STATE OF MICHIGAN
MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

Publication 19. Geological Series 16.
MINERAL RESOURCES OF MICHIGAN
WITH
STATISTICAL TABLES OF PRODUCTION AND VALUE OF MINERAL PRODUCTS
FOR
1914 AND PRIOR YEARS.

WITH A TREATISE ON MICHIGAN COPPER DEPOSITS BY R. E. HORE.

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PUBLISHED AS A PART OF THE ANNUAL REPORT Of THE BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY F0R 1914.

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1915

PART II. NON-METALLIC MINERALS.
R. A. SMITH.

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COAL IN MICHIGAN.

MICHIGAN COAL BASIN.

Location and Extent.

The Michigan Coal Basin* is the only coal field in the St. Lawrence drainage basin. It covers an area, of about 11,000 square miles almost in the geographic center of the Southern Peninsula, extending from the central part of Tuscola county on the east to the western part of Newaygo county on the west and from the south central part of Roscommon and Ogemaw counties on the north to the central portion of Jackson county on the south.

The limits of the Coal Basin on the south and east have been approximately determined, but the margin is more or less irregular. On the north and northwest the boundary is more uncertain owing to the thick screen of surface deposits.

*See 22nd Ann. Rept. U. S. G. S., The Northern Interior Coal Field by A. C. Lane; also Vol. VIII, Pt. II Mich. Geol. Survey, Coal in Michigan by A. C. Lane.

Surface Features.

The greater part of the Coal Basin lies in a low flat to gently undulating region bordered by a rim of higher and more broken land, broken on the northeast by Saginaw Bay and on the west by the valley of the Grand. The low flat portion of the interior basin, largely included in Saginaw Valley, has an elevation ranging from about 580 feet above sea level to 800 feet, and the higher undulating portions from 800 to 1,000 feet above sea level. The marginal higher broken tracts on the south and east rise from a height of about 1,000 feet to over

1,200 feet and those on the north and northwest from 1,000 to 1,600 feet, or respectively 400 to 600 feet and 400 to 1,000 feet above Lakes Huron and Michigan.

To a large extent the rim of high land is due primarily to an underlying rim of hard limestone (Bayport) and heavy sandstone (Marshall) of the Upper Mississippian. On the northeast this rock rim is breached by Saginaw Bay and on the northwest by an old pre-glacial valley which runs southwest from the head of the bay through northern Gratiot county and, veering to the west and then northwest through Montcalm and Newaygo counties, enters the basin of Lake Michigan in western Mason and Manistee counties. The height of the rim was further accentuated in the Pleistocene period by a greater piling up of glacial debris along the rim than in the interior of the basin.

Though the rock surface is very uneven the mantle of drift is so thick that nearly everywhere it completely buries and conceals the coal measures. Southwest of a line from the mouth of Saginaw River to Grand Rapids the drift over the Coal Basin is generally 50 to 150 feet thick and only in a few places is it more than 200 feet. Northwest of this line, excepting in Arenac county, the drift is generally much thicker. Particularly is this true along the northern and northwestern margin and over the old pre-glacial valley previously noted where the glacial deposits are usually from 300 to 600 feet or more in thickness. This excessive thickness of drift has been an effective barrier to exploration and development.

The areas in the Coal Basin in which the drift is thin or absent are few and small. Most of the exposures of the Coal Measures are generally along stream courses, as 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 the 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.

Accessibility.

The Coal Basin, especially the more developed southeastern half, lies in a thickly populated and rapidly growing industrial section of the state. Saginaw Bay breaks through the rim on the northeast and, with its estuary, Saginaw River, penetrates to the heart of the chief coal districts. Numerous manufacturing cities within or just outside the Basin, a natural water route to the Great Lakes, and a web of railroads radiating in every direction from Saginaw and Bay City, the chief coal centers, afford exceptional means for transportation and marketing.

Geology.

Structure.—In structure the coal field is that of a very flat synclinorium with its longer axis extending north and south. The strata in general do not conform to the basin-like structure of the pre-coal measure formations but are nearly flat except for minor undulations and folds. Locally the strata are faulted but most of the observed faults are small, having a throw or displacement of only a few inches or feet. Recently several faults of considerable size have been found and one in Bay County has a displacement of over 50 feet. Further observations may show that faults are much more prevalent in the coal series than formerly supposed.

Character of the coal beds.—The Coal Measures belong to the Upper Carboniferous or Pennsylvanian and consist of an upper productive portion called the Saginaw formation, and a lower barren one, the Parma sandstone.

The Saginaw formation is essentially a series of relatively thin beds of white shale or so-called fire clays, blue or gray and black shales, sandstones, and coal seams. Limestone is uncommon but locally thin seams of black band ore (siderite) and nodules of the same with zinc blend and iron pyrites occur in the coal or the associated shales.

In general the beds vary markedly in thickness and character within relatively short distances. Many of the beds are merely local lenses and few are continuous over any considerable area. Rapid variation is also characteristic of the coal seams. They generally undulate sharply and the rise and fall may be more than 20 feet in a few hundred feet. Locally the coal thins, pinches out, or grades into black shale, or is cut out entirely by sandstone. In some localities, however, the strata are predominately sandstone, in others, shale. The manner of the occurrence of coal is similar; in some areas there are several beds and in others none.

There is a more or less orderly sequence of the different strata. Generally white shale, the "fire" or "underclay" of miners, underlies the coal seams. The coal beds usually grade upward into so-called "cannel" or "bone" coal, or into black shale which in turn is followed by blue shale. Sandstone may succeed the shale or it may cut out the shale entirely and rest directly on the coal. The "fire" clays are locally very sandy or may be replaced by sandstone. These clays are not true fireclays since they do not possess particularly high refractory properties. The blue shales above the coal locally contain thin bands and nodules of siderite or iron carbonate. Some of the nodules contain sulphides of iron and zinc, and also kaolin. In some places, carbonaceous limestone replaces the blue shale. Sandstones, some of which are very massive, occur at any horizon but the repetition of the sequence upward—white shale or "fire clay", coal, "cannel" or "bone" coal, black shale, blue shale or limestone and in many places, sandstone, for each of the coal beds is characteristic.

The Parma is a white sandstone locally conglomeratic. The pebbles, generally of very white quartz are small and scattering. The Parma is to be considered as the basemental and shoreward facies of the overlying Saginaw formation, hence is not referable to a definite age. It is very persistent, being continuous over most of the Coal Basin and varies in thickness from about 170 feet to a feather edge. Locally, however, it is either absent or not present as a sandstone. Generally it yields an abundance of water, fresh near the margin and saline in the central part of the Basin. Its waters and brines contain a relatively high content of sulphates in comparison with the waters and brines of the Marshall sandstone below.

The Coal Measures were deposited upon the much eroded surface of the Grand Rapids group of the upper Mississippian, hence, in Michigan, there is a great unconformity separating the Mississippian and the Pennsylvanian. The erosion which followed the continental uplift in North America at the close of the Mississippian was so severe that deep valleys were carved in the land surface and in places these cut completely through the Bayport limestone and into or even through the Michigan Series below. The topography was much rougher than that of the present land surface. Along much of the southeastern side of the Coal Basin both the Bayport limestone and the Michigan Series appear to be absent, probably having been removed by erosion, or perhaps never deposited. As a consequence, the Parma sandstone locally rests directly but unconformably on the Marshall sandstone and, since the two are lithologically similar, they cannot be readily distinguished in well records. In northern Jackson and northeastern Calhoun counties and perhaps along the southeastern margin of the Coal Basin, coal measures were deposited in the bottom of valleys between ridges and hills capped with Bayport limestone and rocks belonging to the Michigan series.

Thickness of the Coal Measures.—The Coal Measures in some parts of the Coal Basin vary greatly in thickness within very short distances. This is due to two causes; first they were deposited upon a very uneven basement, the eroded surface of the Grand Rapids group, as noted above and, second, their upper surface has been heavily eroded. The Appalachian Revolution, the general upheaval at the end of the Pennsylvanian permanently converted the Michigan sea and its bordering swamps into a land surface probably a thousand feet higher at least than the present. During the ensuing long period of erosion, extending to the Pleistocene, the surface of Michigan was greatly dissected. A large drainage system trending to the west was developed in the central portion of the Southern Peninsula. The trunk stream, represented by the old pre-glacial channel previously noted, headed in Saginaw Bay, ran southwest into the center of the Coal Basin, and then, veering northwest through Manistee county, entered the valley or basin now occupied by Lake Michigan. The bottom of this channel at the head of Saginaw Bay is nearly 200 feet below the surface of Lake Huron, over 325 feet in Gratiot county, and more than 700 feet below Lake Michigan in Manistee county, or over 100 feet below sea level. Numerous tributary streams dissected other parts of the Coal Basin producing a topography much rougher than that of the present land surface. The relief of the former surface was later more or less modified by the ice invasions of the Pleistocene which, in general, smoothed and rounded off the sharper topographic features.

The pre-glacial channels or "washouts," as they are termed by the miners, are now filled with drift, in places heavily water bearing. They cut out the coal beds and make mining uncertain and hazardous, particularly in the upper veins. In numerous instances, miners in driving entries have encountered these drift filled channels, sometimes with serious consequences from floods of water and quicksand. The amount of coal lost through pre-glacial erosion is very considerable but the data necessary for its calculation is insufficient. Few of the present rivers have cut through the thick mantle of drift, hence little coal has been lost through post-glacial erosion.

The troughlike deposits of the productive Coal Measures along the southern margin are very thin, being generally less than 100 feet in thickness. 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 Mt. Pleasant and Midland, 410 and 525 feet respectively. Around the northern and northwestern border no drillings of reliable record penetrate completely through the productive Measures, hence little definite information is known of their average thickness in that part of the basin. In the central part of the Coal Basin, however, the thickness averages from 300 to 400 feet and probably nowhere is it much more than 500 feet.

Occurrence of the coal.—Coal does not occur in all parts of the Coal Basin. In several borings near the center of the Basin which penetrate completely through the coal bearing series neither coal nor black shale were found, the Saginaw formation being a series of sandstones and gray shales. Coal beds are apparently thicker and more numerous toward the margin of the Basin and tend to thin and disappear toward the center.

Thousands of test drillings have shown the presence of more than a dozen coal seams, most of which are too thin for mining under present conditions. Lane* recognized seven distinct beds and made the following provisional series: Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne, Upper Verne, and Upper Rider. Cooper† added seven more, making fourteen in all, the complete series from bottom upwards being: Bangor Coal, Bangor Rider, Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne, and Lower Verne Rider, Upper Verne and Upper Verne Rider, Salzburg Coal, and Salzburg Rider.

*Mich. Geol. Surv., Vol. VIII, Pt. II, p. 46.

†Mich. Geol. Surv., Ann. Rept. 1905, Bay County Report, p. 174.

When it is considered that the whole coal series is characterized by extreme variation, that the fourteen or more coal seams occur in a section of barely 400 feet, that a given coal bed may rise or fall from 30 to 50 feet or more in a quarter of a mile, thicken, thin, or pinch out entirely in a few hundred feet, or split into two or more distinct seams, that many of the seams are merely local lenses or "pockets," that faults occur locally and that all of the above phenomena may be observed in a single mine, little weight should be attached so such an elaborate system of correlations. None of the coal beds extend continuously over the whole basin and few are continuous over any considerable part of it, and most of the areas in which the coal is of minable thickness are very small indeed. A rider of coal may or may not occur over each prominent coal seam but some beds have two or three lenses or so-called riders over them in the deeper troughs or valleys. The prominent coal seam of one locality may be unimportant in another and the main coal of the latter may correspond to a rider in the former. This reflects the transfer of favorable coal forming conditions from one part of the basin to another.

In the field of Wolverine Mine No. 3, Bay county, no less than ten seams of coal, not including the parts of split seams, occur in a section barely 175 feet in thickness, the seams averaging but little more than 15 feet apart. Deeper drilling in adjacent territory shows that there are at least three or four coal beds lower down. Of the upper ten veins only the so-called Verne, a split seam, is of minable thickness over any considerable area while some of the beds appear to be only thin lenses or "pockets" of coal of very limited extent. The "Verne Split" is continuous over a relatively large area, but it is variable in thickness, quality of the coal and number and distance apart of its members. Generally it is composed of two parts, the "Upper" and the "Lower Verne" seams, separated by a parting of "bone" coal or black shale. The bed in the field of Wolverine Mine No. 3 has a combined thickness of four to seven feet exclusive of the parting of shale. In turn either or both of the parts of the Verne may divide into a number of seams too thin for mining. Other coal beds exhibit this tendency to divide and it is certain that the "Verne" seams of one locality are not always related to the "Verne" of other localities.

It is generally impossible to satisfactorily correlate the thin lenses or "pockets" of coal encountered in different parts of the same field and it is very difficult to trace accurately the thicker and more continuous beds even with closely spaced drillings on account of the great variation in thickness, character and elevation. In test hole No. 965, in the field of Wolverine Mine No. 3, the split seam between 180 and 183 feet occurs at the depth at which the "Verne" split might be expected and it was not definitely known that the group of splits between 191 and 196 feet was the "Verne" until a tunnel entry was driven through the coal at this point. It is possible that the upper split represents the "Upper Verne" and the lower the "Lower Verne." In one part of the Bliss mine at Swan Creek, Saginaw county, test holes showed a thin coal seam at the depth at which the main bed should occur and this part of the field was marked on the mine maps as unminable. Mining operations later showed that the main seam at this point was depressed into a trough and occurred at some distance below the thin seam in greater thickness than the average for the field.

In the field of Wolverine Mine No. 2 several faults have been dicovered and one has been encountered in the mine workings for more than a quarter of a mile along the southern limit of the coal area, where the coal bed on the south of the fault line has been upthrown approximately 55 feet.

Since it is so difficult to make satisfactory correlations between coal seams in different parts of the same field, correlations between different fields and over long distances, where test holes are far apart, must be very uncertain and any elaborate system of coal seams based on such data can have very little value.

Of the fourteen or more distinct coal beds but four or five are known to contain areas of minable coal of any considerable size. The minable deposits are in the form of conclave lenses, though generally very irregular in outline and thickness. Most of the proven areas of minable coal contain less than 150 acres, only a few, more than 250 acres, and but two or three, more than 1,000 acres, and none exceed 2,000 acres.

Few of the deposits average more than three feet in thickness and some of them average only about 30 inches, which in Michigan appears to be the lower limit of average thickness at which coal can be profitably mined, unless other conditions are exceptionally favorable. Even in these thicker areas, the coal in places is inferior in quality, too thin for profitable mining, or is cut out entirely. The undulating floor of the coal basins results in a series of "rolls" or hills and valleys, which make haulage of coal and drainage of water to the central shaft difficult. The irregular form of the coal basins and the rapid variation in thickness and quality of the coal necessitate close and careful drilling in proving up a coal field. Some fields not sufficiently tested by drilling have proved to be so "pockety" or variable in the quality of the coal that mining operations were unprofitable.

Quality of the coal.—All of the coals of Michigan are bituminous, but are of the domestic variety, non-coking for the greater part. In general the coals are of a lower grade than those of Ohio, Pennsylvania, and West Virginia, but the quality varies greatly not only in the different seams but also in the same seam within very short distances. The shallow and marginal beds are characteristically high in ash and sulphur and low in fixed carbon. Most of the coal formerly mined near Jackson, Jackson county; at Owosso and Corunna, Shiawassee county; and at Grand Ledge, Eaton county, contains from 2% to 14% of ash, 3% to 7% of sulphur, and only 40% to 45% of fixed carbon. Much of the coal mined in Bay county, is similar in that it is high in ash and low in fixed carbon. The sulphur, however, is low in some beds and very high in others, the range being from 1.5% to

6% and over. Some of the Bay county coals resemble lignite in their weak physical character, low specific gravity, and high content of volatile matter.

The coals mined in the vicinity of Saginaw and St. Charles, Saginaw county, are of better grade, the ash varying from 1% to 7%, the sulphur from 0.5% to 2%, and the fixed carbon from about 50% to 58%.

Many of the Michigan coals are characterized by a high content of moisture, the extreme range being from 2% to about 13%. The Bay county coals contain on the average from 3% to 8% and those from Saginaw county from 6% to over 12%. While most of the coals are high in volatile matter and many of them are coking coals, they are not used for gas and coke making. The coke is usually inferior, being light and friable; the sulphur injures the quality of both the coke and gas, and the moisture gives more or less trouble in the ordinary types of gas producers. The Saginaw and St. Charles coals, though low in sulphur, are largely non-coking and high in moisture.

Most of the coals are good to excellent domestic coals and fair to good steam coals. Unfortunately they are weak and friable and do not stand long shipment well or permit of stocking. On exposure to the action of the air, sun, and rain many of the coals are rapidly reduced to slack. Owing to these qualities there is also a relatively large amount of slack produced in mining, especially in thin veins when shot "off the solid."

The ash content in most seams varies greatly from place to place. In portions of some fields, the coal is so high in ash (see analyses) that it is not marketable. Such coal is popularly called "cannel" coal, but it is not true cannel as it burns with much smoke. At the bottom or top of coal beds there is locally an inch to a foot or more of shaly and, in places, pyritous coal termed by the miners "Black Jack" or "dirty" coal. The early drillers failed to recognize this impure coal, and some of the areas of supposedly good coal have been found later to contain much "cannel" or "Black Jack" coal. This is the case in certain parts of the St. Charles coal field in Saginaw^ county.

The following analyses may be taken as fairly representative of the general character of Michigan coals. It is to be noted that the Bay county coals are in general lower in fixed carbon and higher in sulphur than those of Saginaw county.

Analyses

*ANALYSES OF MICHIGAN COAL.

	Locality.	Mine.	Bed.	Sample.
	Arenac county.			
1	Rifle river, Sec. 3, T. 19, N. R. 4 E.	.....	Rifle river "cannel."	Air dried sample.....
2	Rifle river, Sec. 3, T. 19, N., R. 4 E.	.....	Rifle river, lower seam.	Air dried.....
	Bay county.			
3	Secs. 21 and 22, T. 14 N., R. 4 E.	Monitor.....	.....	Run of mine sample...
4	Secs. 16 and 17, T. 14 N. R. 4 E.	Wolverine No. 2.....	.....	Sample from car lots; commercial.....
5	Secs. 16 and 17, T. 14 N., R. 4 E.	Wolverine No. 2.....	.....	Lump coal; dried.....
6	Secs. 16 and 17, T. 14 N., R. 4. E.	Wolverine No. 2.....	.....	Lump coal; commercial.
7	Sec. 7, T. 14 N., R. 3 E. and Sec. 12, T. 14 N., R. 4. E.	Wolverine No. 3.....	"Verne".....	Lump coal; air dried...
8	Sec. 30, T. 13 N., R. 6 E.	What Cheer.....	.....	Run of mine; commercial.
	Calhoun county.			
9	Sec. 13, T. 2 S., R. 4 W.	Albion.....	.....	Composite sample from sections from different Places. Includes slaty coal at top of seam. Dried.
	Eaton county.			
10	Grand Ledge	Jenkins "drift".....	.....	Lump sample; dried.
11	Grand Ledge	Jenkins "drift".....	.....	Selected lump sample; air dried.
	Huron county.			
12	Sebewaing.....	Standard.....	"Verne".....	Sample from stockpile; air dried.
	Jackson county.			
13	Jackson, Sec. 21, T. 1 N., R. 2 W.	New Hope.....	.....	Selected lump.....
	Saginaw county.			
14	Saginaw.....	Pere Marquette No. 1	.....	Section (92 inches) of main coal; natural. Same bed as Caledonia No. 3.
15	St. Charles.....	Robt. Gage No. 1...	"Saginaw".....	Same field as Robt. Gage Mine No. 2. (New) 25 lb. sample; natural.
16	St. Charles.....	Robt. Gage No. 1...	"Saginaw".....	Average of 13 analyses; air dried.
17	St. Charles.....	Robt. Gage No. 1...	"Saginaw".....	Bone or cannel coal from top of seam, 8 inches; natural.
18	Saginaw.....	Saginaw and St. Charles mines.	"Saginaw".....	Coal as marketed from Saginaw and St. Charles mines by the Consolidated Coal Co.
	Shiawassee county.			
18	Owosso.....	Owosso.....	.....	Section (33 inches) from main coal, natural.
19	Corunna.....	Corunna.....	.....	Average analysis of coal shipped.

