan, that too little attention and study has been given to the precise effects of the various components in particular classes of diseases. This contention still seems to hold. Although both a sulphurated water and a saline water have medicinal values, they are not exactly the same. Yet the usual custom is to let them flow together and to continue boring until the salinometer shows considerable strength, so that "the bathers may feel the buoyancy and feel that they are getting their money's worth." It is also desired that the analysis may show as strong a water as a neighboring establishment, or a similarity to some famous water. No attempt to separate the various waters and use them according to the circumstances of the case seems to have been made, further than to have one well for drinking and another for bathing. And yet anywhere along the Detroit and St. Clair rivers it would be easy to have, even from one well, a sulphurated water, a calcium chloride water and a strong salt water, and perhaps other varieties, to be used as each case required.

*A. C. Peale, Natural Mineral Waters of the United States, 14th Ann. Rep't., U. S. G. S., Pt. II, p. 57-1892-92.

†Lane, A. C.—Lower Michigan Mineral Waters., U. S. G. S., Water Supply Paper No. 31, p. 88-1899.

From 1902 to 1906 there was a steady decline in the mineral water industry of Michigan, despite annual fluctuations in amount and value of mineral and spring water produced, but from 1906 to 1923 there was little change. The principal factors affecting the production are local conditions affecting municipal water supplies, and general business conditions. When a municipal water supply becomes unpalatable or unsafe the vending of mineral waters becomes profitable, only to decline, however, when a filtration plant is installed or a new source of water supply is developed in a town.

The general business depressions of 1906, 1907, and 1914 caused the greatest decrease in production in Michigan. During the past few years the increased demand for soft drinks has for a few firms occasioned a temporary increase in the sale of mineral waters used in the manufacture of "prohibition beers." The production of 8,653,680 gallons valued at $275,763 in 1902 decreased to 884,893 gallons valued at $52,642 in 1913. From 1913 to 1919 production and value steadily increased and reached a total of 1,570,906 gallons valued at $132,312. There were ten commercial springs. In 1921 production and value of mineral waters increased from 1,227,485 gallons valued at $122,.010 to 1,344,900 gallons valued at $154,405, an increase of 117,415 gallons or 9.5 per cent in quantity and of $32,395 or 26.2 per cent in value. There were nine commercial springs in 1921. In 1922 with nine producing springs, Michigan again was ninth in the production of mineral waters although there was a decline from the 1921 production of 1,344,900 gallons at $154,405 to 1,229,802 gallons at $150,237, or a decrease of 8.5 per cent in quantity and of 2.7 per cent in value. In 1923 Michigan produced 1,478,135 gallons valued at $164,-968, an increase of 20% in quantity and 10% in value.

After 1923 the Division of Mineral Statistics, Bureau of Mines, discontinued their annual census of mineral waters. A local state census carried on in 1924 showed five active springs producing a quantity of 898,255 gallons valued at $90,032, or an average of 10 cents per gallon. This represented a very material decrease of 39.23 per cent in quantity and 45.26 per cent in value over that of 1923. No figures were obtained for 1925.

Figures of the mineral water industry cannot be at all representative of the entire mineral water production. It is next to impossible to get data on the output from bath-house consumption because of the large number of operators and absence of meters and measuring devices on the wells. Usually the only possibility would be an appraisal or estimate but during the summer of 1927 work was carried on which makes certain approximate statistics available.

At Mt. Clemens there is a large seasonal variation, but the peak production comes during the months of May, June, July, and August. Of these, July is usually the largest month with August ranking second. In 1926 the total production of the Mt. Clemens district was approximately 6,298,920 gallons for bath purposes and about 200,000 gallons evaporated and sold as concentrata. The Detroit district showed no seasonal variation, and the production was approximately 750,000 gallons.

PRODUCTION AND VALUE OF MINERAL WATERS IN MICHIGAN, 1900-1924.

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	$111,935	....	....	$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	5,955	82,915	0.044
1909	5	16	19	2,760,604	104,454	6,099	98,255	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	72,111	5,165	67,546	0.080
1916	17	13	18	996,875	108,867	....	....	0.109
1917	12	12	11	1,069,164	105,641	500	105,641	0.098
1918	10	8	9	1,216,882	129,592	....	128,809	0.103
1919	7	9	10	1,570,906	132,312	760	132,252	0.080
1920	11	9	9	1,227,485	122,010	1,485	120,525	0.099
1921	6	7	9	1,344,900	154,405	....	....	0.114
1922	8	8	9	1,229,802	150,237	....	....	0.122
1923	7	6	10	1,478,135	164,969	....	....	0.11
1924	......	......	5	898,255	90,302	....	....	0.10
TOTALS	......	......	......	57,551,971	$4,444,242	....	....	....

