STATE OF MICHIGAN
MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

Publication 12. Geological Series 9.
GEOLOGICAL REPORT ON WAYNE COUNTY

BY
W. H. SHERZER.

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF GEOLOGICAL SURVEY FOR 1911.

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1913

Contents

List of Illustrations

Plates

Figures

CHAPTER VI. HARD-ROCK GEOLOGY.

MISSISSIPPIAN SYSTEM.

With the progress of geological knowledge in the United States it has been ascertained that the long recognized, but poorly named *Carboniferous* system, consists of three distinct groups of strata, These have been variously known as:

1. Subcarboniferous, Mountain limestone. Carboniferous limestone, Early or Lower Carboniferous, Mississippian.

2. Carboniferous proper, Upper Carboniferous, Coal Measures, Pennsylvanian.

3. Permian, Upper Barren Coal Measures.

The term "Subcarboniferous" was first used by David Dale Owen in 1838 for an extensive series of sandstones, shales and limestones lying below the Coal Measures, but including also Devonian and Silurian strata.[1] The term was soon restricted to include those strata only of later age than the Devonian and constituting the base of the Carboniferous series. As thus restricted, it was known to have a wide distribution in North America, attaining its maximum thickness in the Appalachians but also well developed in the Mississippi region where it consists largely of limestones. The term *Mississippian* was proposed for the formation by Williams in 1891[2] and has come into quite general use in the more recent literature. This is a slight modification in form and usage of the terms proposed by Alexander Winchell, some 12 years earlier, the "Mississippi limestone series or Mississippi group."[3] In their recent Geology (vol. II, 1906, page 508) Chamberin and Salisbury proposed advancing the Mississippian to the rank of a distinct system, coördinate with Devonian, Silurian, etc., and thus separating it from the Coal Measures or Pennsylvanian.

Within the limits of the state of Michigan the Mississippian comprises four sets of strata, which in ascending order are,

1. Berea sandstone.

2. Coldwater shales.

3. Marshall sandstone.

4. Grand Rapids group; dolomite, limestone, shale and gypsum. Of these only the first two, or lowest, cross the county of Wayne and hence fall strictly within the limits of this report. They are, however, under a heavy burden of drift and are only very imperfectly known from well borings.

Coldwater shales. Where exposed in Branch and Hillsdale counties the Coldwater shales (from their good exposures along Coldwater River)[4] are seen to consist of light colored, thin-bedded, shales, with occasional bands of limestone, becoming sandy towards the top as they pass into the overlying Marshall. Occasionally there occur irregular nodules of brownish, kidney iron ore, often mistaken by drillers for limestone or sandstone.

These shales have been utilized in Branch County in the manufacture of Portland cement and numerous analyses have been made. The following table shows their range in composition in the vicinity of Coldwater.[5]

TABLE XXVIII.—ANALYSES OF COLDWATER SHALE, NEAR COLDWATER, MICHIGAN.

(Analyst H. E. Brown).

Silica, (SiO_2)	57.26 to 61.25%
Alumina, (Al_2O_3)	18.12 to 21.59%
Ferric oxide, (Fe_2O_3)	6.53 to 8.30%
Calcium oxide, (CaO)	1.25 to 1.50%
Magnesium oxide, (MgO)	1.49 to 2.31%
Sulphuric anhydride, (SO_3)	.65 to 1.34%
Carbon dioxide, (CO_2)	.95 to 1.18%
Titanium oxide, (TiO_2)	.82 to 1.12%
Alkalies, (Na_2O and K_2O)	2.25 to 3.45%
Loss on ignition (H_2O and organic matter)	6.19 to 8.32%

According to Lane, the minimum thickness in the state is 600 feet, giving a broad exposure beneath the drift from Hillsdale and Lenawee counties northeastward to Lake

Huron, crossing the northwestern corner of Wayne. Upon the Lake Huron shore, good exposures of the shale occur at White Rock Point and Forestville, Sanilac and Huron counties. As in the case of all the strata to be described the *dip* of the formation is to the northwestward, giving a northeast-southwest *strike*. Were the drift completely removed from the Southern Peninsula, the outcropping edges of the strata would be seen encircling the central (Saginaw) basin, dipping towards and under it suggestive of a nest of wooden butter-bowls. The younger and geologically higher formations are hence found toward the northwest, the older and geologically lower toward the southeast. Originally the entire series was approximately horizontal and seems to have been deformed about the close of the Palaeozoic era by the pronounced subsidence of the Saginaw area. Within the limits of Wayne County, there are no well sections that penetrate the Coldwater series from which the thickness could be determined. In the village of Plymouth, a 280-foot well (Alfred X. Brown, driller) showed 25 feet of gray shale at a depth of 100 feet of drift. A stratum of sandrock yielded a flow of fresh water which rose to within two feet of the surface. Beneath was reported 10 feet of excessively hard "conglomerate rock" and in to 20 feet of sandstone, underlain by limestone. About one mile west upon the place of Dwight Berdan (NW. ¼ SW. ¼ sec. 27), a light flagstone was entered six inches at a depth of 122.5 feet. The Plymouth record would indicate that we are there near the eastern margin of the series of lighter colored shales. Toward the northwest, more of them should be encountered just beneath the drift and less and less to the southeastward, until they give out completely. In the deep wells of Ypsilanti and Ann Arbor, we have more complete data relative to the geological series of the county. Four of these records are here reproduced from the Ann Arbor Folio (1908, page 3).