*A. C. Lane, 22nd Ann. Rept. U. S. G. S., p. 322; also Vol. VIII, Pt. II, Mich. Geol. Surv.' pp. 110-119.

*ANALYSES OF MICHIGAN COAL.

Sp. Grav.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Heating power in B. T. U. (British Thermal units.)	Authority.
.....	11.35	35.80	41.10	11.87	5.84	.....	Sample through S. G. Higgins. Dickman and Mackenzie, analysts.
.....	3.60	40.00	55.40	1.00	.....	.....	
.....	4.60	38.70	48.40	8.30	1.20	12,732	Handy Bros. Mining Co.
.....	6.72	42.67	42.01	8.65	3.50	12,842	Analysts, Dickman and Mackenzie.
.....	.....	42.36	51.01	6.63	3.39	13,712	Wolverine Coal Co.
.....	7.72	39.08	47.09	6.11	3.11	12,653	Wolverine Coal Co.
.....	4.14	45.70	42.14	8.02	3.53	12,520	Wolverine Coal Co.
1.26	6.96	37.08	52.90	3.56	1.01	13,694	What Cheer Coal Co.
.....	.....	44.31	43.14	12.55	7.64	13,410	Analyst F. S. Kedzie. Sample contained 11.43 per cent of moisture, as received.
.....	.....	38.48	.....	10.14	4.61	.....	
.....	7.00	39.10	46.40	7.50	3.42	.....	Analyst, A. N. Clark.
1.34	6.09	39.54	46.06	8.26	5.72	12,767	Analyst, H. J. Williams.
1.24	5.93	46.59	44.64	2.84	3.07	13,580	Analyst, H. J. Williams.
1.260	10.15	33.14	53.95	2.76	1.10	12,726	Analyst, H. J. Williams.
1.285	7.79	34.74	52.58	4.89	1.01	12,836	Analyst, H. J. Williams.
.....	2.37	35.67	58.47	2.46	1.03	.....	Analyst, F. S. Kedzie.
.....	8.08	30.74	49.29	11.89	0.88	.....	Analyst, F. S. Kedzie.
.....	7.60	37.90	50.73	3.77	0.99	12,521	Analyst. Solvay Process Co., Syracuse, N. Y.
1.27	7.58	35.70	52.96	3.76	1.50	13,016	Analyst, H. J. Williams.
.....	6.33	35.46	45.45	12.04	.....	.....	

Development.

History of Coal Mining.—Coal mining apparently began at Jackson, Jackson county, as early as 1835, and certainly at Grand Ledge, Eaton county, in 1839. Until 1910 small mines were operated in Jackson county in the small shallow trough-like deposits of coal which were generally not more than 200 or 300 yards wide and a few hundred in length. At the present time a similar deposit is being worked near Spring Arbor, Jackson county, and a larger deposit is being developed just across the county line in Calhoun county four miles north of Albion. At Grand Ledge two coal beds 18 to 26 inches in thickness formerly outcropped in places in the bed of Grand River and along the banks for more than a mile. Most of the easily accessible coal has been mined out, but at present small quantities are obtained from clay pits of tile companies, utilizing the so-called fire clays which are locally associated with the coal beds. Coal was mined near Corunna and Owosso, Shiawassee county, prior to 1860. The coal deposits thus far discovered in the vicinity of these places have been small and pockety and of poor quality, hence mining operations have been intermittent and largely unprofitable.

In 1858-9 an unsuccessful attempt was made to mine coal near Millets, Eaton county, and a successful one at Williamston, Ingham county in the early 60's. A small mine is still in operation at the latter place. About 1875 several small pockets of coal were discovered along Rifle River, Arenac county, and some cannel coal was mined. The deposits were near the margin of the-Coal Measures and were without proper roof, which together with much water and lack of transportation facilities discouraged further exploration and development.

In 1861 coal was discovered at Bay City by William Walker in drilling a salt well. The discovery created considerable interest at the time, but since there was an abundance of cheap wood fuel from the lumber industry nothing came of the discovery. In the early 90's coal was discovered in Saginaw and Bay counties, but it was not until 1897 that the real growth of the coal industry began. Numerous mines were opened up, chiefly in the vicinity of St. Charles, Saginaw, and Bay City. A few years later coal mining began in Huron, Tuscola, and Genesee counties, and in 1913 in Calhoun county. The production grew from about 90,000 tons in 1896 to more than 2,000,000 tons in 1907, the maximum amount in the history of the industry.

Mining conditions.—The irregular form of the minable coal areas and the variable thickness and quality of the coal makes systematic plans of mining difficult or impracticable to carry out. Some of the coal basins are very irregular in form, being made up of several subordinate basins. For ease in handling the coal and water the shaft should be sunk in the lowest part of the basin but the uneven bottom makes the location of this uncertain without thorough drilling. Even when located at the most advantageous point the numerous hills and valleys are so pronounced that it is difficult to drain the water to the central shaft. In some mines auxiliary pumps are installed at various points to pump the water over the "rises" or to the surface through drill holes. To take advantage of gravity in hauling the coal to the shaft the entries follow the troughs in the coal bed as far as possible but heavy grades cannot always be avoided and auxiliary power must be provided at these points. The areas of "cannel," "Black Jack," or thin coal are very irregular in extent and mining plans must be constantly changed to meet the varying conditions. As a consequence maps of the workings of some mines resemble gigantic spiders.

Faults have been observed in a number of mines but most of faults are very small, the vertical displacement being measured in inches or two or three feet at most. In the Wolverine Mine No. 2 a large fault has been discovered in the workings for more than a quarter of a mile along the south side of the field. The coal bed on the south side of the fault has been upthrown a vertical distance of 55 feet along a fault plane having a hade of about 35° to the south. Such faults are apparently very rare in the Coal Measures of Michigan and most of the faults are so small that they interfere but little with mining operations.

Practically all of the coal seams except at Grand Ledge and Williamston are below the water table and largely in artesian territory, hence the most of the mines are very wet. The water comes in through the roof; the foot wall or both, or from the coal seam itself. Water has caused the abandonment of several mines and it is a serious menace to the successful operation of some of the present mines. The drift generally contains thick beds of quicksand and gravel, heavily water bearing. This makes shaft sinking very costly and uncertain. Several shafts have been lost owing to the quicksands and floods of water encountered. The erosion channels or "washouts" which are numerous in Bay county, are very wet and are a source of great danger. Several mines have been flooded, some permanently and such channels were encountered in mining. In general, water is very troublesome and its control and removal forms an important item in mining costs, especially in summer when the mines are practically idle.

Most of the proven areas of minable coal in Michigan have an average thickness of only about three feet, therefore the maximum yield of coal per acre which can be expected is relatively small It follows that a larger acreage is required for a tonnage sufficiently great to warrant mining operations. The rapid variation in the thickness of the coal beds gives rise to local areas of thin coal, perhaps too thin for profitable mining. The coal in such areas is not only lost but much expense is entailed by the extra dead work of driving entries through or around these areas. Areas of "bone," "cannel," or "blackjack" coal further reduce the total expected tonnage. In general the greater acreage, the irregular form of the coal bodies, their variable thickness and the uneven bottom, necessitate longer and more numerous entries, greater trackage, and more dead work to win a given amount of coal than in Ohio, West Virginia, or Pennsylvania. The roof is generally weak and treacherous requiring heavy and costly timbering to support it. In places the shale roof slacks upon exposure to the air and breaks into innumerable fragments. The cost of sustaining such a roof is usually prohibitive. The "fire" or "underclays" beneath the coal likewise slack upon exposure to air and water and become soft and plastic. The pressure from the overlying strata forces them up into the workings, causing constant trouble and expense through heaving the tracks and choking the entries.

Mining Costs.—The thick surface materials, usually heavy water bearing, makes shaft sinking in Michigan very expensive. In Ohio a shaft may be sunk and a small plant built and equipped for $15,000 to $20,000 but in Michigan a shaft, mine-plant and equipment of similar capacity would generally cost from $40,000 to $50,000 or even more. The amount of dead work—entry driving, timbering, track laying, cutting through bars and areas of unminable coal, etc. is greater than in competitive fields. The expense of pumping and keeping the mines in running order during the idle season is excessive. The wage scale is higher and is interpreted more liberally for dead work than elsewhere. In addition the mines work but six eight hour shifts per week and are practically idle during part of the summer. All this tends to make mining costs very high, or two or three times as high as in Ohio and West Virginia. To make matters worse the relatively inferior quality and weak nature of Michigan coals demand that they shall sell at lower average prices than the firmer higher grade coals from bordering states.

The future of coal mining in Michigan depends largely upon the ability of the operators to reduce the present excessive mining costs and to increase the average sale price by improving the average quality of the coal through better methods of mining. The following table shows that the average daily wage increased from $2.34 in 1900 to $3.49 in 1913, and that the average cost of mining a ton of coal correspondingly has increased during the same period from $1.387 to $1.977. (See table of production and mining costs.)

Methods of mining.—The room and pillar double entry system of mining is the principal one used in Michigan. Attempts have been made to use the long wall system but it was found impracticable on account of the weak and treacherous roofs in most of the mines, and the difficulty of adapting the long wall mining scale of other states to the scale conditions in Michigan.

Until 1898 all of the coal was mined by hand or "shot off the solid." The latter method is very wasteful particularly in Michigan where the seams are thin and the coal weak. The inordinately heavy charges of powder required in "shooting off the solid" shatters the coal producing much fine coal or slack and rendering the lump coal so friable that it disintegrates badly in handling and transportation. In addition the heavy charges shatter the weak roofs, which become a source of trouble and great danger.

In 1898 seven coal cutting machines were introduced into Michigan and they were so successful that eighteen more were brought in the following year. At first considerable difficulty was experienced, however, in adapting the machines, particularly the chain breast types to thin seams and to the weak roofs which require the timbering to be kept up close to the face. As a result there were only 46 machines in use in 1903, five years after their introduction. In the next five years, however, the number of machines increased to 120, but with the decline in coal production, which began in 1908 and has continued to the present, the number of machines also decreased. In 1912 and 1913, however, with the introduction of the short wall type of machine the number increased to 126 and 130 respectively.

In 1903, 13.2 per cent of the total production of coal was mined by machines and in 1908 the percentage increased to 29.2 per cent, in 1910 to 45.5 per cent, in 1912, to 52.7 per cent and in 1913, to 70 per cent. While nearly 30 per cent of the coal is still shot off the solid, the wonderful increase in the percentage of machine mined coal during the last three years is indicative of the recognition on the part of the operators of the importance of using efficient methods of mining. If

the present rate of increase in machine mined coal is maintained, coal mining in Michigan will soon be conducted as efficiently as in West Virginia, Pennsylvania, and Ohio, where the per cent of coal shot from the solid in 1913 ranged from less than one per cent in the first state to 3.7 per cent in Ohio.

Up to 1904, the machines were chiefly of the pick or puncher type but after this the chain breast machine came into prominence. They never became so widely used as the puncher type since they are not well adapted to thin coal seams and to the close timbering required by the weak and treacherous roofs. A few long wall machines were experimentally used in a number of mines but they were impracticable as their use requires more room at the face than the chain breast type. In 1910 the short wall machine was introduced with such success that it threatens to displace all other types.

Pick machines are operated by air and the difficulty and trouble of laying air pipes forms a serious objection to their use. The chain breast and short wall machines are electrically operated and the work of stringing the necessary power wires is comparatively easy. The latter machines on account of their compactness and ease of manipulation are especially adapted to the room and pillar method and to the close and narrow workings obtaining in most of the mines in Michigan.

Formerly so much slack was produced that it became a drug on the market. Modern manufacturing concerns, equipped with mechanical stokers, preferred to use slack from Ohio, West Virginia, and elsewhere which was of better quality and could be obtained very cheaply. To improve the quality of the slack a washery was established at Saginaw by the Consolidated Coal Company to wash the slack from their mines. This so improved the quality that the present demand for Michigan washed slack far exceeds the supply. Much more coal could be recovered if washing plants were established by the other large operators.

Prospective Development.—Most of the proven coal areas are in Bay and Saginaw counties, but Genesee and Tuscola counties are known to possess large reserves of minable coal. The largest group of developed and undeveloped coal areas occurs between Midland and Bay City, the second most important group is between Saginaw and St. Charles, a third in the northern part of Bay county, and a fourth in the vicinity of Flint, Genesee county. Important areas have also been located in northeastern Tuscola county.

Coal beds from three to five feet in thickness have been struck in many places around the southern margin of the Coal Basin, but as yet little systematic drilling has been done to determine the extent of such beds except near Albion. In this part of the Basin the beds are shallow and the drift is thin, but the coal apparently occurs principally in troughs of very limited extent. Coal beds probably containing areas of minable coal occur in the northwestern half of the Coal Basin, but the great depth of the drift and the abundance of water and quicksand are effective barriers against exploration or mining operations in this region.

Mines have been opened in most of the known coal deposits in Saginaw county but only a few of the proven coal areas in Bay county have been developed as yet. There are a dozen or more of undeveloped coal areas between Midland and Bay City and new mines will probably be opened in these as fast as the present mines become exhausted. The development of the reserves in the northern part of Bay county will probably be slower as they are relatively distant from means of transportation.

From the fact that the local price of coal is generally much higher than that of competitive markets small isolated mines supplying merely the local trade have been operated with success at various times and places as at Jackson, Williamston and Grand Ledge. A small mine is being opened at the present time near Albion, Calhoun county, to supply local markets.

Markets.

From the central position of the Coal Basin Michigan coals should command the markets of the state with the exception of the extreme southern portion in close proximity to the Ohio and Indiana fields. In the portion of the state north of a line from Port Huron, Lansing, and Grand Rapids Michigan coal has a natural protection in differential freight rates varying from $.75 to $1.40 per ton for coals from Ohio fields and about 25 cents per ton more for coals from West Virginia. The cost of mining coal in Michigan, however, is upwards of $1.00 per ton more than in Ohio and West Virginia and this counterbalances most of the advantage in lower freight rates. In addition much of the Michigan coal is inferior in grade to the average from those states, hence Michigan coal must compete at a lower average price. From these facts the market for Michigan coals is restricted chiefly to the Coal Basin itself and to the northern portions of the state.

Production.

Although coal mining began as early as 1835 it was not until 1860 that any records were kept. In that year Michigan is credited with an output of 2,320 tons. Ten years later the production had increased to a little over 28,000 tons, and in 1880 and the two following years it exceeded the 100,000 ton mark. After this there was a sharp decline, less than 37,000 tons being mined in 1884. The production gradually Increased until 1895 when the 100,000 ton mark was again passed. In 1897 with the discovery and opening of the Saginaw and Bay county fields the production was nearly a quarter of a million tons. Two years later it was nearly 625,000 tons, and in 1901 it approached 1,250,000 tons, but a strike of the miners in Saginaw Valley in 1902 caused a sharp decrease to less than 1,000,000 tons. In 1906 another strike caused a decline in production but in the following year the maximum output of 2,035,858 tons was

attained. In 1908 a pronounced decline in production set in and this continued until 1912 when the output totalled only 1,206,230 tons. In 1913 there was a slight increase, the production being 1,231,786 tons.

According to the State Department of Labor, nearly complete figures for 1914 give a total production of 1,153,869 tons and it appears very probable that the final figures will not exceed 1,161,000 tons.

Statistical Tables

PRODUCTION OF COAL AND COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1914.[1]

January.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	7	1,194	8	22.1	$3 52	$93,148 18	7	1,427	17,419	41,449	58,868	$2 12	$124,940 42
Saginaw	8	922	8	22.8	3 22	67,896 80	8	1,474	19,450	30,668	50,118	1 88	94,351 93
Other counties	6	236	8	23.3	2 69	14,420 00	3	359	4,478	2,114	6,592	2 88	19,010 23
Total	21	2,352	8	22.4	$3 32	$175,465 74	18	3,260	41,347	74,231	115,578	$2 06	$238,302 58

February.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	7	1,187	8	17.5	$3 60	$74,906 26	7	1,139	10,455	36,067	46,522	$2 20	$102,556 30
Saginaw	8	974	8	20.3	3 25	64,273 10	8	1,299	16,370	33,125	49,495	1 75	86,985 22
Other counties	7	249	8	21.6	3 21	17,263 68	2	413	4,602	1,761	6,363	2 74	17,409 47
Total	22	2,410	8	19.0	$3 41	$156,443 04	17	2,851	31,427	70,953	102,380	$2 01	$206,950 99

March.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	8	1,205	8	20.4	$3 69	$90,758 29	8	1,306	14,666	43,853	58,519	$2 07	$121,532 49
Saginaw	8	979	8	22.3	3 28	71,784 70	8	1,388	18,499	35,264	53,763	1 82	97,865 74
Other counties	7	220	8	22.0	3 14	15,893 70	2	222	4,491	3,478	7,969	2 64	21,056 15
Total	23	2,404	8	21.4	$3 46	$178,436 69	18	2,916	37,656	82,595	120,251	$1 91	$240,454 38

April.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	7	889	8	14.1	$3 59	$45,109 83	6	600	8,624	22,464	31,088	$2 11	$65,665 09
Saginaw	7	968	8	18.8	2 95	53,779 99	7	930	9,260	41,942	51,202	2 01	82,695 62
Other counties	6	209	8	18.6	3 21	12,481 28	1	78	1,480	1,270	2,750	4 66	12,825 48
Total	20	2,066	8	16.7	$3 22	$111,371 10	14	1,608	19,364	55,516	74,880	$2 15	$161,186 19

May.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	7	851	8	18.7	$3 54	$56,401 79	6	815	10,292	26,746	37,038	$2 05	$76,274 98
Saginaw	7	951	8	18.4	3 36	58,801 54	7	1,032	9,621	30,509	40,130	1 91	76,931 59
Other counties	6	192	8	20.5	3 50	13,787 62	1	74	726	3,327	4,053	3 01	12,184 25
Total	20	1,994	8	18.7	$3 46	$129,080 95	14	1,921	20,639	60,582	81,221	$2 03	$165,390 82

June.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	6	638	8	14.0	$3 52	$31,054 64	5	634	9,361	11,542	20,903	$2 12	$44,449 04
Saginaw	6	837	8	13.8	3 46	40,069 22	6	616	8,951	22,249	31,191	1 92	60,161 53
Other counties	4	175	8	26.9	3 14	14,830 16	1	123	1,745	5,387	7,132	2 41	17,171 14
Total	16	1,650	8	15.2	$3 42	$85,950 52	12	1,373	20,057	39,169	59,226	$2 05	$121,781 71

July.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	5	469	8	18.9	$3 43	$30,346 58	2	563	8,219	13,680	21,899	$1 44	$41,619 27
Saginaw	7	889	8	15.3	3 59	48,941 73	7	768	11,196	26,430	37,626	1 84	69,254 78
Other counties	4	191	8	24.7	3 01	14,233 12	1	99	3,181	3,031	6,212	2 39	14,860 47
Total	16	1,549	8	17.6	$3 36	$93,521 43	11	1,430	22,596	43,141	65,737	$1 75	$125,734 52

[1]Adapted from statistical data, compiled and published in the Annual Report of the State Department of Labor for 1914.

PRODUCTION OF COAL AND COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1914.—*Concluded.*

August.