GOLD IN MICHIGAN

The occurrence of gold in Michigan has been known ever since the time of Douglass Houghton, the first State Geologist. He brought some specimens of gold ore back to his camp while on one of his exploration trips to the Upper Peninsula. His untimely death shortly after prevented his disclosing the location of his discovery or any facts about its importance. It is generally believed that the location of the camp was not far from the place where gold was found in later years.

An analysis was made in 1864 of some specimens of quartz found near Ishpeming which showed gold was present in the quartz. Nothing came of this reported find of gold until 1880 when Mr. Julius Ropes located the gold vein that was afterwards to become the Ropes Gold Mine. This vein was discovered northwest of Ishpeming in the south half of the northwest quarter of Section twenty-nine, Township forty-eight north, Range twenty-seven west. This was worked for a number of years, has a shaft to the 15th level but mining was done below that through a winze to the 16th level. The gross yield of the Ropes Mine is reported to be $605,-056.95 in gold and silver.

The Michigan Gold Mine was located in the same territory in Section thirty-five, Township forty-eight, Range twenty-eight. This property produced $17,699.36 from workings not over one hundred feet in depth. Some very fine specimens of free gold were found in the Michigan Mine, some analyses of which ran over $100,000 to the ton.

Just west of the Michigan Mine was Gold Lake Mine which was not as extensive at the other two as the vein pinched out at a depth of 60 feet. Two other mines, the Superior in Section thirty-five, Township forty-eight, Range twenty-eight, and the Peninsula in Section twenty-five, in the same township were started about this time, neither of which were of any particular importance.

The Dead River area north of Ishpeming was the scene of other gold discoveries. This river basin is located about eight miles north of Ishpeming. The Fire Center Mining Company put down two shafts in Section thirty-five, Township forty-nine north, Range twenty-seven west. This gold discovery is also credited to Mr. Ropes. Work was started here in 1892 and abandoned in 1898. Some of the ore found here was run through the mill at the Ropes Mine with very encouraging results.

There have been a few other reported occurrences of gold in the Dead River area but none of these have developed beyond the stage of prospects. With cessation of work at the Ropes, Michigan and the Fire Center mines interest gradually dropped in the possibility of finding a profitable gold mine in the region and little prospecting has been done in this part of the country since 1900. This does not mean that this area does not contain profitable deposits of gold and silver but merely indicates that the old ventures were not able to survive under the conditions that were in existence at that time.

The Ropes Mine was inadequately financed and had to use crude methods of mining and extracting the ore. It is quite probable that if opened up at this time with good management and with the present knowledge of mining and metallurgy, the operation would have been a commercial success. It seems very likely also that all the rich gold veins have not been located and careful geological work and intelligent prospecting may discover some veins as rich or richer than those already known.

Gold has been reported in other parts of Michigan but there has been no occurrences that compare in importance with the discoveries around Ishpeming. Most of these other reported finds of gold are placer or stream deposits. It is possible that workable deposits of placer gold may be found in and around the Ishpeming area but it is very unlikely that any gold of commercial importance will be found in the stream gravels of the lower peninsula. The distance of the Lower Peninsula from any rocks that carry gold in primary deposition is so great that the chances of placers there are very remote.

NOTE: This short description of the occurrence of gold in Michigan is condensed from the report on this subject that was published in Mineral Resources for Michigan for 1911. A full account of the occurrence of "Gold in Michigan" is found in this report.

MISCELLANEOUS

Granite occurs in unlimited amounts in the western half of the Upper Peninsula. There are varieties excellent for building near Marquette and at other points convenient to cheap water transportation.

Quartzite likewise exists in large amounts in the western half of the Upper Peninsula and has been quarried at Deer Lake, just north of Ishpeming for ganister.

Asbestos has been reported in considerable quantities in the serpentine rocks north of Ishpeming, the fibres averaging five inches in length. It has also been reported near Republic.

A considerable deposit of *talc* of good quality has also been reported in the serpentine area.

Concentrations of *muscovite mica* have been reported near Republic and Bessemer. That near Republic tends to be smoky and of doubtful value.

Pyrites (pyrite, marcasite, pyrrhotite) are used chiefly in the manufacture of sulphuric acid. They occur in Michigan coals in sufficient amounts to warrant recovery from the wastes under conditions which would cause a shortage in the domestic supply.

Gems and Precious Stones. Several small diamonds have been found in the drift in Michigan since 1890. The largest weighed two carats and was found near Dowagiac, Cass County. The diamonds have been brought down by glaciers from somewhere in Canada.

Chlorastrolite, an attractive green mineral and Thomsonite, a mottled reddish stone are found on Isle Royale. Amethysts of inferior quality and excellent agates are fairly common in the crystalline rocks of the Lake Superior region.

Coral reef formations are abundant in the Traverse limestone near Alpena and Petoskey. Certain of these when polished have a very attractive appearance and are known as "Petoskey Agates." These are very commonly found in gravel pits in various parts of the State.