County.	Number active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	8	1,180	8	15.9	$3 51	$66,017 58	7	878	15,613	25,416	41,029	$2 21	$90,939 60
Saginaw	7	929	8	22.4	3 43	71,527 80	7	1,278	15,019	39,405	54,424	1 75	95,599 09
Other counties	5	193	8	24.8	3 16	15,152 95	1	115	2,461	4,355	6,816	2 34	15,925 28
Total	20	2,302	8	19.2	$3 45	$152,699 33	15	2,271	33,093	69,176	102,269	$1 97	$202,464 06

September.

County.	Number active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	7	1,048	8	20.3	$3 41	$72,728 46	7	1,275	15,881	33,548	49,429	$2 03	$100,785 77
Saginaw	8	942	8	20.7	3 33	64,966 68	7	1,173	13,344	34,713	47,257	1 76	83,287 14
Other counties	5	207	8	23.6	3 06	14,915 42	1	134	2,479	4,127	6,606	2 24	14,822 26
Total	20	2,197	8	20.7	$3 37	$152,609 96	15	2,582	31,874	71,418	103,292	$1 92	$198,895 17

October.

County.	Number active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per week.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs of powder used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	8	1,162	8	20.9	$3 38	$82,142 06	7	1,391	18,720	37,333	56,053	$1 94	$108,823 83
Saginaw	8	967	8	21.7	3 03	63,666 20	8	1,281	15,963	31,990	47,953	2 23	106,321 75
Other counties	5	220	8	20.5	3 59	16,174 81	1	127	4,488	2,133	6,621	2 12	14,019 61
Total	21	2,349	8	21.5	$3 20	$161,983 07	16	2,799	39,171	71,456	110,627	$2 07	$229,165 19

November.

Bay	8	1,196	8	19.6	$3 57	$83,803 93	7	1,235	15,814	40,141	55,955	$1 99	$111,415 54
Saginaw	8	995	8	19.0	3 31	62,647 87	8	1,094	13,279	30,960	44,239	1 91	84,516 41
Other counties	5	219	8	23.7	3 13	16,170 62	1	108	4,843	2,171	7,014	2 18	15,313 54
Total	21	2,411	8	19.7	$3 43	$162,622 42	16	2,437	33,936	73,272	107,208	$1 97	$211,245 49

*December.

Bay	6	1,078	7.8	23.4	$3 56	$89,806 04	6	1,093	15,159	47,857	63,016	$1 79	$113,007 85
Saginaw	8	815	7.9	20.3	3 33	65,861 84	8	1,020	6,734	41,193	47,927	1 72	82,045 09
Other counties	3	19	8	26.7	2 95	1,501 00	.....	.....	257	.....	257	6 74	1,736 45
Total	17	2,072	7.9	24.7	$3 49	$157,168 88	14	2,113	22,150	89,050	111,200	$1 78	$197,389 39
Average per mo.	.....	2,146	8.0	19.9	$3 35	.....	.....	2,400	29,487	66,712	96,155	.....	$191,580 11
State total	.....	.....	.....	.....	.....	$1,717,352 71	.....	27,561	353,310	800,559	1,153,869	$1 99	$2,298,960 49
Total for Cos.													
Bay	.....	.....	.....	.....	.....	$816,223 58	.....	12,356	160,223	393,177	540,319	.....	$1,020,010 27
Saginaw	.....	.....	.....	.....	.....	734,306 87	.....	13,353	157,864	387,309	545,165	.....	1,020,615 89
Other counties	.....	.....	.....	.....	.....	166,804 36	.....	1,852	35,231	33,154	68,385	.....	176,334 33

*Figures incomplete for December.

PRODUCTION, COST OF MINING, AND VALUE OF COAL IN MICHIGAN, 1900-1914.

Year.	*Number active mines.	Average number employees per mine.	**Average daily wage.	Total tons of coal mined.	Total cost of coal mined.	Average cost per ton.	**Total tons of coal mined.	**Total value of coal mined.	***Average price received per ton.	Profit made per ton.
1900	31	1,676	$2 34	871,388	$1,209,228	$1.387	849,475	$1,259,683	$1 483	80.096
1901	30	1,847	2 44	1,016,496	1,442,415	1.419	1,241,241	1,753,064	1 412	.007
1902	32	1,616	2 75	899,967	1,284,342	1.427	964,718	1,653,192	1.714	.287
1903	34	3,014	2 91	1,601,984	2,529,027	1.579	1,367,619	2,207,527	1.979	.400
1904	33	2,733	3 01	1,408,375	2,266,098	1.609	1,342,840	2,424,935	1.806	.197
1905	38	2,776	2 96	1,413,307	2,244,434	1.588	1,473,211	2,512,607	1.705	.117
1906	38	2,106	2 40	1,267,385	2,090,489	1.529	1,346,338	2,427,404	1.803	.274
1907	37	2,807	3 24	1,911,291	3,162,837	1.655	2,035,858	3,660,833	1.798	.143
1908	38	3,115	3 02	1,842,775	3,089,759	1.677	1,835,019	3,322,904	1.811	.134
1909	36	2,907	2 93	1,796,573	2,865,083	1.650	1,784,602	3,199,351	1.793	.143
1910	34	2,471	3 07	1,462,276	2,626,342	1.796	1,534,967	2,930,771	1.909	.103
1911	32	2,539	3 39	1,380,585	2,623,244	1.887	1,476,074	2,791,461	1.891	.004
1912	26	1,886	3 19	1,160,768	2,170,676	1.869	1,201,230	2,399,451	1.989	.120
1913	24	2,076	3 49	1,138,163	2,250,559	1.977	1,231,786	2,455,227	1.993	.016
1914	23	2,146	3 35	1,153,869	2,285,281	1.99	.....	.....	.....	.....

*Compiled and adapted from reports of State Coal Mine Inspector, Ann. Repts. State Department of Labor.
**For year beginning Dec. 1 and ending Nov. 30.
***From Mineral Resources of United States, U. S. G. S.

PRODUCTION OF COAL BY COUNTIES, 1899-1914.

	Bay.	Eaton.	Ingham.	Jackson.	Saginaw.	Shiawassee.	Tuscola.	Other counties.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
*1914	540,319	82	1,376	1,287	545,165	603	†45,195	.....
*1913	579,123	155	2,953	457	521,848	2,170	31,480	453
*1912	607,740	374	3,874	.....	489,198	4,532	59,252	.....
1911	766,470	100	.....	.....	667,282	13,000	66,427	19,000
1910	766,470	100	.....	.....	667,282	.....	.....	101,215
1909	822,577	558	.....	1,500	859,434	.....	.....	100,628
1908	782,503	2,286	.....	5,539	999,338	.....	.....	45,355
1907	962,574	5,982	.....	5,645	1,047,927	.....	.....	13,730
1906	481,398	18,507	.....	8,658	835,475	.....	.....	2,300
1905	544,154	4,058	.....	9,196	915,803	.....	.....	.....
1904	410,634	9,057	.....	16,860	906,289	.....	.....	.....
1903	325,021	7,393	.....	23,307	1,011,898	.....	.....	.....
1902	248,645	8,800	.....	23,889	670,304	.....	.....	13,400
1901	253,821	4,803	.....	20,288	938,042	.....	.....	24,284
1900	190,814	4,530	.....	23,317	601,112	.....	.....	.....
1899	104,588	3,421	.....	21,600	455,607	.....	.....	39,492

*Compiled from Annual Report of State Department of Labor.
†Incomplete returns, tonnage approximate.

PRODUCTION OF COAL IN MICHIGAN, 1860-1914, IN SHORT TONS.

Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.
1860	2,320	1871	32,000	1882	135,339	1893	45,979	1904	1,342,840
1861	3,000	1872	33,600	1883	71,296	1894	70,022	1905	1,473,211
1862	5,000	1873	56,000	1884	36,712	1895	112,322	1906	1,346,338
1863	8,000	1874	58,000	1885	45,178	1896	92,882	1907	2,035,858
1864	12,000	1875	62,500	1886	60,434	1897	223,592	1908	1,835,019
1865	15,000	1876	66,000	1887	71,461	1898	315,722	1909	1,784,602
1866	20,000	1877	69,197	1888	81,407	1899	624,708	1910	1,534,967
1867	25,000	1878	85,322	1889	67,431	1900	849,475	1911	1,476,074
1868	28,000	1879	82,015	1890	74,977	1901	1,241,241	1912	1,164,973
1869	29,980	1880	100,800	1891	89,307	1902	964,718	1913	1,138,639
1870	28,150	1881	112,000	1892	77,990	1903	1,367,619	*1914	1,153,869

*Approximate, returns incomplete. Report of State Coal Mine Inspector, State Department of Labor.

LIMESTONE.

The limestone industry in Michigan has made a relatively rapid growth since 1899, but the period of most rapid growth was after 1904. In 1899, the total value of the product including lime was $281,769, while in 1914 the total value exclusive of lime, which amounted to $287,648, was $1,457,961. The gain in 1914, however, was small, the increase amounting to only $49,258 as against $269,143 in 1913. The cause of the small increase in 1914 was due to the general business depression throughout the country.

The chief increases were in stone for blast furnace flux, sugar making, and fertilizer; the chief decreases, in the output of crushed stone for road making and railroad ballast, and of stone for the manufacture of soda ash. The large increase in flux stone made in spite of the

depressed condition of the iron trade is chiefly owing to the fact that large deposits of high grade limestone near water transportation and very suitable for blast furnace use have been extensively developed in the northern part of the state in the past three or four years, and this stone is successfully invading the flux stone market formerly dominated by limestone from other states. The use of pulverized or ground limestone as a fertilizer and soil rectifier is growing very rapidly and the increase in value of this product in 1914 was more than 57 per cent.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1914.

Year.	Rough building. Value.	Dressed building. Value.	Paving. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone. Road making. Tons.	Crushed stone. Road making. Value.
1899	$30,299	*	$62,815				$1,111		
1900	32,362	*	105,266				799		
1901	47,785	*		*	$380	$5,098	*		$31,605
1902	58,797	*		$480	200	3,101	5,740		56,264
1903	36,528	*	49,000	250	5,150	710	800		61,342
1904	32,941	805	37,665			2,800	2,405		58,655
1905	17,071			160		744	1,568		112,113
1906	9,368	641	90,723	75		4,654	1,204		78,437
1907	15,120	100	56,500			1,433	1,234		131,708
1908	7,276		10,825	300	100	15,907	1,574		182,510
1909	4,450	7,445				1,572	3,615		132,902
1910	3,522		35,500			2,205	908		110,184
1911	7,526					165	380	224,207	113,574
1912	9,997					380	75	663,553	295,440
1913	8,274					3,511	610	532,311	266,316
1914	8,537					1,651	6,727	505,133	242,830
Total	$324,793					$43,931	$28,750		$1,873,895

*Included in total for year.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1914.—*Continued.*

Year.	Crushed stone. Railroad ballast. Tons.	Crushed stone. Railroad ballast. Value.	Crushed stone. Concrete. Tons.	Crushed stone. Concrete. Value.	For blast furnace flux. Tons.	For blast furnace flux. Value.	To sugar factories. Value.	To alkali works. Value.
1899						$27,512		
1900						3,200		
1901		$18,200		$75,643		13,488		
1902		40,810		49,430		32,246		
1903		35,340		48,504		15,902		
1904		57,100		60,745		62,586		
1905		43,640		107,396		109,883		
1906		103,442		61,852		81,517	$224,336	
1907		46,516		97,762		109,429	22,234	
1908		33,900		72,200		56,841	32,594	
1909		42,445		112,829		91,915	25,845	
1910		42,358		178,318		100,149	69,647	
1911	91,713	34,998	306,385	137,285	341,027	186,046	65,141	*
1912	54,827	28,368	185,423	97,298	295,941	157,812	36,944	$508,044
1913	116,000	48,400	262,616	145,965	1,202,817	494,495	38,215	320,961
1914	38,000	20,600	362,209	166,959	1,604,240	565,012	69,477	269,087
Total		$596,126		$1,413,186		$2,087,633	$584,453	

*Concealed—included in total.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1914.—*Concluded.*

Year.	To carbonic acid plants. Value.	To paper mills. Value.	Fertilizer. Tons.	Fertilizer. Value.	Other purposes.	To lime burners.	Rank of state. Value.	Total. Value.
1899					$2,375	$157,657		$281,769
1900					124,220	65,000	12	330,847
1901					101,399	156,173	12	429,771
1902					68,164	98,000	13	413,148
1903					4,747	132,600	14	390,473
1904					5,323	180,683	10	501,708
1905					142,790	9,380	12	544,754
1906							10	656,269
1907					278,297		11	760,333
1908					253,990		9	669,017
1909					327,571		11	720,589
1910					299,305		9	842,126
1911		$12,558		$3,003	440,857		8	1,005,751
1912		8,156		3,447	13,396		8	1,139,560
1913		10,723		7,048	395,874		7	1,408,703
1914	$53,138	8,307	10,907	11,104	39,523			1,457,961
Total		$39,738		$24,602	$2,408,031			$11,582,779

Twenty-five quarries were in operation in 1914. Some quarries, chiefly small ones, were idle but the loss was compensated for by the opening of new or the reopening of old quarries. The crushing plant of the France Stone Co. of Monroe was destroyed by fire the first of the year, but the company rebuilt at once, and now have a new plant completely equipped with modern machinery for producing crushed stone for roadmaking, railway ballast and concrete. The Great Lakes Stone & Lime Co. were unable to complete their crushing plant at Rockport before the close of the 1914 season, but according to reports they will begin active operations in 1915. Their stone is very high calcium limestone, bituminous and very fossiliferous. The Cheboygan Limestone Products Co. opened a quarry near Mackinaw City in high calcium beds belonging to the Dundee limestone.

Owing to the purity and favorable situation of the limestone deposits near water, in which the more recent and larger quarries have been opened, it is very probable that the limestone industry in Michigan will continue to make a steady and rapid growth. With the return of more normal conditions in the iron industry, the season of 1915 promises to be the greatest in the history of the limestone industry in Michigan.

During a portion of the field season of 1913 and 1914, R. A. Smith of the State Geological Survey made an examination of the limestone resources of the state and a complete report is now in preparation.

LIME.

In the last ten years the lime industry in Michigan has made very little growth in comparison with the limestone industry. This is due largely to several causes, viz.: (1) the growing scarcity of cheap wood fuel for burning lime, (2) the substitution of concrete for stone and lime mortar in construction work, (3) the rapidly growing use of gypsum wall plaster and plaster substitutes, and (4) the unfavorable location of suitable limestone deposits. Formerly, owing to the abundance of wood fuel, lime was burned at many localities in the state, but now lime is produced only at Menominee, Manistique, Marblehead, and Rexton in the Northern Peninsula, and at Alpena, Afton, Petoskey, Bay Shore, and Charlevoix, and near Omer, and no lime is burned in the southern half of the Southern Peninsula. Most of the limestone deposits are in the northern part of the state relatively distant from large markets and the consequent high transportation charges make it difficult for Michigan burners to compete with lime producers in Indiana, Ohio, and Illinois, situated near cheap coal fuel supplies.

PRODUCTION AND VALUE OF LIME IN MICHIGAN, 1904-1914.

Year.	Total lime burned. Quantity, tons.	Total lime burned. Value.	Average price per ton.	No. of plants operating.	Rank of state. Production.
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
Total	768,172	$3,230,889			

Concrete mortar owing to the ease and rapidity with which it can be handled has largely replaced stone and sand-lime mortar in construction work, and gypsum plasters and plaster board similarly have replaced sand-lime mortar for plastering.

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

The total lime burned in 1914 was 66,507 tons valued at $287,648 as compared with 77,088 tons valued at $331,852 in 1913. This represents a decrease in amount of 10,851 tons and in value of $44,204, or a loss

of 13.7 per cent in amount and 13.3 per cent in value. The average price per ton was $4.33 as against $4.05 in 1913.

SANDSTONE.

The value of the annual output of sandstone in Michigan has decreased from $188,073 in 1902 to only $12,983 in 1911. In 1912 and 1913 there were slight increases, the total value of the output in each of these years was $16,438 and $19,224 respectively. In 1914 the industry almost ceased to exist, there being but one operator.

*PRODUCTION AND VALUE OF SANDSTONE IN MICHIGAN, 1899-1914.

Year.	Rough building. Value.	Dressed building. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone. Road making. Value.	Crushed stone. Concrete. Value.	Other. Value.	Total. Value.
1899	$102,447	$51,682	$109	a	.....	.....	.....	.....	$23,800	$178,038
1900	73,850	58,800	.....	.....	.....	.....	.....	.....	.....	132,650
1901	128,909	.....	.....	.....	$26,519	b	.....	.....	19,000	174,428
1902	136,280	23,600	.....	.....	27,393	$800	.....	.....	.....	188,073
1903	89,931	10,365	.....	.....	15,554	.....	$2,050	$3,450	.....	121,350
1904	47,593	14,818	.....	.....	10,657	.....	1,400	400	.....	74,868
1905	64,056	36,035	.....	.....	10,352	.....	.....	.....	12,700	123,123
1906	35,272	18,950	.....	.....	10,403	770	.....	.....	.....	65,395
1907	33,561	10,918	.....	$528	7,900	96	.....	.....	.....	53,003
1908	15,100	18,813	.....	.....	5,190	.....	.....	.....	.....	39,103
1909	12,985	16,805	.....	.....	6,294	.....	.....	.....	.....	36,084
1910	13,312	15,416	.....	.....	2,505	.....	.....	.....	.....	31,233
1911	5,682	2,809	.....	.....	3,068	1,140	.....	.....	286	12,985
1912	c	c	.....	.....	c	c	.....	.....	a	16,438
1913	c	c	.....	.....	c	3,127	.....	.....	c	19,224
1914	.....	.....	.....	.....	.....	.....	.....	.....	.....	d
Totals	.....	.....	$109	.....	.....	.....	.....	$3,850	.....	.....

a Included under curbing.
b Included under rubble.
c Included in total.
d Figures not given—only one operator.
* Exclusive of sandstone made into grindstones and scythestones.

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

Quarries were formerly operated in Coal Measure sandstones near Ionia and Grand Ledge and at many places in the Marshall sandstone in Calhoun, Hillsdale, Jackson, and Huron counties. Most of the sandstone in these formations, upon exposure to the weather for a few years, alters uniformly or in spots to an unsightly yellow color. The sandstone near Ionia, however, though soft and friable is streaked and mottled with red, orange, and yellow and makes a pleasing appearance in buildings. No quarries are now operating in sandstone of the Coal Measures or the Upper Marshall, but some rubble and riprap are produced in connection with the quarrying of grindstone from the Lower Marshall in Huron County.

All of the output of sandstone for 1914 was derived from the Jacobsville sandstone, apparently the local equivalent of the Lake Superior or Upper Cambrian sandstone. Extensive quarrying operations have been carried on for a number of years near Jacobsville but the Portage Entry Redstone Co. is now the only active operator. The "redstone" or "brownstone" of the Jacobsville is well cemented, permanent in color and pleasing in appearance, but the great distance of the deposits from large markets has been and will continue to be a serious obstacle in the way of their development.

Formerly much sandstone was quarried for foundations but now concrete has largely replaced block stone for such purposes on account of the cheapness of concrete materials and the rapidity and ease with which concrete can be handled. Front and fancy brick, owing to their cheapness and to the artistic effects which can be obtained by their use, have largely supplanted stone as a building material, and apparently the sandstone industry in Michigan except the quarrying of grindstones will not again attain its former importance.

TRAP ROCK.

Almost inexhaustible resources of trap rock occur in the western half of the Northern Peninsula, chiefly in the iron and copper bearing regions, but trap rock is quarried on an extensive scale only in the vicinity of Marquette. Large quantities of amygdaloid trap rock, however, are taken out in connection with copper mining in the Keweenaw peninsula. The trap rock from Marquette county is harder, tougher, and much less altered than the amygdaloid trap of the Copper Range. The inferior wearing qualities of the latter for road purposes, however, are partly compensated for by most superior cementing powers.

Most of the product is crushed for road making and concrete. On account of its hardness, toughness, and high cementing power trap rock is unexcelled as a road material. The great distance from markets with the consequent high transportation charges and the high cost of quarrying prevents the extensive development of the trap rock resources for concrete and road making in competition with the more easily accessible and cheaply obtained materials—limestone and gravel.

In 1914 the trap rock industry in Michigan suffered from the general depression in trade conditions and as a result there was a large decrease, the total value falling from $92,201 in 1913 to only $34,406 in 1914—a little more than one-third that of the year preceding. The decreases, however, were in crushed trap for concrete and in riprap, while there were slight increases in both the amount and value of crushed stone for road making. A new quarry was opened in the vicinity of Negaunee and the rock is reported to be gabbro rather than trap.

PRODUCTION AND VALUE OF TRAP ROCK IN MICHIGAN, 1911-1914.

Year.	No. of producers.	Crushed stone. Road making. Quantity.	Crushed stone. Road making. Value.	Crushed stone. Concrete. Quantity.	Crushed stone. Concrete. Value.	Riprap. Value.	Total. Value.	Rank. Value.
		Tons.		Tons.				
1911	3	.....	.....	45,250	$38,429	.....	$51,000	8
1912	5	21,805	$18,366	11,355	9,340	$8,500	36,206	8
1913	5	24,920	23,369	*	*	*	92,201	10
1914	.....	25,690	24,853	4,448	4,771	.....	34,406	.....
Total	.....	72,415	$66,598	.....	.....	.....	$213,813	.....

*Included in total.

GRINDSTONES AND SYTHESTONES.

Although Michigan ranks second to Ohio in the production of grind-stones and scythestones, the production of the latter state is five or six times that of Michigan. The "grit or grindstone" occurs in the lower part of the Marshall formation in Huron county. The Wallace Company of Port Austin and the Cleveland Stone Company operate quarries at Eagle Mills and

Grindstone City respectively, where the gritstone occurs in low-lying and thinly drift covered ledges near the shore of Lake Huron. The surface deposits are removed by stripping and channeling machines cut the stone into square blocks eight feet or more in thickness. These are split with wedges along the bedding planes into thinner slabs which are loaded on cars by derricks, then taken to the mills.

The grindstones produced vary in size from very small ones up to those seven feet in diameter with a 14 inch face. The broken stone is worked up into scythestones.

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

SAND AND GRAVEL.

PRODUCTION AND VALUE OF SAND AND GRAVEL IN MICHIGAN, 1904-1914.

Year.	Glass sand.		Molding sand.		Building sand.		Fire sand.		Engine sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1904	.....	.....	167,147	$76,299	69,656	$30,898	.....	.....	.....	.....
1905	.....	.....	19,382	13,247	263,315	148,065	5,000	$2,500	.....	.....
1906	600	$3,000	61,387	26,108	403,199	127,937	.....	.....	4,000	$400
1907	4,300	8,600	54,172	24,190	451,646	157,150	6,000	3,000	1,534	153
1908	17,000	34,000	4,584	2,892	474,238	228,393	.....	.....	1,991	319
1909	65,000	79,000	53,226	20,756	1,090,419	327,247	4,000	2,000	12,415	1,493
1910	16,212	25,675	93,812	24,004	1,151,588	334,336	5,000	3,000	22,270	2,172
1911	*	*	68,878	17,901	833,729	247,997	*	*	25,392	4,447
1912	*	*	152,433	40,145	902,556	294,115	.....	.....	18,575	4,774
1913	*	*	50,763	17,493	1,326,016	415,737	4,542	4,524	4,447	647
1914	26,035	32,593	53,400	36,583	1,088,650	360,152	.....	.....	6,357	1,066
Totals	.....	.....	779,185	299,618	8,055,012	2,672,029	.....	.....	96,981	15,471

Year.	Furnace sand.		Paving sand.		Other sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.	
1904	.....	.....	.....	.....	.....	.....
1905	.....	.....	.....	.....	50,187	$14,476
1906	5,000	$2,500	.....	.....	51,005	12,140
1907	3,858	3,133	.....	.....	173,724	12,187
1908	3,329	3,828	.....	.....	29,187	6,850
1909	3,183	3,660	.....	.....	295,612	50,053
1910	3,185	4,924	.....	.....	372,880	57,385
1911	*	*	152,144	$29,650	114,801	52,005
1912	.....	.....	68,453	16,898	130,624	54,746
1913	†	†	533,261	108,328	113,318	20,342
1914	†	†	320,322	74,866	115,291	107,392
Totals	.....	.....	1,074,180	$229,742	1,446,629	$388,476

Year.	Railroad ballast.		Gravel.		Total.		Rank.	
	Quantity.	Value.	Quantity.	Value	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1904	.....	.....	.....	.....	236,803	$107,197	.....	.....
1905	.....	.....	76,625	$32,321	414,509	210,609	10	11
1906	.....	.....	72,598	25,614	597,789	197,699	12	13
1907	.....	.....	329,407	81,182	1,024,641	289,595	10	11
1908	.....	.....	312,262	94,081	842,591	370,365	8	9
1909	.....	.....	695,902	209,523	2,219,757	685,632	8	8
1910	.....	.....	1,197,791	364,841	2,862,738	816,337	7	8
1911	.....	.....	935,072	203,218	2,185,165	565,969	9	10
1912	.....	.....	1,409,180	407,925	2,681,821	818,603	9	8
1913	.....	.....	3,928,874	915,205	6,422,818	1,528,892	4	5
1914	7,565	$781	2,140,359	530,338	3,757,979	1,143,771	8	7
Total	7,565	$781	11,098,070	$2,855,248	23,246,611	$6,734,669	.....	.....

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

Owing to the general use of sand and gravel in the building trades, no other industry reflects general business conditions better than that of sand and gravel. As a consequence of the general industrial depression prevailing throughout the country during 1914 there was a large falling off in the output of sand and gravel particularly in building sand, and gravel for concrete. The total production in 1914 was 3,757,979 tons as compared with 6,422,818 tons in 1913, a net decrease of 2,664,839 tons or nearly 42 per cent. The decline in total value, however, was relatively less, the value falling from $1,528,892 in 1913 to $1,143,771 in 1914, a decrease of $385,121, or about 25 per cent. In 1914 the production of building sand in Michigan was 1,088,650 tons valued at $360,152. This represents a decrease in amount of 237,466 tons and in value $55,585. In 1914, 2,140,359 tons of gravel valued at $530,338 were produced as against 3,928,874 tons valued at $915,205 in 1913. This represents a decrease in amount of 1,788,515 tons or about 45.5 per cent and in value of $384,867 or over 42 per cent.

Michigan has enormous sand and gravel resources. The most important deposits occur in the form of ridges known as eskers or hogbacks, in irregular hills called kames, in outwash plains and deltas and in old beach ridges, features resulting from the last or Wisconsin glacial invasion.

Only a small portion of the sand and gravel resources have been developed and the chief developments are in the vicinity of cities, in river channels and along the lake shores where means of transportation are favorable. The localities and counties in order of importance in production are Detroit and St. Clair rivers, Jackson, Macomb, Kent, Oakland, Ingham, Manistee, Livingston, Washtenaw, Ottawa and Lenawee counties, and the shores of Lake Michigan and Lake Huron.

SALT.

The amount and value of salt produced in Michigan in 1914 were greater than in any previous year. The total quantity of salt in 1914 was 11,670,976 barrels, or 142,176 barrels more than in 1913. The total value was $3,299,005, which represents a gain of only $5,973. The small gain was due to slightly lower prices, the general average price per barrel being $0.283 per barrel as compared with $0.285 in 1913. During the period from 1905 to the present the average price has risen from $0.196 to $0.283 per barrel.

From 1880 to 1892 inclusive Michigan held first rank in the amount of salt produced. In 1893 New York assumed the lead and held it continuously with the exception of 1901 until 1905 when Michigan regained the leadership. Excepting the years of 1910 and 1911, Michigan has since held first place as a salt producer with New York as a close second.

Thirty years ago the center of the salt industry was in Saginaw Valley, chiefly along Saginaw River from Saginaw to Bay City. The industry was carried on in connection with the lumber mills and waste steam and fuel from the mills were utilized by more than a hundred lumber concerns in evaporating natural brines obtained from the Upper Marshall sandstone at depths varying from about 600 feet in Saginaw to nearly 1,000 feet in Bay City. With the decline of the lumber industry in Saginaw Valley the salt industry has become unimportant, there being but eight producers in 1914,

one in Bay City and seven in Saginaw. Less than three per cent of the total output of salt in the state for 1913 and only 3.6 per cent for 1914 was produced in this district.

PRODUCTION AND VALUE OF SALT IN MICHIGAN AND UNITED STATES, 1860-1914.

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.
1860	.....	4,000	.....	.....	....	.....	.....	.....
1861	.....	125,000	.....	.....	....	.....	.....	.....
1862	.....	243,000	.....	.....	....	.....	.....	.....
1863	.....	466,000	.....	.....	....	.....	.....	.....
1864	.....	529,073	.....	.....	....	.....	.....	.....
1865	.....	477,200	.....	.....	....	.....	.....	.....
1866	.....	407,997	.....	.....	....	$734,395	.....	$1.80
1867	.....	474,721	.....	.....	....	840,255	.....	1.77
1868	.....	555,690	.....	.....	....	1,028,027	.....	1.85
1869	.....	561,288	.....	.....	....	786,835	.....	1.58
1870	.....	621,352	.....	.....	....	820,185	.....	1.32
1871	.....	728,175	.....	.....	....	1,063,135	.....	1.46
1872	.....	724,481	.....	.....	....	1,057,742	.....	1.46
1873	.....	821,346	.....	.....	....	1,127,984	.....	1.37
1874	.....	1,026,970	.....	.....	....	1,220,094	.....	1.19
1875	.....	1,081,856	.....	.....	....	1,190,042	.....	1.10
1876	.....	1,482,729	.....	.....	....	1,556,865	.....	1.05
1877	.....	1,660,997	.....	.....	....	1,411,847	.....	0.85
1878	.....	1,855,884	.....	.....	....	1,577,501	.....	0.85
1879	.....	2,058,040	.....	.....	....	2,099,200	.....	1.02
1880	5,961,060	2,676,588	2,485,177	41.69	1	2,271,931	.....	0.75
1881	6,200,000	2,750,299	.....	44.35	1	2,418,171	.....	0.85
1882	6,412,373	3,037,317	3,037,317	47.36	1	2,126,122	.....	0.70
1883	6,192,231	2,894,672	2,894,672	46.74	1	2,344,684	.....	0.81
1884	6,514,937	3,161,806	3,161,806	48.53	1	2,392,648	.....	0.757
1885	7,038,653	3,297,403	3,297,403	46.84	1	2,967,663	.....	0.900
1886	7,707,081	3,667,257	3,667,257	47.58	1	2,426,989	.....	0.661
1887	8,003,962	3,944,309	3,944,309	49.17	1	2,291,842	.....	0.581
1888	8,055,881	3,866,228	3,866,228	47.99	1	2,261,743	.....	0.585
1889	8,005,565	3,846,979	3,856,929	48.17	1	2,088,009	.....	0.541
1890	8,776,991	3,838,637	3,838,632	43.72	1	2,302,570	.....	0.600
1891	9,987,945	3,927,671	3,966,748	39.52	1	2,037,289	.....	0.518
1892	11,698,890	3,812,504	3,829,478	32.81	1	2,046,963	.....	0.523
1893	11,897,208	3,514,485	3,057,898	25.70	2	888,837	.....	0.287
1894	12,968,417	3,138,941	3,341,425	26.53	2	1,243,619	.....	0.375
1895	13,669,649	3,529,362	3,343,395	24.46	2	1,048,251	.....	0.315
1896	13,850,726	3,336,242	3,164,238	22.89	2	718,408	.....	0.229
1897	15,973,202	3,622,764	3,993,225	24.99	2	1,243,619	.....	0.313
1898	17,612,634	4,171,916	5,263,564	29.88	2	1,628,081	.....	0.311
1899	19,708,614	4,732,669	7,117,382	36.14	2	2,205,924	.....	0.309
1900	20,869,342	4,738,085	7,210,621	34.55	2	2,033,731	2	0.282
1901	20,566,661	5,580,101	7,729,641	37.58	1	2,437,677	1	0.328
1902	23,849,231	4,994,245	8,131,781	34.10	2	1,535,823	2	0.188
1903	18,968,089	4,387,982	4,297,542	22.65	2	1,119,984	2	0.260
1904	22,030,002	5,390,812	5,425,904	24.62	2	1,579,206	2	0.309
1905	25,966,122	5,671,253	9,492,173	35.24	1	1,851,332	2	0.196
1906	28,172,380	5,644,559	9,936,802	36.31	1	2,018,760	2	0.203
1907	29,704,128	6,298,463	10,786,630	35.39	1	2,231,129	2	0.208
1908	28,822,062	6,247,073	10,194,279	35.34	1	2,458,303	1	0.241
1909	30,107,646	6,055,661	9,966,744	33.10	1	2,732,556	1	0.274
1910	30,305,656	5,597,276	9,452,022	31.18	2	2,231,262	2	0.236
1911	31,183,968	.....	10,320,074	33.10	2	2,633,155	1	0.255
1912	33,324,808	.....	10,946,739	32.84	1	2,974,429	1	0.277
1913	34,393,227‡	.....	11,528,800	33.52	1	3,293,032	1	0.285
1914	34,402,772	.....	11,670,976	33.92	1	3,299,005	1	0.283
Tot'l.	.....	.....	209,217,812	.....	....	$89,897,763	.....	.....

*Office of State Salt Inspector abolished in 1911.
†In cooperation with the Michigan Geological Survey after 1909.
‡Includes production of Porto Rico.

The chief salt producing districts are along the Detroit-St. Clair Rivers and at Ludington and Manistee. In these districts artificial brines are used for the manufacture of salt. The brine is obtained by forcing water through casings down to rock salt beds and then back to the surface. Rock salt is also mined. Over 96 per cent of the state output of salt for 1913 and 1914 came from these two districts. The salt industry in Wayne county has made a most remarkable growth. Salt was first produced in this country in 1895, the output for that year being 13,077 barrels. In 1906 the production exceeded 1,000,000 barrels and in 1914 it was 6,593,816 barrels. Much of the salt produced in Wayne county is in the form of brine which is used in the manufacture of soda ash, bleach, caustic, etc. The Solvay Process Co. at Delray, the Michigan Alkali Co. at Ford City and Wyandotte, and the Pennsylvania Salt Co. of Wyandotte use great quantities of brine in the manufacture of such products.

In St. Clair county the chief salt producing centers are Port Huron, St. Clair and Marine City. The output of St. Clair county in 1914 was only 19 per cent of the state output, yet the value was 42.88 per cent of the total value for the state. The exceptionally high value of the product from this county is due to the fact that much of the salt produced is of the better grades, 59.2 per cent being table and dairy salt.

PRODUCTION AND VALUE OF SALT IN MICHIGAN BY GRADES, 1906-1914.

Year.	Table and dairy. Quantity.	Table and dairy. Value.	Packers. Common fine. Quantity.	Packers. Common fine. Value.	Packers. Common coarse. Quantity.	Packers. Common coarse. Value.
	Barrels.		Barrels.		Barrels.	
1906	509,905	$362,368	2,927,478	8757,470	2,021,287	8618,727
1907	657,509	392,641	3,601,270	914,154	1,743,840	471,378
1908	584,452	620,647	3,454,062	968,617	2,020,956	610,286
1909	585,370	732,907	3,530,303	1,125,095	2,103,719	647,878
1910	798,434	565,653	2,216,181	734,828	1,992,465	596,301
1911	817,486	742,702	2,362,075	698,203	2,070,745	745,720
1912	905,593	920,782	2,225,337	645,692	2,086,492	835,673
1913	1,028,000	1,037,402	2,704,936	852,135	2,259,164	896,521
1914	1,092,344	1,025,164	2,668,989	911,016	2,380,378	870,715

Year.	Packers. Quantity.	Packers. Value.	Other, rock, etc. Quantity.	Other, rock, etc. Value.	Brine and other.* Quantity.	Brine and other.* Value.
	Barrels.		Barrels.		Barrels.	
1906	91,098	$33,733	.....	.....	4,387,043	$246,462
1907	119,459	48,455	.....	.....	4,664,552	235,729
1908	134,726	53,669	.....	.....	3,993,083	205,084
1909	93,357	3,983	.....	.....	3,648,395	185,051
1910	92,426	43,942	.....	.....	4,104,934	211,317
1911	105,401	45,421	576,595	$181,865	4,387,772	219,244
1912	223,866	84,638	763,908	250,080	4,737,038	236,852
1913	50,557	25,371	727,364	244,172	4,756,779	237,431
1914	†	†	772,530	252,024	4,816,735	240,086

Year.	Total. Quantity.	Total. Value.
	Barrels.	
1906	9,936,802	$2,018,760
1907	10,786,630	2,062,357
1908	10,194,279	2,458,303
1909	9,966,744	2,732,556
1910	9,452,022	2,231,262
1911	10,320,074	2,633,155
1912	10,946,739	2,974,429
1913	11,528,800	3,293,032
1914	11,670,976	3,299,005

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

Rock salt is mined at Oakwood, a small suburb on the western side of Detroit by the Detroit Rock Salt Co. A drill hole at the shaft showed the presence of salt aggregating more than 450 feet in thickness, but present mining operations are in a 20 foot bed at the depth of 1,040 feet. A large part of the product is shipped to Chicago and St. Louis, and other large cities, where it is used chiefly in curing fish, meats, and hides, and in the manufacture of ice cream and for general refrigeration.

In the Manistee-Ludington district salt is made at Manistee, Filer City, and East Lake, all situated on Manistee Lake, Manistee county; and at Ludington, Mason county. In this district the salt industry is still largely carried on in connection with the lumber industry, utilizing waste steam and waste fuel for evaporating artificial brines. This district produced 2,420,334 barrels of salt or 20.82 per cent of the state output. Nearly all of the product is packer's salt, i. e., common fine and common coarse, only one company manufacturing table and dairy salt.

Bromine and bromides are produced from the natural brines of the Marshall sandstone at Midland and Mt.

Pleasant, and calcium chloride at Mt. Pleasant and Saginaw.

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

In Alpena and Presque Isle counties the salt area while undoubtedly very large is of unknown extent. Rock salt was struck at Onaway, Grand Lake, and Alpena in great force, and the greatest aggregate thickness of rock salt yet penetrated in Michigan and Ontario is at Onaway, Presque Isle county. A test hole drilled for oil at this place penetrated over 800 feet of rock salt in a distance of 1,200 feet, and the lowest bed was 225 feet in thickness. At Grand Lake over 300 feet of salt were penetrated in a deep well without reaching the bottom of the rock salt formation.

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

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

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

PRODUCTION AND VALUE OF SALT IN MICHIGAN BY COUNTIES IN 1914.

County.	Table and dairy.		Packers.			
			Common fine.		Common coarse.	
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
Bay, Isabella, Mason, Midland	*	*	1,026,419	$277,191	290,328	$82,852
Manistee			*	*	*	*
Saginaw			360,633	175,302	30,795	15,065
St. Clair	837,559	$884,112	687,683	267,402	671,979	257,181
Wayne	204,647	114,729	342,613	61,516	606,800	183,669
Total barrels	1,092,344	$1,025,164	2,668,989	$911,016	2,380,378	$870,715
Tons	152,028		373,659		333,253	

County.	Other grades.		Rock salt.		Brine.	
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
Bay, Isabella, Mason, Midland	*	*			*	*
Manistee	*	*				
Saginaw	*	*			*	*
St. Clair	*	*				
Wayne	*	*	*	*	*	*
Total barrels	34,180	$9,038	*	*	4,816,735	$240,086
Tons	4,785		*	*	674,343	

County.	Total.		Quantity, per cent.	Value, per cent.
	Barrels.	Value.		
Bay, Isabella, Mason, Midland	1,421,617	$388,555	12.18	11.78
Manistee	1,040,634	422,346	8.92	12.80
Saginaw	398,067	191,068	3.40	5.79
St. Clair	2,216,842	1,414,668	19.00	42.88
Wayne	6,593,816	882,368	56.50	26.75
Total barrels	11,670,976	$3,299,005		
Tons	1,633,987			

*Included in total.

CEMENT.

Growth of Industry.

In 1895 less than 1,000,000 barrels of Portland cement were manufactured in the United States, less than quarter of the present production of Michigan, At this date the rotary kiln, burning powdered coal, was successfully introduced and inaugurated the present era of concrete construction. From 1895 to 1907 the growth was phenomenal, nearly 48,000,000 barrels being produced in the latter year. The general financial depression in 1907 caused a temporary check, but the growth was resumed in 1908 and continued until 1913 when over 92,000,000 barrels were made. In 1914, however, there was a decrease of more than 3,865,000 barrels, owing to the unsettled business conditions largely engendered by the present European war.

In Michigan as early as 1878 a vertical kiln plant was erected near Kalamazoo for the manufacture of Portland cement from marl and clay but the enterprise was a failure on account of the high cost of production and the

plant was abandoned in 1882. The Peerless Portland Cement Co. in 1896 erected a vertical kiln plant at Union City, Branch county, and began the successful manufacture of cement from marl and shale. In 1902, however, the old vertical kilns were replaced by modern rotary types. In 1897 the Bronson Portland Cement Co. erected a mill at Bronson, Branch county, and the next year the Coldwater Portland Cement Co., now the Wolverine Portland Cement Co., was formed, a plant being built at Coldwater and later another at Quincy, Branch county.

The "boom" years in Michigan were between 1899 and 1901, twenty companies being organized during this period for the manufacture of cement from marl. Some of the companies made very elaborate plans but never got beyond this stage; only ten ever reached the productive stage and but five of these are now in operation. In all, since 1896, 34 cement plants have been projected or built in Michigan, only eleven of which were in operation in 1914 and one, the Egyptian. Portland Cement Co. at Fenton, Genesee county, was reorganized and the plant rebuilt in preparation for active operations in 1915.

Raw Materials.

In Michigan the principal raw materials for the manufacture of Portland cement are marl and limestone, and clay and shale. Gypsum is also used but in relatively small amounts. Nearly all of the early companies organized planned to utilize marl and clay or shale, but the high cost of driving off the large amount of water contained in marl has caused some of them to change to limestone. At present six of the companies are using marl and clay, and four limestone and shale or clay. According to reports, the reorganized Egyptian Portland Cement Co. at Fenton will use marl and shale.

The following table shows that Michigan produced 4,285,345 barrels of Portland cement in 1914, as against 4,186,236 barrels in 1913. This represents an increase of over 99,109 barrels or 2.36 per cent as compared with an increase of 691,615 or 19.79 per cent in 1913. Shipments increased from 4,081,281 barrels in 1913 to 4,218,429 barrels in 1914, a gain of 137,148 barrels or 3.36 per cent. In both production and shipments the totals were the largest in the history of the industry in Michigan. Owing to lower average prices, however, the value of cement sold decreased from $4,228,879 in 1913 to $4,064,781 in 1914, a loss of $164,098 or 3.88 per cent.

Of the total shipments 2,970,524 barrels were sold in Michigan and 1,314,821 barrels in other states and in Ontario. Of the extra-state shipments 368,722 barrels were shipped to Ohio, 293,923 barrels to Indiana, 273,225 barrels to Minnesota, 235,012 to Wisconsin, 134,588 to Illinois, and the remainder to Kentucky and Ontario.

During the latter part of 1912 and throughout 1913, cement operators enjoyed the highest prices since 1907. This accounts for the great increases in production, shipments, and total value in 1913. In 1914, however, prices were on the average considerably less though the demand was reported nearly equal to that in 1913. The average price per barrel fell from $1.036 in 1913 to $0.964 in 1914, a loss of $0.072 per barrel.

PRODUCTION, VALUE, ETC., OF PORTLAND CEMENT IN MICHIGAN AND UNITED STATES, 1896-1914.

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 common made.	Michigan, Cement shipped. Bbls.	Michigan, Cement shipped. Value.	U. S., Cement shipped. Value.	Michigan, per cent of value.	Michigan, stock on hand Dec. 31. Bbls.	Michigan, average price per barrel.	U. S., average price per barrel.
1896	1	.....	.....	.....	4,000	1,543,023	0.25	.....	.....	$7,000	$2,424,011	0.29	.....	$1.75	$1.57
1897	2	.....	.....	.....	15,000	2,677,775	0.56	275.0	.....	26,250	4,315,891	0.6	.....	1.75	1.61
1898	2	.....	.....	.....	77,000	3,692,284	2.11	413.3	.....	134,750	5,970,778	2.3	.....	1.747	1.62
1899	4	4	.....	.....	343,566	5,652,266	6.1	346.2	.....	513,849	8,674,371	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	35.7	.....	2,134,396	20,804,676	10.2	.....	1.355	1.21
1903	13	3	.....	.....	1,955,183	22,342,073	8.7	23.9	.....	2,674,780	27,713,519	9.7	.....	1.367	1.24
1904	16	4	.....	.....	2,247,160	26,305,881	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	48,785,200	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	76,549,051	4.8	11.7	.....	3,378,040	68,205,800	4.9	.....	0.916	0.891
1911	11	8	96	22,400	3,686,716	78,528,637	4.69	—0.03	.....	3,024,676	66,248,817	4.56	506,758	0.82	0.843
1912	11	8	92	19,450	3,494,621	82,438,096	4.23	—5.21	3,651,094	3,145,001	69,109,800	4.55	370,956	0.861	0.813
1913	11	8	83	19,900	4,186,236	92,097,131	4.21	19.79	4,081,281	4,228,879	88,089,377	4.77	473,563	1.036	1.005
1914	11	7	77	19,100	4,285,345	88,290,170	4.85	2.37	4,218,429	4,064,781	86,437,956	4.70	538,846	0.964	0.927

*Minus sign indicates decrease.

GYPSUM DEPOSITS IN MICHIGAN.

OCCURRENCE AND DEVELOPMENT.

Gypsum in Michigan occurs chiefly in the Michigan Series or Lower Grand Rapids of the Mississippian and in the Lower Monroe and the Salina of the Silurian. The Grand Rapids group immediately underlies the interior coal basin and outcrops at many places in a nearly continuous belt around it. On the southeastern side of the coal basin, the gypsum bearing series is absent or present only locally, either having been removed by erosion or never deposited. The Monroe formation outcrops only in the extreme southeastern portion of the state and in the St. Ignace peninsula and adjacent islands. The Salina does not come to the surface in southern Michigan and has not been certainly differentiated from the Monroe formation in St. Ignace peninsula.

The gypsum deposits of Michigan are all of the massive rock variety. In the Michigan Series gypsum occurs in lenticular beds intercalated in shales and shaly limestones. The beds vary in thickness from a fraction of an inch up to 25 feet or more. Some, particularly the thinner ones are of very local extent, while some of the thicker ones have been traced over areas many square miles in extent. In some localities there are numerous beds of gypsum, in others none. Drillings, however, indicate that gypsum beds are generally present throughout much of the formation, but that within the limits of the coal basin they are largely replaced by anhydrite and are too deep to be of commercial importance at present.

The gypsum rock is generally very pure especially in the thicker beds and it is usually white to reddish in color.

In the Lower Monroe and the Salina of southeastern Michigan the gypsum is largely anhydrite, or anhydrous calcium sulphate and occurs in association with dolomite and rock salt beds. The beds are very numerous and some of them are very thick, thicknesses of over 50 feet

having been reported. The areas in southern Michigan underlain by anhydrite apparently cover thousands of square miles but this mineral has no commercial value at present. Though the beds were gypsum instead of anhydrite, their generally great depth would render them of little value.

The deposits of gypsum have been developed in three areas, the Grand Rapids-Grandville in Kent county, the Alabaster in southeastern Iosco county, and the St. Ignace in Mackinac county, but operations ceased in the last district many years ago. Large but undeveloped deposits are known to occur in western Iosco county, southeastern Ogemaw, and southern Arenac county. Gypsum beds 5 to 30 feet in thickness are reported to occur at comparatively shallow depths at Ionia, Ionia county, and also in Saginaw county. Beds 6 to 12 feet thick were encountered in shallow wells at Bellevue and Eaton Rapids, in Eaton county. The wide spread occurrence of gypsum beds in the Michigan Series is indicated not only by the numerous deposits of gypsum near the margin of the formation but also by the striking of thick beds of gypsum within the limits of the Coal Basin in deep wells at Grayling, Gladwin, Bay City, Midland, Saginaw, Mt. Pleasant, Alma, and St. Johns. These beds are probably too deep for development under present conditions.

The Grand Rapids-Grandville gypsum area, as developed, extends in a belt three or four miles in width along the valley of Grand River from the northern part of Grand Rapids southwest through Grandville and into eastern Ottawa county, a distance of 10 miles or more. Although the productive area extends in a general northeast-southwest direction, the strike of the gypsum bearing rocks in Kent county is northwest-southeast. The valley of the Grand varies in width from one to one and one-fourth miles at Grand Rapids to three or four miles at Grandville, the bluffs along the valley being formed by drift material and rising 100 to 150 feet above the river flats. Exploration and development were naturally confined to the valley and its tributaries where the rock is covered by only a few feet of river silt or sand and gravel. Further exploration along creek valleys to the northwest and to the southeast along the strike of the formation will probably show that the gypsum beds have a much greater extent in these directions than now known. The known productive portion of the Grand Rapids-Grandville area is estimated at about 25 square miles. In the district there are several beds of gypsum of minable thickness, three of which, and probably five, have been developed on a commercial scale. At Grand Rapids, the first bed, six feet in thickness is quarried, the second, a twelve foot bed is both quarried and mined, and the third a 22 foot bed, about 60 feet below the second is mined. The upper bed is absent in many places, having been removed by erosion, and the second is locally very thin, or even entirely wanting, apparently from solution. When the twelve foot bed is mined the six foot bed is generally left for the roof of the mine. The 22-foot bed is divided near the middle by a shale parting one foot or less in thickness. Until a few years ago only the two upper beds at Grand Rapids were worked for it was supposed that water would be very troublesome in mining, but when a shaft was sunk to this bed mining conditions were found to be ideal, the mine entries being perfectly dry.

At Grandville the upper bed is about 11 feet in thickness and is overlain by eight to ten feet or more of gravel and soil. This bed is quarried, the overburden being removed by stripping. The floor of the quarry consists of four feet of hard limestone which rests directly on the second bed of gypsum, 14 feet in thickness, which is mined. These two beds of gypsum may be the equivalent of the 22-foot "split" in west Grand Rapids, the four feet of limestone corresponding to the shale parting. More evidence, however, is needed before definite correlations are warranted.

North of the river near Grand Rapids the mines enter the bluffs at the level of the mills but down an incline. The mines are locally known as "caves." South of the river, near Plaster creek, the bottom of the lowest bed quarried is about ten feet above the river. At Grandville the quarries are about a mile south of the river and but little above it. From their slight elevation above the water the quarries on the river flats have much trouble from water and several quarries have been abandoned from this cause.

The overburden in. the vicinity of the quarries varies from a few feet to more than 20 feet of sand and gravel. Near the Plaster creek quarries surface materials are relatively thin but there is 12 to 15 feet of shale above the six foot bed of gypsum. The heavy cost of removing the overburden and water has caused the gradual abandonment of quarries and the opening of mines.

The Alabaster quarry and mill are located in the southeastern part of Iosco county, six miles south and west of Tawas City, and three-fourths of a mile from the shore of Saginaw Bay. The bed of gypsum is from 18 to 23 feet in thickness, and near the Bay it was covered by five to eight feet of gravel, but farther west the overburden is a tough boulder clay 9 to 14 feet or more in thickness, which is removed by steam shovels. The base of the bed is about 15 feet above the level of the Bay. A large area has been worked out and the face which has been developed in the form of a horse shoe is nearly a mile in length. This is not only the largest quarry In the state but one of the largest in the United States.

The Alabaster bed is known to be of commercial thickness over an area of 25 to 30 square miles in southeastern Iosco county and northwestern Arenac county, but its surface exposure is of limited extent. The bed dips gently to the south-southwest, where it is buried under other strata. In the western part of Iosco county and southern Ogemaw county gypsum outcrops in numerous places or occurs at shallow depths. Drillings north and west of Alabaster show the presence of at least five workable beds below the Alabaster bed, the thickness of the beds ranging from 4 to 22 feet.

In Arenac county in the vicinity of Turner and in the northeastern part of the county a persistent bed of gypsum 50 to 100 feet above the Alabaster bed has been discovered in wells. This is known as the Turner* bed. There are two areas in the county in which this bed is thick enough for mining, one in the vicinity of Turner and the other in the northeastern part of the county. The combined area of the two territories is 20 to 25 square miles, but further exploration will probably increase the m in able area of the Turner bed very greatly.

Gypsum occurs at various places in the St. Ignace peninsula† and on adjacent islands. In 1850 a quarry was opened near Pt. Aux Chenes seven miles west of St. Ignace. A dock was built and gypsum was shipped to mills in Chicago. Owing to various troubles, chief of which were water in the quarry and a scourge of smallpox, the quarry was operated more or less interruptedly for a number of years and finally, when an ice floe carried away the dock, the enterprise was abandoned. Nothing further was done until 1894 when test holes were put down two miles west of the old quarry. According to reports a ledge of gypsum a few feet in thickness was found under light cover and beds totalling 60 feet in aggregate thickness were penetrated by the borings. In a deep well two miles north of St. Ignace some gypsum was struck at 35 feet, 13 feet of gypsum at 174 feet and five feet at 255 feet. Drillings on a bench at the foot of Rabbit's Back Peak, a high limestone spur projecting into the lake four miles north of St. Ignace, showed some gypsum a few feet below the surface, a 21 foot bed at about 30 feet, and a nine foot bed at 57 feet. The surface of the land on which the drillings were made is only 10 to 15 feet above the lake. In some places gypsum was found under only about 14 inches of soil and near the extremity of Rabbit's Back Point a bed outcrops close to the water's edge arid can be seen beneath the water near the shore. Gypsum is found on adjoining tracts of land and at Gross Point four miles farther north. From this point eastward outcrops of gypsum occur along the shore for several miles. On St. Martins Island directly east of Gross Point, gypsum, is struck in shallow wells over a large part of the southern portion of the island and may be seen in the water along the shore. The top ledge, said to be three feet thick, is near the surface, and other beds occur lower down. According to analysis the rock is very pure, containing over 98 per cent of gypsum. Present evidence indicates the presence of seven easily accessible heavy beds of gypsum in St. Ignace peninsula and adjacent islands, but whether or not water would be generally troublesome in quarrying or mining is uncertain. According to Lane there are many signs of gypsum deposits in the northern part of the Beaver Island group in Lake Michigan.

*W. M. Gregory, Geological Rept. Arenac county, Pub. 11., Geol. Ser. 8, pp 54-55.

†G. P. Grimsley, Vol. IX, p. 83, Mich. Geol. Survey.

*HISTORY.**

In 1827 gypsum was discovered on Plaster creek which flows into Grand River in the southwestern part of Grand Rapids and it was first calcined some years later by James Clark who used an old Indian corn mill for grinding the rock and a caldron kettle for calcining. The first mill was built on Plaster creek in 1841 near the crossing of the Grandville road. The machinery consisted of one run of millstones and a thick bottomed two-barrel caldron kettle. Most of the gypsum, however, was ground into land plaster, and 10 years later 60 tons were produced daily. In 1843 gypsum was discovered on the north side of Grand River and in 1849 a mill was built near the site of the present Eagle Mill No. 1 of the Grand Rapids Plaster Co. A second mill, now the Eagle Mill No. 2 of this company, was erected on neighboring property in 1869.

In the early 60's gypsum was discovered south of Grandville, six miles southwest of Grand Rapids, through the overturning of an old tree by high wind, and two mills were built, one in 1873 and the other in 1874. Other mills were built and quarries opened later at various times but owing to the keen competition and faulty methods of calcining many of the ventures were unsuccessful. About 1901 consolidation of the various interests began and at present the seven mines and quarries and eight mills in the Grand Rapids-Grandville district are owned or controlled by four companies.

Gypsum had been discovered by the Indian traders at Alabaster before 1841 but it was not until 1862 that a quarry was opened, supplying small mills at Winona and Bay City, Bay county, and Monroe, Monroe county, with gypsum for the manufacture of land plaster. Later a mill was built and at present this quarry, operated by the U. S. Gypsum Company, is one of the largest in the United States. Another quarry was opened in 1870 about three miles south of Alabaster but trouble with water caused its abandonment.

In 1823 Dr. J. J. Bigsby made the first discovery of gypsum in Michigan on St. Martins Island. In the 50's a gypsum quarry was opened near Pt. Aux Chenes seven miles west of St. Ignace, Mackinac county, and supplied mills at Chicago with gypsum. Water was very troublesome and after a few years, when an ice gorge carried away the dock the quarry was abandoned and no attempt has been made to reopen the quarry since.

*Vol. IX, Pt. II. The Gypsum of Michigan by G. P. Grimsley. Mich. Geol. Surv.

PRODUCTION.

From 1860 to 1890 inclusive the annual production of gypsum in Michigan never reached 75,000 tons. In 1891 the production increased to nearly 98,000 tons and the next year reached 139,557 tons. The industry suffered severely from the general financial depression in the country in 1892-1893 and three years later, in 1895, the production had decreased to only 66,519 tons or less

than half the production of 1892. By 1899 the industry had recovered from the effects of the depression and entered a period of growth and development which continued almost without interruption up to the close of 1913. In 1913 the total quantity of gypsum mined was 423,896 tons, the largest in the history of the industry, but, in 1914, owing to the industrial depression prevailing throughout the United States, there was a marked decrease, the production falling to 393,006 tons, or about 30,000 tons less than in the previous year. The value of gypsum products in 1914, however, was $705,841 or only $15,484 less than in 1913.

From 1868 to 1887 more than half of the gypsum output was ground and sold as land plaster. Since 1887 the grinding of land plaster has become relatively of less and less importance, the production in 1913 and 1914 being respectively only 9,604 and 9,322 tons. The rapid and steady growth of the gypsum industry since 1898 is due largely to the invention of various mixed gypsum wall plasters, plaster board and calcimines and to the increased use of gypsum in the manufacture of Portland cement. The mining and quarrying operations of the gypsum industry have become relatively unimportant in comparison with the manufacturing of gypsum products.

PRODUCTION OF GYPSUM IN MICHIGAN, 1868-1914.

Year.	Ground into land plaster. Tons.	Gypsum calcined into plaster. Tons.	Sold crude. Tons.	Total production. Tons.	Total value.	Rank.	
						Quantity.	Value.
Before 1868	132,043	14,285	.....	146,328	$671,022	.....	.....
1868	28,837	6,244	.....	35,081	165,298	.....	.....
1869	29,996	7,355	.....	37,351	178,824	.....	.....
1870	31,437	8,246	.....	39,683	191,718	.....	.....
1871	41,126	8,694	.....	49,820	234,054	.....	.....
1872	43,536	10,673	.....	54,209	259,524	.....	.....
1873	44,972	14,724	.....	59,696	297,678	.....	.....
1874	39,126	14,723	.....	53,849	274,284	.....	.....
1875	27,019	10,914	.....	37,933	195,386	.....	.....
1876	39,131	11,498	.....	50,629	248,504	.....	.....
1877	40,000	9,819	.....	49,819	238,550	.....	.....
1878	40,000	8,634	.....	48,634	229,070	.....	.....
1879	43,658	9,070	.....	52,728	247,192	.....	.....
1880	49,570	18,929	.....	68,499	349,710	.....	.....
1881	33,178	20,145	.....	53,323	293,872	.....	.....
1882	37,821	24,136	.....	61,957	344,374	.....	.....
1883	40,082	28,410	.....	68,492	377,567	.....	.....
1884	27,888	27,959	.....	55,847	335,382	.....	.....
1885	28,184	25,281	.....	53,465	286,802	.....	.....
1886	29,373	27,370	.....	56,748	308,094	.....	.....
1887	28,794	30,376	.....	59,170	329,392	.....	.....
1888	22,177	35,125	.....	57,302	347,531	.....	.....
1889	19,823	36,800	.....	56,623	353,869	.....	.....
1890	12,714	47,163	15,000	74,877	192,099	.....	.....
1891	15,100	53,600	11,000	97,700	223,725	.....	.....
1892	14,458	77,599	47,500	139,557	306,527	.....	.....
1893	16,263	77,327	31,000	124,590	303,921	.....	.....
1894	11,982	47,976	20,000	79,958	180,620	.....	.....
1895	9,003	51,028	6,488	66,519	174,007	.....	.....
1896	6,582	60,352	700	67,634	146,424	.....	.....
1897	7,193	71,680	16,001	94,874	193,576	.....	.....
1898	13,345	77,852	1,984	93,181	204,310	.....	.....
1899	17,196	88,315	39,266	144,776	283,537	.....	.....
1900	10,354	86,972	33,328	129,654	285,119	2	2
1901	9,808	129,256	46,086	185,150	267,243	1	1
1902	13,022	158,320	68,885	240,227	459,621	1	1
1903	18,409	198,119	52,565	269,093	700,912	1	1
1904	18,294	185,422	34,669	238,385	541,197	1	1
1905	20,285	203,313	24,284	247,882	634,434	1	2
1906	30,220	208,715	27,517	341,716	753,878	1	2
1907	15,500	197,666	36,543	317,261	681,351	3	3
1908	11,414	192,403	40,324	327,810	491,928	1	3
1909	11,890	344,171	45,781	394,907	1,213,347	2	1
1910	7,097	240,905	64,566	357,174	667,199	2	2
1911	15,548	206,299	79,050	347,296	523,926	3	4
1912	10,103	243,656	63,819	384,297	621,547	2	3
1913	9,604	278,368	60,706	423,896	721,325	3	3
1914	9,322	249,648	61,227	393,006	705,841	3	3
Totals	1,232,477	4,185,635	928,289	6,894,576	$18,244,311	.....	.....

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1914.

Year.	Crude gypsum mined.	Gypsum sold crude.							
		To Portland cement mills.		As land plaster.		For other purposes.		Total sold crude	
	Quantity.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Tons.		Tons.		Tons.		Tons.	
1911	347,296	63,489	$69,497	15,548	$15,706	13	852	79,050	$85,255
1912	384,297	53,711	52,420	10,103	9,375	5	50	63,819	61,845
1913	423,896	*	*	9,604	10,222	10,320	9,011	60,706	55,969
1914	393,006	*	*	9,322	10,761	.....	.....	61,227	51,242

Year.	Gypsum sold calcined.									
	As mixed wall plaster.		As plaster of Paris, etc.		As stucco.		As dental plaster.		To plate glass works.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1911	146,920	$381,362	47,989	$88,168	.....	.....	20	$110	11,370	$19,031
1912	146,999	368,676	937	3,229	82,010	$168,734	3	12	6,214	8,678
1913	166,711	437,720	*	*	95,402	202,675	*	*	*	*
1914	163,972	475,638	*	*	83,780	173,172	*	*	.....	.....

*Included in total.

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1914.—*Concluded.*

Year.	Gypsum sold calcined.				Total value.	Kettles in mill.		Daily capacity of mill.	Shifts run by mills during year.		No. mines and quarries.	No. mills.
	For other purposes.		Total sold calcined.									
	Quantity.	Value.	Quantity.	Value.		No.	Size.	24 hrs.	Total No.	Hrs. in shift.		
	Tons.		Tons.					Tons.				
1911	.....	.....	206,299	$488,671	$573,926	20	8 x 10	2,200+	.....	.....	8	8
1912	8,393	$10,973	243,656	559,702	621,547	28	8 x 10	2,140	1,850	11	6	8
1913	9,897	15,850	278,368	665,356	721,325	28	8 x 10	1,785	1,368	11	7	8
1914	1,811	5,433	249,648	654,599	705,841	28	8 x 10	1,860	2,043	11	8	8

CLAY.

The clays of Michigan are of three general classes, viz., (1) morainic or drift clays (2) lake clays and (3) river silts. Deposits of kaolin or china clays are unknown in Michigan and the chances for the occurrence of commercial deposits of such clays appear to be small. Deposits of kaolin have been reported at various places in the Northern Peninsula, but these as far as investigated proved to be white highly calcareous lake clays of the slip variety. The morainic clays—boulder and till clays, are always calcareous, some of them being exceptionally high in lime. The lake clays are generally less calcareous but locally, as in limestone areas, they may contain a large percentage of lime. The river silts are the least calcareous but they are usually gritty. On account of the generally high content of lime most of the clays burn white. In many deposits, however, there is an upper portion relatively free from lime which burns red, and a lower one very high in lime which burns white or cream color. The absence of lime in the upper zone is due to leaching.

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

The morainic or boulder clays have been developed for the manufacture of common brick and tile at many

places in the state but generally on a small scale. The lake clays in the vicinity of West Detroit have been developed very extensively for brick making and more than 82 per cent of the common brick produced in Michigan in 1914 were made in the vicinity of Detroit. Important developments have also been made near Paines and West Saginaw, Saginaw county, and at numerous places in Lenawee, Monroe, and Macomb counties.

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

Most of the surface clays in Michigan are low grade and generally the mining of such clays is merely incidental to the manufacturing of common brick and tile. Nearly all of the clay sold as clay in Michigan is slip clay mined chiefly near Rockland, Ontonagon county, and shipped to potteries in Ohio for glazing purposes. The great distance of the slip clay deposits from ready markets, however, makes development slow and difficult. A small amount of clay is sold for medicinal purposes.

PRODUCTION OF CLAY IN MICHIGAN, 1910-1914.

Year.	Slip clay.		Brick clay.		Miscellaneous clay.		Total.	
	Quantity.	Value.	Quantity.	Value	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1910...	1,363	$3,889	60	$105	1	$400	1,424	$4,394
1911...	1,744	5,090	18	32	2	150	1,764	5,272
1912...	2,034	6,164	.....	.....	9	9	2,043	6,173
1913...	1,710	6,504	.....	.....	.....	.....	1,710	6,504
1914...	1,463	4,572	.....	.....	.....	.....	1,463	4,572
Total..	8,314	$26,219	.....	.....	.....	.....	8,404	$26,915

POTTERY.

From 1899 to 1904 the development of the pottery industry in Michigan was erratic, increasing from $29,741 in 1899 to $83,098 in 1902, and then decreasing to $40,621 in 1904. From the latter year, however, the industry has made a substantial growth every year to 1914 when the production was the largest in its history. In 1909 the total value was $95,439, in 1913 $222,133, and in 1914 $265,194, the value nearly trebling in five years. The production in 1914 represents a gain of $43,061, or 17.8 per cent over that for 1913.

The principal products are red earthenware, chiefly flower pots, and porcelain electrical supplies. Of the five pottery firms three, the Detroit Flower Pot Co., Anton Hupprich of Detroit, and the Ionia Pottery Co, manufacture flower pots almost exclusively. The Jeffery-DeWitt Co., Detroit, manufactures various porcelain products—sanitary ware, insulators, tumbling jars, crucibles, etc., and the Pewabic Pottery & Tile Co., also in Detroit, art tile and miscellaneous ware. A new pottery firm, The Mount Clemens Pottery Co., according to reports, began operation in January, 1915, and will produce decorated ware.

Clays suitable for the manufacture of red earthenware are obtained in Michigan but the clays used for porcelain electrical supplies and white ware are imported from other states or countries.

VALUE OF POTTERY PRODUCTS IN MICHIGAN, 1899-1914.

Year.	Rank of state.	No. firms.	Red earthenware, value.	Porcelain electrical supplies, value.	C. C. ware, value.	Miscellaneous, value.	Total value.	Gain per cent.	Per cent. of total product in U. S.
1899	18	4	$29,641	.....	$100	.....	$29,741	.....	.17
1900	17	4	34,317	.....	.....	.....	34,317	15.4	.17
1901	16	5	42,465	.....	.....	82,400	44,865	30.2	.20
1902	14	4	44,098	.....	.....	39,000	83,098	87.4	.41
1903	19	4	42,007	.....	.....	6,000	48,007	−42.2	.19
1904	17	4	40,621	.....	.....	3,000	43,621	−9.1	.17
1905	17	5	*	.....	*	7,000	45,961	4.5	.16
1906	17	6	43,510	.....	.....	7,600	51,110	11.2	.16
1907	16	6	54,474	.....	.....	7,100	61,574	18.5	.20
1908	16	6	54,650	.....	.....	7,750	62,400	1.5	.25
1909	15	5	60,939	.....	.....	34,500	95,439	52.9	.31
1910	13	6	90,450	*	.....	13,300	112,607	18.1	.33
1911	13	6	80,580	*	*	*	130,490	15.8	.38
1912	10	6	99,555	*	*	*	194,802	49.3	.53
1913	10	5	65,000	*	*	*	222,133	20.8	.59
1914	9	5	106,452	*	*	*	265,194	33.0	.75
Totals	.....	.....	.....	.....	.....	.....	$1,525,548	.....	.....

*Included in the total.

BRICK AND TILE PRODUCTS.

Raw Materials.—Most of the surface clays (see Clay) in Michigan are low grade in character and are of three general classes, (1) morainic or drift clays, (2) lake clays and, (3) river silts. The morainic clays are generally high in lime and also contain sand and pebbles; the content of the latter giving rise to the term boulder clay. The lake clays are generally less calcareous, and likewise the river silts. Owing to the general gritty character or the high lime content, the clays are adapted chiefly for making common brick and tile. Due to their calcareous nature the clays burn cream or white in color. In some deposits however the lime has been removed by leaching to the depth of a few feet, and clay from this surface portion burns red.

Clay or shale deposits suitable for the manufacture of fire, vitrified and front brick, vitrified tile, fire-proofing, and other higher grade products are not abundant. Near Rockland, Ontonagon county, some of the clays belong to the slip varieties and are used for glazing purposes. At Grand Ledge, Jackson, Corunna, and near Bay City and Flushing shales belonging to the Coal Measures have been developed for vitrified and front brick, vitrified tile, sewer pipe, conduits, fire proofing, etc. A project for the development of shale deposits at Williamston for the manufacture of front brick is now under way, and during 1914 a new company, the Baker Clay Products Co., at Grand Ledge built a modern plant equipped with continuous kilns for the manufacture of vitrified products. According to reports the plant is now in operation.

Deposits of shale belonging to the Coldwater occur in the southeastern part of Huron county and in the vicinity of Coldwater, and some of these probably are suitable for making high grade products. The deposits are undeveloped as yet. Some of the shales associated with coal in the mines in Saginaw and Bay counties are apparently adapted for making vitrified products, but these have been exploited only near Bay City. Deposits of soft blue shale in the Traverse formation have been exposed in limestone quarries near Charlevoix and in the vicinity of Rockport, Alpena county, but these have not been developed. Numerous outcrops of these shales are also reported in the central part of Cheboygan county. The black shales of the Antrim exposed in a number of places in Alpena, Cheboygan and Charlevoix counties are probably too bituminous for making high grade clay products.

Production.—In 1914 the value of brick and tile products in Michigan exclusive of pottery was $2,434,872 as compared with $2,451,242 in 1913. This was a decrease of $25,370 or 1.08 per cent from 1913 in spite of the fact that substantial gains were made in the production and value of common and front brick, drain tile, and fire proofing. The chief losses were in the production of vitrified brick and fire brick, and miscellaneous products.

In 1914 Michigan ranked sixth in the number of common brick produced, sixth in value, and tenth in the total value of brick and tile products, exclusive of pottery.

The manufacture of common brick has made a great development in the vicinity of Detroit where suitable lake clays occur in great abundance. In 1914 Michigan produced 269,154,000 common brick of which 222,085,000, or 82.5 per cent were made in Wayne county. Drain tile is next to common brick in importance with a reported value of $421,941, and vitrified brick or block third with a value of $120,562. Sewer pipe is manufactured on a large scale at Grand Ledge and Jackson, but there are only two producers, hence no figures of production and value are given. Grand Ledge is also the chief center in the state for the production of drain tile.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1914.

Year.	Common brick.		Average price per M.	Front brick.		Average price per M.	Vitrified brick.		Average price per M.	Fire brick.		Average price per M.*
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
1899	200,144,000	$933,176	$4 66	4,290,000	$58,920	$13 73	*	*	.....	.....	.....	.....
1900	180,892,000	863,250	4 77	8,421,000	48,411	5 75	*	*	$12 42	.....	.....	.....
1901	215,836,000	1,093,254	5 07	9,476,000	64,031	6 76	*	*	12 30	.....	.....	.....
1902	237,254,000	1,331,752	5 61	5,684,000	42,792	7 53	*	*	12 26	.....	.....	.....
1903	215,791,000	1,251,372	5 80	2,225,000	19,000	8 54	*	*	13 27	.....	.....	.....
1904	205,196,000	1,116,714	5 44	1,080,000	7,500	6 94	*	*	13 28	.....	.....	$13 00
1905	211,558,000	1,152,505	5 45	693,000	5,995	8 65	6,112,000	$81,796	13 37	.....	.....	19 37
1906	206,583,000	1,178,202	5 70	1,474,000	14,162	9 61	6,229,000	81,834	13 13	.....	.....	10 05
1907	200,817,000	1,181,015	5 88	3,956,000	32,116	8 12	7,911,000	94,601	11 96	.....	.....	12 00
1908	181,049,000	994,525	5 49	1,896,000	19,496	10 28	6,165,000	76,630	12 43	.....	.....	.....
1909	219,820,000	1,250,787	5 69	2,379,000	18,654	7 84	10,473,000	129,283	12 34	.....	.....	.....
1910	232,551,000	1,363,310	5 86	2,209,000	27,533	12 46	9,080,000	116,446	12 82	.....	.....	.....
1911	252,466,000	1,301,998	5 16	2,498,000	31,572	12 64	5,597,000	78,336	14 00	.....	.....	.....
1912	271,189,000	1,592,283	5 87	3,934,000	41,476	10 54	6,600,000	92,000	13 94	*	*	18 08
1913	273,571,000	1,626,287	5 94	505,000	5,941	11 76	8,571,000	126,062	14 71	*	*	17 78
1914	269,154,000	1,633,216	6 07	1,488,000	21,121	14 19	7,753,000	120,562	15 59	*	*	16 41
Totals	3,573,870,000	$19,865,852	.....	52,208,000	$458,720	.....	74,471,000	$997,440	.....	.....	.....	19 78

*Concealed, less than three producers.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1914.—*Concluded.*

Year.	Stove linings.	Drain tile.	Sewer pipe.	Fire-proofing.	Tile (not drain.)	Miscellaneous.	Hollow building tile or blocks.	Per cent of total product in U. S.	Rank of state.	No. of firms operating.	Total value.
	Value.	Value.	Value.	Value.	Value.	Value.	Value.				
1899	.....	$140,171	$59,300	$5,900	.....	$22,709	.....	1.68	13	196	$1,254,256
1900	.....	114,747	57,916	2,350	.....	406	.....	1.50	17	180	1,147,378
1901	*	98,972	*	1,880	.....	637	.....	1.71	14	180	1,497,160
1902	*	96,645	*	3,290	.....	.....	.....	1.69	13	182	1,660,942
1903	*	129,028	*	.....	.....	.....	$19,138	1.58	14	174	1,662,414
1904	*	208,088	*	.....	.....	.....	8,080	1.38	14	168	1,670,892
1905	*	205,445	*	*	.....	.....	3,585	1.41	16	154	1,719,746
1906	*	314,008	*	.....	.....	.....	4,290	1.38	16	142	1,793,367
1907	*	289,868	*	.....	.....	1,500	6,386	1.39	17	136	1,786,190
1908	*	327,630	*	4,100	.....	40,100	.....	1.54	16	132	1,666,381
1909	*	364,006	*	*	.....	66,128	.....	1.44	16	122	1,947,059
1910	*	348,205	*	.....	.....	*	.....	1.53	15	118	2,083,525
1911	$3,971	313,072	*	*	*	228,530	*	1.53	15	111	1,953,442
1912	*	387,945	*	1,461	*	235,439	*	1.73	13	101	2,350,606
1913	.....	415,543	*	*	*	350,000	*	1.73	13	95	2,451,242
1914	*	421,941	*	3,752	*	234,280	*	1.88	10	90	2,434,872
Totals	.....	$4,175,404	.....	.....	.....	.....	.....	.....	.....	.....	$29,070,481

*Concealed under miscellaneous; less than three producers.

SAND LIME BRICK.

The first sand-lime brick plant in the United States was started at Michigan City, Indiana, in 1901. The sand-lime brick industry was a "boom" industry and within two years nine plants were projected, building or in operation in Michigan. Under the erroneous impression that sand-lime brick satisfactory for all purposes could be made much more cheaply than ordinary brick, many plants were erected all over the country regardless of markets, transportation facilities, and competition with clay brick. The industry naturally suffered from the many failures consequent.

The sand-lime brick industry is more adapted to regions where good brick clays are absent and sand abundant. In Michigan most of the sand-lime brick plants were started in widely separated localities far from large clay working industries or near large cities which afforded a ready market for a limited output, hence the industry did not experience numerous failures and has maintained a relatively steady growth.

The growth has not been in an increased number of plants but in the average output per plant. In 1904 ten plants were in operation and produced nearly 10,000,000 common brick and 600,000 front and fancy brick valued at $69.765. In 1905 twelve plants were in full operation and the production of common brick increased to 24,844,000 and face brick to 1,577,000 with a total value of $169,302. Since 1905 the number of plants has remained about the same, fluctuating between ten and thirteen, but the production and value have greatly increased, reaching the maximum of 49,373,000 common brick and a total value of $321,245 in 1913. In 1914, however, due to the general business depression throughout the country the production of common brick fell to 41,456,000 and the total value to $255,784. This represents decreases of 7,817,000 in common brick and $65,461 in total value. Of the twelve firms operating in 1914 eight reported decreases in sales and nine poorer to much poorer trade conditions owing to the great decrease in building operations in the state.

The production of front and fancy brick has fluctuated greatly, the former increasing from about 600,000 in 1904 to 2,000,000 in 1907, then decreasing the following year to 900,000 and reaching the maximum of 3,255,000 in 1910. During the last two years less than three companies manufactured front and fancy brick, hence figures have not been given. The evidence indicates that front or fancy sand-lime brick as manufactured are not as satisfactory for general purposes or cannot be produced as cheaply as clay front brick.

ANNUAL PRODUCTION AND VALUE OF SAND-LIME BRICK IN MICHIGAN AND UNITED STATES, 1904-1914.

Year.	No. of operating firms reporting—Mich.	No. of operating firms reporting—U. S.	Michigan production.								Total value Michigan.	Change in per cent—Michigan.	Total value United States.	Per cent of total production of U. S.	Rank.	
			Common brick.		Average price per thousand.	Front brick.		Average price per thousand.	Fancy brick.						Production.	Value.
			Quantity (thousands).	Value.		Quantity (thousands).	Value.		Quantity (thousands).	Value.						
1904	10	57	9,886	$64,034	$6 64	580	$5,234	$9 02	19	$497	$69,765	.....	$463,128	15.6	1	1
1905	12	84	24,841	155,383	6 28	1,577	12,893	8 17	24	526	169,302	142.7	972,064	17.4	1	1
1906	11	87	27,281	162,879	5 97	1,796	12,022	6 69	7	20	174,921	3.3	1,170,065	15.0	1	2
1907	13	94	28,488	158,606	6 22	*2,000	14,234	7 17	.....	.....	172,840	−1.2	1,225,769	14.1	1	1
1908	10	87	21,997	131,827	5 99	*900	6,982	7 76	.....	.....	138,809	−19.7	1,029,699	13.5	1	1
1909	11	74	34,217	207,082	6 05	*1,600	11,144	6 97	.....	.....	218,226	57.2	1,150,580	19.0	1	1
1910	10	76	37,648	218,627	5 81	3,256	22,022	6 76	.....	.....	240,649	10.3	1,169,153	20.5	1	1
1911	10	66	32,889	192,224	5 84	2,726	17,777	6 52	.....	.....	210,001	−12.7	897,664	23.4	1	1
1912	11	71	48,129	307,196	6 38	1,163	9,626	8 27	.....	.....	316,732	50.8	1,200,223	26.4	1	1
1913	12	68	49,373	315,882	6 40	†	†	.....	†	†	321,245	1.7	1,238,325	25.9	1	1
1914	12	62	41,456	248,113	5 98	†	†	.....	†	†	255,784	−24.4	1,098,812	23.5	1	1
Total	.....	.....	353,205	$2,162,263	$6 12	.....	.....	.....	.....	.....	$2,288,274	.....	.....	.....	.....	.....

*Estimated. †Included in total.

Since 1904 Michigan has held first rank in number of plants and total production, and first in value with the exception of 1906 when it was exceeded by New York. For a number of years Michigan has produced nearly or more than twice as many sand-lime brick as any other state. In 1913 twelve plants were in operation as against five each for New York and California, the nearest competitors. In 1914, the number was the same, the Manistee Brick Company which went out of business being compensated for by a new firm, the Fairview Brick Company of Detroit. Two plants are located at Detroit

and one each at Flint, Grand Rapids, Kalamazoo, Menominee, Ripley (Houghton county), Rives Junction (Jackson county), Rochester (Oakland county), Saginaw, Sebewaing (Huron county) and Sibley (Wayne county).

MINERAL AND SPRING WATERS.

The amount and value of mineral and spring waters produced in Michigan are subject to large fluctuations from year to year. The chief factors which influence the production are (1) business conditions and (2) local conditions affecting the quality of the municipal water supplies. The most pronounced decreases in production in Michigan occurred during the general depression in business in 1906 and 1907, and during the past two years there have been large decreases in great part due to poor trade conditions throughout the country. In certain cities the municipal water supplies are unsafe and as a consequence a thriving business of vending mineral and spring waters has grown up in these cities. During the past two or three years the municipal water supply in some cities has been greatly improved in quality through the development of new sources or the installation of filtration plants, as at Marquette and Grand Rapids.

Due to various causes, but largely to the gradual improvement in municipal water supplies, there has been a general though intermittent decrease in the production of mineral and spring waters since 1902, the production falling from 8,653,690 gallons in that year to only 884,893 gallons in 1913 valued at $52,642. In 1914 there was a slight increase, the total output being 931,343 gallons valued at $70,310. In 1914 there were 22 active springs as against 20 in 1913 and 28 in 1902.

PRODUCTION AND VALUE OF MINERAL WATERS IN MICHIGAN, 1900-1914.

Year.	Rank.		No. of springs active.	Total.		Medicinal. Value	Table. Value.	Average price per gal.
	Quantity.	Value.		Quantity. Gals.	Value.			
1900	6	4	28	3,398,996	$411,935	.....	.....	$0.121
1901	2	1	28	7,019,168	1,195,614	.....	.....	0.170
1902	1	9	28	8,653,690	275,763	.....	.....	0.032
1903	1	9	19	6,949,107	200,668	.....	.....	0.029
1904	7	13	19	3,385,675	118,422	.....	.....	0.035
1905	4	4	17	2,684,800	277,188	$38,900	$238,288	0.100
1906	13	23	19	902,528	73,357	.....	.....	0.081
1907	8	15	19	1,472,679	127,133	35,091	92,042	0.086
1908	8	16	24	2,004,433	88,910	5,995	82,915	0.044
1909	5	16	19	2,760,654	104,454	6,099	98,355	0.035
1910	9	17	17	1,454,020	69,538	100	69,438	0.048
1911	11	24	23	1,713,401	72,253	12,156	60,097	0.042
1912	12	19	17	1,420,465	75,611	777	74,834	0.053
1913	17	24	20	884,893	52,642	3,605	49,037	0.059
1914	16	20	22	931,343	70,310	12,252	58,058	0.075
Total	.....	.....	.....	45,605,802	3,213,798	$108,975	$823,064	$0.070

NATURAL GAS.

Natural gas is produced chiefly in southeastern Michigan in Oakland, Macomb, and St. Clair counties, and in Manistee county. In the first two counties the gas occurs at shallow depths in the surface deposits in association with water. Apparently the source of the gas is from the underlying bituminous and petroliferous Devonian formations. The gas usually occurs in small volume and under small pressure, a well generally being sufficient to furnish only a farmhouse or two with heat and light for a few years. The average life of the wells is from six to ten years but some have been known to last 20 years or more; many others, however, play out in a few weeks or months. In Oakland, Macomb and Washtenaw counties some 25 or 30 of such wells are utilized by farmers for domestic purposes. According to reports many of the gas wells in the vicinity of Warren, Macomb county; and Royal Oak, Oakland county, have been declining rapidly in both volume and pressure during the past year.

Around Portage Lake, Manistee County, there are many artesian wells in the drift, which is locally 500 to 600 feet or over in depth. A number of these wells yield gas in association with water and one, the Onekama well, drilled by W. W. Davis in 1913 on the Northern Transportation Co. property near the fish hatchery yielded a large volume of gas at the depth of 437 feet under a pressure of 185 to 190 pounds per square inch. As far as known this well has not been utilized. Some of the other wells yield gas sufficient for heating and lighting a single dwelling and others only enough for a few lights.

At Port Huron many of the oil wells yield in addition to the oil very considerable quantities of gas known as "casing gas." The G. B. Stock wells, owned and operated by the Michigan Development Co., yield more than enough gas for pumping the wells. Some of the Michigan Central Oil & Gas Co. wells, two miles west of North Port Huron, are reported to yield from 20,000 to 40,000 cubic feet of gas per day and the work of laying a pipe line from the wells to Campau, a subdivision on the west side of Port Huron, is under way. At present the gas from two of the nine wells is much more than sufficient to fire the boiler used in drilling and to operate the gas engine for pumping the oil wells. The other wells are capped to prevent the loss of the gas. Some of the wells are reported to develop a rock pressure of over 250 pounds per square inch and when blown for some time, the pressure falls considerably but after closing the valves it requires but little over an hour for the wells to develop the maximum pressure. Recently the G. B. Stock Xylite Grease and Oil Co. drilled three oil wells on the Hoyt and Boyce plats about one-half mile southeast of the Stock wells and all yield gas. One yields a very considerable quantity and the gas from the three wells is more than sufficient for operating purposes.

At the Draper Manufacturing Co. plant in North Port Huron opposite the entrance to St. Clair River a well was drilled in the winter of 1914 for oil and a small flow of oil and gas was struck at 564 feet. The gas is utilized in heating the boiler and, it is stated, furnishes daily heat-equivalent to about 1,200 pounds of coal. The pressure is low, the maximum being only about 45 pounds which can be reduced to only about one pound in a few hours, if the burners are opened to their maximum capacity.

Several other wells in various parts of Port Huron yield small to considerable quantities of gas. Some are utilized for domestic purposes, but others have been abandoned, the gas being allowed to go to waste. In

one or more instances the casings have been pulled and the wells abandoned without plugging. Water is thus allowed to enter the oil bearing rock and sooner or later serious injury must result to the oil field.

The gas and oil occur in the top of the Dundee limestone known locally as the "Lower Lime." The depth to the oil horizon in the Port Huron field ranges from about 500 to 710 feet. In some wells the gas occurs a few feet above the oil horizon, while in other wells the gas appears to be absorbed in the oil.

PRODUCTION OF NATURAL GAS IN MICHIGAN, 1911-1914.

Year.	No. of producers.	Domestic.		Industrial.		Other.		Total.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
		M. cu. ft.		M. cu. ft.		M. cu. ft.		M. cu. ft.	
1911...	22	930	$930	.....	.....	800	$400	1,730	$1,330
1912...	17	.....	1,020	900	$450	.....	.....	900	1,470
1913...	.....	.....	.....	.....	.....	.....	.....	1,805	1,405
1914...	.....	.....	.....	.....	.....	.....	.....	2,442	*1,642
Total...	.....	.....	.....	.....	.....	.....	.....	6,877	$5,847

*Figure subject to revision.

PETROLEUM.

Although oil has been struck in Michigan in small quantities in the vicinity of Port Huron, Allegan, Saginaw, and other places only at the former place have the quantities proved to be of commercial importance. A group of small oil wells have been operated in Port Huron for many years and during the past two or three years a considerable number of new wells have been drilled in various parts of the Port Huron field by different parties in further developing the local oil and gas possibilities.

**PORT HURON FIELD.*

The early explorations for oil and gas in the Port Huron district were the direct results of the discoveries of oil in western Ontario. The Petrolia and Oil Springs fields were discovered in the early 60's. The longer axes of these fields are roughly parrallel and extend in a nearly northwest-southeast direction. A third pool was discovered in 1886 in Euphemia township southeast of the Petrolia and Oil Springs pools and parrellel to their longer axes. A line projected from the Euphemia pool northwest through the Oil Springs pool would pass in the vicinity of Sarnia and Port Huron and upon the supposition that other pools might be discovered along this line, explorations were made in Sarnia and Port Huron. In 1886-87 C. A. Bailey drilled a number of wells in the western part of the city. Small quantities of oil and gas were struck in the Dundee limestone, the top of which was struck at depths ranging from about 540 to 575 feet. The wells were not considered worthy of operation, and were abandoned. In 1887 F. L. Wells put down a test hole 1,685 feet in depth on the bank of Black river opposite Kerns Brewery and near Seventh Street Bridge. Only a show of oil and gas was struck.

No further attempts were made to develop the field until 1898 when G. B. Stock, an operator from the Ontario oil fields, organized the Michigan Development Company and drilled a number of wells in and about Port Huron. Most of the wells were drilled on what is known as the Goodrich property, a tract of about 15 acres in the western part of the city between the Grand Trunk railroad and Howard street. Oil in small but commercially important quantities were struck in all of the wells in the top of the Dundee which occurs in this part of the city at a depth of about 520 feet. At first some of the wells yielded two or three barrels per day, but gradually all of them decreased until the average daily production was only about one-half barrel per well. The decrease in many cases is due to the caving of the "soapstone" or soft calcareous shale of the Traverse formation, immediately overlying the Dundee.

*C. H. Gordon, Ann. Rept. Mich. Geol. Surv. for 1901, pp. 269-281.

With such shallow and cheap drilling the field was considered worthy of further development and new wells* were drilled from time to time until there were some 21 wells on the Goodrich property ranging in depth from about 500 to 650 feet. Owing to caving and other causes, only about 15 of the wells are now in operation. All of the wells in addition to the oil yield more or less gas known as "casing gas" and it is more than sufficient to furnish motive power for a 25-horse power gas engine which pumps the wells.

The energetic example of Mr. Stock and the showings of oil in nearly all of the test wells incited other men to further explorations. A number of wells were drilled at various places in St. Clair county as at Abbottsford and in North Port Huron. Some of the holes were dry but most of them yielded small amounts of oil and gas, comparable in quantity to the Stock wells. About 1907 the Black River Oil & Gas Co. began explorations on the Henry May and Lawrence Gillette farms (Sees. 32 and 33; T. 7 N, R. 17 E.) on the north side of Water Street two miles west of North Port Huron and about two miles north-northwest of the Stock wells. Three or four wells were drilled and according to reports small quantities of both oil and gas were obtained. In 1912-1913 the Black River Oil & Gas Co. leases were taken over by the Michigan Central Oil & Gas Co. and more wells were drilled from time to time until at present there are nine wells on the May and Gillette farms. According to statements of officials of the company, all of the wells yield oil in small quantities varying from one-fourth to three barrels per day, and also very considerable quantities of gas. A number of the wells are said to yield from 20,000 to 40,000 feet of gas per day under a rock pressure varying from 125 to 250 pounds. After the wells have been blown some time the pressure is materially decreased but the maximum is regained in about one and one-quarter hours after the valves are closed.

On account of the small individual production of the wells pumping machinery and tankage were not installed until the spring of 1915. Up to the first of June only three

wells had been put under operation and the total production from these to the above date was about 300 barrels. All of the wells are capped to prevent the escape of the "casing" gas and the supply of gas from two wells is stated to be more than sufficient for firing the boiler used for drilling and in operating a 20 H. P. gas engine for pumping the oil wells. The quantity of gas from all of the wells has been deemed sufficient to warrant utilizing for village purposes and the work of laying a small pipe line is under way to furnish Campau, a small subdivision containing about 300 houses in the western part of Port Huron, with gas for heating.

*For the record of these and other wells in the Port Huron field, see Publication 14, Geological Series 11. The Occurrence of Oil and Gas in Michigan, Chapter III; also Appendix, Ann. Rept, for 1901.

The G. B. Stock Xylite Grease and Oil Co. in 1913 drilled three wells on the Boyce and Hoyt plats in the western part of Port Huron directly east of the Bailey and about one-half mile southeast of the Stock wells. The Boyce well according to statements of the officials of the company made an initial production of six or seven barrels per day but fell off rapidly to about two barrels or less. Of the two Hoyt wells one yields only a little oil but considerable gas and the other the most oil of the three wells. The gas is said to be more than sufficient for operating purposes.

In 1914 the Draper Manufacturing Co. of Port Huron drilled a test well at their plant near the foot of Church street in North Port Huron. In the Draper well some gas was struck in the Dundee limestone at 534 feet and a small quantity of oil at 564 feet. The gas was piped to the boiler and furnishes fuel equivalent to about 1,200 pounds of coal per day. The pressure is low, the maximum being only about 45 pounds and this can be reduced in a few hours to less than one pound if the burners are turned on to full capacity. The yield of oil is estimated at about one-eighth barrel per day. Mr. Thomas Draper, general manager of the company drilled a well on his farm, formerly known as the D. H. Bryce farm on the west side of Black River in the S. W. ¼, Sec. 27, T. 7 N., R. 17 E. The well was on the river flats 500 or 600 feet west of the entrance of the Black River drainage canal. The elevation of the top of the casing was about eight feet above the river or about 590 feet above sea level. According to Mr. Draper the Dundee limestone was struck at the depth of 549 feet or at a slightly lower elevation than in the Draper No. 1 at the plant to the southeast, or in the May and Gillette wells to the west. This indicates the presence of a shallow syncline. No oil or gas was struck though the well reached a depth of 700 feet and probably penetrated completely through the Dundee into the Monroe dolomites below. The Dundee was found to be composed of very hard gray to buff close grained limestone.

A careful log of the Draper No. 1 well was kept and a good set of samples preserved and Mr. Thos. Draper, manager of the company, kindly presented a copy of the record and a nearly complete duplicate set of samples to the Survey from which the following record was compiled:

Draper Mfg. Company Well No. 1.
Port Huron, Mich.

Location: About 50 feet east of the boiler house of the Draper Mfg. Company's plant, located near the foot of Church street. North Port Huron, and 300 feet from and directly opposite the head of St. Clair River. Well began in January and finished February 20, 1914. Record by R. A. Smith from samples and log furnished by Thos. Draper, President of the Draper Mfg. Co.

ELEVATION OF TOP OF CASING 587 FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or surface deposits:		
Sand and coarse gravel, heavily water bearing	40	40
Blue calcareous clay; vig. eff	67	107
Sand and gravel, water bearing	1	108
Antrim shale:		
Brownish black bituminous shale, micaceous and pyritic	52	160
Grayish black bituminous shale, micaceous and pyritic	20	180
Traverse (Hamilton) formation:		
Hard cherty very pyritic, fossiliferous and finely crystalline ("top lime") limestone with "shells". Shells probably chert and seams of pyrite; viol. eff. Atrypa reticularis. Chert nodule at or just above 180 feet	5	185
Soft gray and very calcareous shale or "soapstone." viol. eff	40	225
Hard white and light gray crystalline limestone; viol. eff. Atrypa reticularis	3	228
Limestone (sample missing)	17	245
Hard gray and white crystalline limestone; viol. eff. Atrypa reticularis	15	260
Limestone (sample missing)	15	275
Very calcareous gray shale "soapstone" and gray argillaceous limestone	5	280
Limestone (sample missing)	15	295
Very calcareous gray shale "soapstone" and gray argillaceous limestone	5	300
"Soapstone," very calcareous gray shale (sample missing)	50	350
Very calcareous gray shale, "soapstone"	5	355
"Soapstone," very calcareous gray shale (sample missing)	45	400
Very calcareous gray shale, "soapstone"	5	405
"Soapstone," very calcareous gray shale (sample missing)	5	410
Dary gray argillaceous limestone, pyritic and fossiliferous (Atrypa and corals)	5	415
"Soapstone," calcareous shale (sample missing)	30	445
Very calcareous gray shale, "soapstone;" viol. eff	5	450
"Soapstone," calcareous shale (sample missing)	15	465
Very calcareous gray shale, "soapstone" and hard gray crystalline limestone	5	470
"Soapstone," calcareous shale (sample missing)	25	495
Very calcareous gray shale	5	500
"Soapstone," calcareous shale	11	511
Dundee (Onondaga, Corniferous) limestone:		
Light buff dense-ly crystalline limestone; viol. eff. "Lower Lime"	17	528
Limestone (sample missing). Considerable gas at 534 ft	6	534
Hard light buff dense grained limestone; viol. eff	16	550
Grayish buff dense grained limestone; viol. eff. Oil at 564 ft	18	568
Light grayish buff and white limestone: viol. eff	7–6"	575–6"

"Well shot with two light shots one just above and one just below the oil at 564 feet." Well yields gas equal to 1,200 lbs. of coal in firing the boiler, and about one-eighth barrel of oil per day. Well develops gas pressure of about 45 lbs. upon standing about 12 hours but this is reduced to less than one lb. after the valves of the gas jets have been open for a few hours.

Recently a well was put down by the Reed Wrecking Co. near their dry dock in South Port Huron, a record of which is given below. This well is reported to yield much gas in spite of a heavy flow of water encountered in the top of the Dundee. According to reports attempts were made to case or plug off the water but these were unsuccessful.

Reed Wrecking Company Well.
Port Huron, St. Clair Co.

Location: At Reed's dry dock in South Port Huron, Well completed in July, 1914. Driller's record.

ELEVATION ABOUT 590 (?) FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or glacial drift:		
Clay (12 inch hole)	90	90
Antrim shale:		
Black shale (four and five-eighth inch hole)	90	180
Traverse (Hamilton) formation:		
Soap	21	201
Gray rock	11	212
Soap	8	220
Lime	12	232
Soap	21	253
Hard pan	7	260
Soap	3	263
Hard pan	7	270
Soap	12	282
Lime	7	289
Bell (Marcellus) shale:		
Soap	195	484
Dundee (Onondaga, Coniferous) limestone:		
Hard pan	3	487
Lime (white) "Lower lime" ?	3	490

"At ninety feet struck heavy flow surface gas and fresh water. Water came within 10 feet of surface. At 487 feet struck heavy flow of gas and salt water. We could not exhaust water by pumping, plugged last foot drilled but water still rose 450 feet. I think water is coming in with gas or else is coming from salt block which is about one mile from here. Gas pressure after water came within 50 feet of surface was 159 lbs. Gas was escaping at head. The gas attained a pressure of over 400 lbs. Finished in July, 1914."

Mr. C. M. Van Curen, President of the Michigan Central Oil & Mineral Company (formerly the Michigan Central Oil & Gas Company), kindly furnished the following record which is said to be representative of their wells on the May and Gillette farms.

Gillette Well No. 3.
Port Huron.

Location: Near the west line of the Lawrence Gillette farm about 1,200 feet north of Water Street, about two miles west of Port Huron, in southwest one-fourth of Sec. 33, Port Huron Township (T. 7 N., R. 17 E.), St. Clair Co. Owners, Michigan Central Oil & Mineral Co. (C. M. Van Curen, Pres.; G. W. Van Curen, Mgr.) Record by Mr. Holme, driller.

ELEVATION ABOUT 620 FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or glacial deposits:		
Clay	115	115
Gravel	6	121
Antrim shale:		
Black shale	82	203
Brown soft shale	27	230
Sharp gray rock	5	235
Soap	15	250
Lime (7 feet hard)	10	260
Soap	14	274
Hard pan	6	280
Soap	7	287
Hard pan	3	290
Soap	1	291
Middle lime	25	316
Bell (Marcellus) shale:		
Soap	239	555
Hard pan	7	562
Soft oil rock	15	577
Oil rock harder	23	600
White lime	7	607
Oil rock (hard)	26	633

Several other wells in Port Huron drilled many years ago yield gas sufficient for domestic purposes and some of them have been utilized in this way. A well drilled a number of years ago by G. B. Stock on the G. F. Howe property near Kewahdin Beach in the northwest one-fourth, northeast one-fourth Sec. 22, Fort Gratiot Township north of Port Huron is reported to yield sufficient gas for several families. Gas in association with water was struck in the Traverse formation at the depth of 395 feet. The Dundee occurs at 574 feet or about 20 feet above sea level, or considerable lower than at the Draper No. 1 in North Port Huron or in the May and Gillette wells west of the city.

G. F. Howe Well.
North Port Huron.

Location: On Geo. F. Howe's property near Keewahdin Beach on northwest one-fourth, northeast one-fourth, Sec. 22, Fort Gratiot (T. 7 N., R. 17 E.) Township, St. Clair county. Drilled for oil and gas in 1903 by Wm. May. Record by R. A. Smith from driller's log furnished by Geo. F. Howe in 1915.

ELEVATION APPROXIMATELY 595 FEET A. T.

	Thickness feet.	Depth feet.
Pleistocene or glacial deposits:		
Sand and gravel	14	14
Marl clay	50	64
Sticky blue clay	45	109
Surface gas. Six inch casing, five one-half inch drill.		
Antrim shale:		
Black shale	12	121
Brown shale	8	129
Traverse (Hamilton) formation:		
Brown limestone	65	194
White soapstone	8	202
Black sandstone	4	206
Brown limestone	16	222
Gray limestone	12	234
Soapstone	14	248
Gray limestone	26	274
White limestone	80	354
Soapstone	8	362
Gray limestone	16	378
Soapstone	8	386
Gray limestone	9	395
With gas and water.		
Soapstone	53	448
Gray limestone	13	461
Soapstone	23	484
Five inch casing, four one-half inch drill.		
Gray limestone	20	504
Soapstone	10	514
Brown limestone	8	522
Hard sandy shale	20	542
Dark sandy shale	32	574
Dundee (Onondaga, Coniferous) limestone:		
Brown limestone	7	581
Limestone "oil rock"	21	602

Well shot twice. Well is artesian and yields considerable gas which is utilized for domestic purposes. Pressure estimated at 40 to 50 lbs.

A report on the Port Huron oil field was published by C. H. Gordon in the Annual Report of the Michigan Geological Survey for 1901, and a second in 1911, by R. A. Smith in Publication 14, Geological Series 11. From the well records then available it appeared that a low anticlinal fold crossed St. Clair River from Sarnia through the southern part of Port Huron and then veering to the north-northwest through the western part of the city extended along Black River valley. The Bailey and Stock wells appeared to be near the crest of the anticline.

The more recent explorations by the Michigan Central Oil & Gas Company, now the Michigan Central Oil & Mineral Company, the Draper Manufacturing Co., the G. B. Stock Xylite Grease & Oil Co., and the Reed Wrecking Co. verify the above conclusions. The records of the above and older explorations show that an asymmetrical anticline crosses St. Clair River from Sarnia and, after passing through the southern part of Port Huron, veers toward the north-northwest through the western part of the city in the vicinity of the Bailey, Stock, and May and Gillette wells. The axis of the anticline if projected northward would pass near Gardendale three miles north of the May and Gillette wells. Further explorations by the Michigan Central Oil & Mineral Co. are being made in this direction along the apparent crest of the anticline.

The western limb of the anticline (see fig. 24) is relatively steep, the dip from the Stock wells southwest to the Grand Trunk Junction well being more than 60 feet per mile. The eastern limb, however, is very gentle and extends into a shallow syncline running northeast in the vicinity of the Draper No. 2 and the G. F. Howe wells. The synclinal structure possibly accounts for the

absence of oil in this well but the hard close grained character of the Dundee limestone encountered at this point would also account for this,

The surface deposits in the Port Huron field vary in depth from about 100 to 125 feet, and are chiefly clay with thin beds of sand and gravel which locally yield small quantities of gas. At the Draper Manufacturing Co. plant, however, 40 feet of very coarse gravel and heavily water bearing quicksand was penetrated before reaching the clay.

Directly beneath the drift there is also 80 to 180 feet of black bituminous shale belonging to the Antrim formation. The shale is thinnest along the crest of the anticline and it thickens rapidly to the west, southwest and south as shown by the Fair,* Grand Trunk Junction, and .Port Huron Salt Co. wells. According to Mr. Thos. Draper samples of black shale from the Draper No. 1 well were tested by a refining company at Petrolia, Ontario, and the yield of oil was reported to be about six and one-half gallons per ton. The Antrim shale from the Draper No. 1 well is less black and apparently less bituminous and petroliferous than in the May and Gillette well about three miles west.

The Traverse formation lies directly below the Antrim shale and consists of a series of limestones and soft calcareous blue shales from 270 to 350 feet in thickness, 325 feet being the average for the Stock, and May and Gillette wells. The top of the formation is a limestone known locally as the "Top lime." Near the center there is another well defined limestone horizon, the "Middle lime," and, at the base of the formation there is a heavy blue shale called the "Lower soap-rock." The "Top lime" locally yields considerable quantities of odorless gas. The "Soapstone" while comparatively soft is firm and "stands up" well in drilling but upon exposure to air and water it slacks quickly and caves. Until recently most of the wells have not been cased through the shale and as a consequence caving has ruined some of the wells and interfered greatly with the operation of others. Experience has shown that all wells should be cased through the shale.

*See Publication 14, Geol. Series 11, pp. 56-63. Mich. Geol. Surv.

The Dundee in the Port Huron field is a hard gray to buff bituminous limestone—the "Lower lime" of drillers, and the oil formation. Locally the Dundee is about 125 feet in thickness and the oil is generally struck in the upper 50 or 60 feet. Salt water is nearly always encountered in the lower part of the formation and sometimes very close to the top. The Draper No. 1 and some of the May and Gillette wells yield small quantities of brine along with the oil. According to reports, in the Reed Dry Dock well a heavy flow of brine was struck almost at the top of the Dundee.

The oil occurs in softer and more porous strata but the pores are generally small and scarcely visible to the naked eye. In the Port Huron field the Dundee contains a large amount of bituminous matter and oil, and if more open grained and porous areas could be discovered very probably good flows of oil would be obtained. The gas in some wells is struck a short distance above the oil horizon but in other places it is associated with the oil, apparently being absorbed in it.

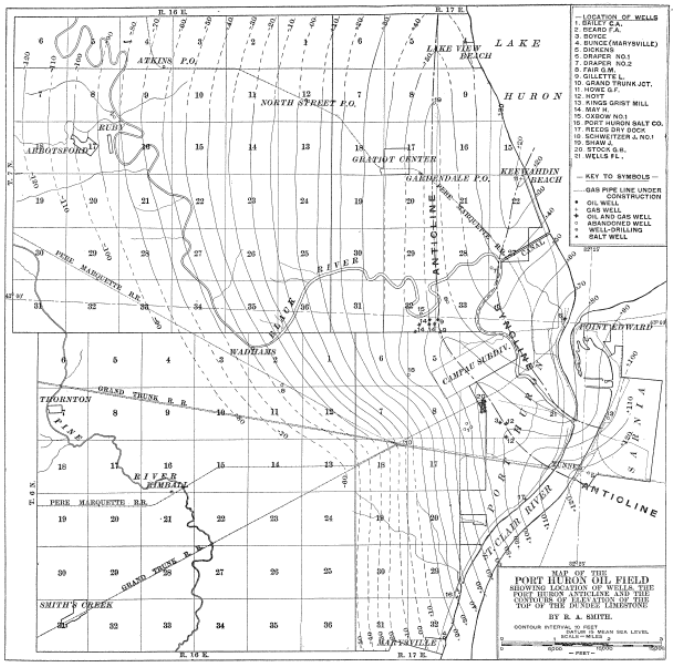

Figure 24. Map of the Port Huron oil field showing location of wells, the Port Huron anticline, and the contours of elevation of the top of the Dundee limestone.

According to Mr. Thos. Draper the oil tests about 34° Baume and is dark green in color and smells strongly of sulphur. It is a natural lubricant and is used by the G. B. Stock Xylite Grease & Oil Co. in the manufacture of a superior grade of lubricants.

Figure 24 is a map showing the contours of elevation for the top of the Dundee and the local structures in the rock strata.

Cadillac.

In 1914 the Cadillac Oil & Gas Co. attempted to test out the oil and gas possibilities of the Trenton at Cadillac. The drift was so thick and so much quicksand and water were struck that the greatest difficulty was experienced in getting down to rock. According to reports rock, a gray sandstone, apparently the Upper Marshall was struck at 795 feet. The enterprise was then abandoned.

If the depth to rock as reported is correct it is the greatest depth of drift yet penetrated in Michigan, 715 feet at Manistee being the greatest depth previously reported.

Dearborn.

At Dearborn, near Detroit, Mr. Henry Ford of the Ford Motor Co. of Detroit is drilling a very deep well for scientific purposes. Actual drilling began June 14, 1915, and by October 18 a depth of over 4,035 feet had been reached. The boring was started with a 14 inch casing

and according to reports it is planned to drill to the depth of 5,000 feet or more, if possible. A careful log is being kept and samples taken at every five feet. This well when completed will furnish definite information as to the character, thickness and depth of the various rock formations, and the location of the wetter, brine, salt, gas, oil and other mineral horizons down to the pre-Cambrian rocks which should, however, be struck at a depth considerably less than 5,000 feet.

QUARTZ.

Vein quartz is mined near Ishpeming by the Michigan Quartz Silica Company of Milwaukee and ground chiefly for wood filler and paint. Some of the ground product is used in making polishes. The quartz rock is practically pure silica with only a trace of impurities and a little moisture. The mills are located at Ishpeming and Milwaukee.

MINERAL PAINTS.

Soft iron ore is mined in Iron county and sold by Pickands Mather Company of Cleveland for the manufacture of paint. The Acme White Lead & Color Company of Detroit manufactures a large amount and a variety of mineral paints but the two firms given above are the only producers, hence statistics of production and value are not given.

RELATIVE TO POSSIBLE POTASH DEPOSITS IN MICHIGAN.

For the past fifteen years Prof. A. W. Grabau of the department of geology of Columbia University, who is one of the foremost geologists and paleontologists in America, has been making a study of the Devonian and Silurian formations in Michigan. In 1900 Dr. Grabau began his work on the Traverse (Hamilton-Marcellus) formation of Michigan and the following year published the results of his investigations in the Annual Report of the Geological Survey of Michigan for 1901. In 1909 he and Dr. W. H. Sherzer published a joint report on the Monroe Formation, the Upper Silurian of Michigan. Since that date Dr. Grabau has been actively engaged in studying the Dundee (Onondaga) limestone and has a manuscript of nearly 600 pages on the Devonian formations of Michigan practically ready for the printer.

As a result of his long study of the Devonian and Silurian formations Dr. Grabau has concluded that there is a strong possibility that the Salina or Middle Silurian, the rock salt bearing formation, may contain potash bearing salts. Recently he communicated his belief in this possibility in a letter to R. C. Allen, State Geologist, from which the following is an excerpt:

"The present is a good time for the discovery of potash salts in Michigan. As I read the Silurian history, the lowest salt beds under Detroit ought to carry the potash salts similar to those found at Stassfurt the history being the same. This is true only for the lowest bed. If that does not contain it, then there is no potash in the deposits in the East [i. e. east of the Rocky Mountains]. I believe it is really worth making a test of this bed."

Potash salts are most extensively used in the United States in the manufacture of fertilizers, glass, soaps, explosives, bleaching powder, dyestuffs and chemicals, and certain industries, notably the fertilizer industry, are vitally dependent upon these salts. The fertilizer and chemical industries have grown to enormous magnitude, yet they are dependent upon foreign sources for their supply of potash salts. Nearly all of the potash used in America is imported from Stassfurt, Germany, where potash salts occur in association with enormous deposits of rock salt. The present European war has cut off this supply and many fertilizer and chemical manufacturers have had to close or to curtail their output for want of raw material.

The importance of a reliable source of potash salts has become so great as to engage the attention of Congress, which in 1911 made specific appropriations to the United States Geological Survey for "determining the geological conditions favorable to the presence of potash salts" and to the Bureau of Soils for determining "a possible source of supply of potash, nitrates and other natural fertilizers." An examination of all of the brine and salt deposits was made but without success. A geologic study of ancient lake beds in the Great Basin was begun upon the theory that the salts contained in the waters of these lakes must have been deposited in their deepest portions, when the lakes were completely evaporated. By the close of 1913 seven test holes totalling more than 10,000 feet had been drilled in the ancient lake basins of Nevada without finding noteworthy traces of the coveted salts. A deposit of alunite, a potash bearing mineral, was discovered in Utah, but the amount of this substance available is relatively unimportant, being sufficient to furnish only a small fraction of the amount needed annually.

In southeastern Michigan from St. Clair to Monroe county and in western Ontario there are enormous deposits of rock salt. Several thousand square miles are known to be underlain with rock salt beds, which in the Detroit-St. Clair river area have an average aggregate thickness of nearly 400 feet. Rock salt is also known to occur in Manistee and Mason and in Alpena and Presque Isle counties. In the first two counties the salt beds have a total thickness of only about 40 feet but in the latter two the rock salt beds have their greatest known thickness, over 800 feet of rock salt having been penetrated in a deep well at Onaway, Presque Isle County. In southeastern Michigan the depth to the first salt beds varies from about 750 feet at Detroit to 1,500 or 1,600 feet at Port Huron, in Manistee and Mason counties, 1,975 to'2,300 feet, and in Alpena and Presque Isle counties, 1,000 to 1,630 feet. From geological considerations it is more than probable that the three known rock salt areas noted above are but parts of one great rock salt area, covering most of the northern and

eastern portions of the Southern Peninsula and western Ontario.

The beds of rock salt vary in thickness from a few inches to over 350 feet but the heaviest bed occurs near the bottom of the series and it is this bed which Dr. Grabau considers as a possible source of potash salts. The depth to this bed in Oakwood, a suburb of west Detroit, is 1,437 feet, at Wyandotte, about 1,100 feet; at Delray, 1,365 feet; at Fort Wayne, 1,445 feet; and at Royal Oak, 2,200 feet.

While the chances for finding potash in the salt beds of Michigan are apparently small, the great rewards for the successful explorer makes the proposition worthy of serious consideration, particularly in the light of Prof. Grabau's investigations and conclusions.

SUMMARY TABLE OF THE PRODUCTION AND VALUE OF MINERAL PRODUCTS IN MICHIGAN, 1910-1914.

	1910.		1911.		1912.		1913.		1914.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Brick and tile products, number of brick	244,403,000	$2,083,525	260,560,000	$1,953,442	281,741,000	$2,350,606	282,664,000	$2,451,242	278,384,000	$2,434,872
Brick, sand-lime, number of brick	.....	240,649	35,615,000	210,001	49,292,000	316,732	50,065,000	321,245	42,465,000	235,784
Bromine	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Calcium chloride	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Cement, Portland; bbls. made, value cement shipped	3,687,719	3,378,940	3,686,716	3,024,676	3,651,094	3,145,001	4,081,281	4,228,879	4,218,429	4,064,781
Clay, tons	.....	8,394	2,202	5,437	2,043	6,173	1,710	6,504	1,463	4,572
Coal, tons	1,534,067	2,930,771	1,476,074	2,791,461	1,906,690	2,906,837	1,231,796	2,455,227	.....	.....
Copper, lbs	221,462,984	28,125,799	218,185,836	27,373,155	219,138,408	35,992,837	183,853,409	28,442,806	158,009,748	21,426,122
Graphite	.....	(a)	.....	(a)	.....	(a)	.....	.....	.....	.....
Grindstones, tons	.....	(a)	.....	(a)	.....	(a)	.....	(a)	.....	(a)
Gypsum and gypsum products, tons mined	357,174	668,201	347,206	573,926	384,297	621,547	423,896	721,325	393,006	705,841
*Iron ore, long tons	13,305,006	41,393,585	8,944,393	29,806,353	12,649,296	29,003,163	12,677,466	31,947,214	8,835,274	19,965,658
Iron, pig; long tons made; value pig iron shipped	307,975	(b)5,119,074	304,654	(b) 4,672,799	459,975	(b)6,579,048	447,188	(b) 6,568,920	379,619	(b) 5,229,948
Lime, tons made	72,345	303,377	80,709	352,608	74,720	311,448	77,088	331,852	66,507	287,648
Limestone	.....	842,126	.....	1,001,535	.....	1,130,560	.....	1,408,708	.....	1,457,061
Mineral paints	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Mineral and spring waters, gallons	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Natural gas, M. cu. ft	1,454,020	69,538	1,713,401	72,253	1,420,465	75,611	884,893	52,642	931,343	70,310
Petroleum	.....	820	.....	1,330	900	1,470	1,803	1,405	2,442	1,642
Pottery	.....	50	.....	(a)	.....	(a)	.....	(a)	.....	(a)
	.....	112,697	.....	130,400	.....	194,892	.....	222,883	.....	265,194
Precious stones	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Quartz	.....	(a)	.....	(a)	.....	(a)	.....	(a)	.....	(a)
†Salt, bbls	9,452,022	2,231,262	10,320,074	2,633,155	10,946,730	2,974,429	11,528,800	3,203,032	11,679,026	3,299,065
Sand and gravel, tons	2,862,738	816,337	2,185,165	565,969	2,681,821	818,603	6,424,168	1,529,142	3,647,796	1,118,978
Sandstone	.....	31,233	.....	72,985	.....	.....	.....	.....	.....	.....
Silver, fine oz. Troy	262,200	141,000	507,700	274,100	528,453	16,438	265,173	19,224	418,500	(a)
Trap rock	.....	.....	.....	51,000	.....	324,099	.....	178,284	.....	228,695
Miscellaneous	.....	278,442	.....	161,030	.....	36,200	.....	92,201	.....	34,406
	.....	.....	.....	.....	.....	522,141	.....	540,626	.....	565,147
Total	.....	$80,581,377	.....	$65,077,232	.....	$79,931,757	.....	$77,860,192	.....	$55,185,986

*Figures from Iron Trade Review.
†Exclusive of bromine and calcium chloride.
(a)Included under miscellaneous
(b)Excluded from total, covered by iron ore.

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