TABLE XXIX.—SECTION OF CORNWELL WELL, YPSILANTI.

On flood plain of Huron. Elevation of mouth about 680 feet.	Thickness in feet.	Total depth in feet.
Earth, clay, gravel, sand, etc., unconsolidated	109	109
"Slate" (probably shale)	241	350
"Flint"	5	355
Sandstone	38	393
Soft "slate" or sandstone (sandy shale)	157	550
"Bedrock" (hard limestone?)	200	750

TABLE XXX.—SECTION OF ATLANTIS WELL, YPSILANTI.

(From manuscript notes by Alexander Winchell.)

Near Normal College Campus. Surface elevation about 785 feet.	Thickness in feet.	Total depth in feet.
Sand, clay, gravel, etc., unconsolidated	185	185
Shale, soft	4	189
Sandstone, fine, slightly calcareous	10	199
Limestone, fine; all dissolves in acid	10	209
Shale, dun, dark; lower 74 feet black	84	293
Shale, sandy, dun	64	357
Sandstone, very fine, slightly calcareous; yields bromine water	4	361
Limestone, pale, cherty	10	371
Shale, sandy	5	376
Limestone, ranging from pale and cherty to dun and sparry	43	419
Shale, bluish to dun, in places gritty	22	441
Limestone, varying from siliceous to pure	24	465
Shale	21	486
Limestone, varying from pale to dun, with some shaly partings, portions magnesian, others siliceous; contains sulphurous (H_2S) water	138	624
Unrecorded	184	808

TABLE XXXI.—SECTION OF COURT HOUSE WELL, ANN ARBOR.

(Record of Dr. Carl Rominger.)

Surface elevation 835 feet.	Thickness in feet.	Total depth in feet.
Soil, gravel, clay, etc., (glacial deposits)	155	155
(According to Winchell thickness of drift is 164 feet.)		
Shale, blue, arenaceous, with seams of fine-grained sandstone	150	305
Shale, black, bituminous, with gas and drops of oil	28	333
Sandstone, gray, with brine	92	425
Shale, blue, with sandstone layers, and seams of pyrite	100	525
Shale, black, very bituminous, with pyrite	85	610
Shale, dark blue, arenaceous, with pyrite, traces of fossils	22	632
Shale, black, bituminous, with pyrite	68	700
Limestone, bluish, cherty	70	770

TABLE XXXII.—SECTION OF CAMPUS WELL, UNIVERSITY OF MICHIGAN, ANN ARBOR.

(Record by Dr. A. C. Lane, based upon drillings.)

Surface elevation 880 feet.	Thickness in feet.	Total depth in feet.
Quaternary:		
Coarse, cross-bedded sand and gravel	90	90
Blue, boulder clay	145	235
Coldwater shale:		
Blue shale	30	265
Pinkish shale	15	280
Fine gray, sandy shale	75	355
Fine soft, gray and black shale	20	375
Fine gray, sandy shale	10	385
Fine bluish shale	15	400
Berea sandstone:		
Fine gray sandstone	15	415
Fine sandy shale	25	440
Glossy black shale	5	445
Fine gray, sandy shale	75	520
(Salt water at 515 feet.)		
Antrim shale:		
Fine black and greenish shale	10	530
Fine gray, sandy shale	15	545
Very fine, black shale	15	560
Black, bituminous shale	15	575
Coarse, gray sandstone	5	580
Black, sandy shale	20	600
Black, bituminous shale	80	680
Traverse formation:		
Shale with pyrites	5	685
Gray, calcareous shale	60	745
Dundee limestone:		
Gray, cherty limestone	25	770
Light-gray limestone	30	800
Gray, argillaceous limestone	130	930
Monroe formation:		
Light-gray dolomite	40	970
Gray dolomite containing sand	60	1,030
Light-gray dolomite with Sylvania sand grains	205	1,235
Pure white friable sand (Sylvania)	35+	....

Well stopped at 1,326 feet in the Sylvania.

The most satisfactory record of the series is that of the University well drilled in 1899-1900, the drillings of which were examined by Lane, then state geologist, with a detailed knowledge of the various formations obtained from a study of the rocks in outcrop. This record assigns 165 feet to the Coldwater and shows that it is composed of pinkish, bluish, gray to black shale; in places somewhat sandy. The Court House well gives 178 feet of shale, above the sandrock, which appears referable to the Coldwater. In passing southeastward to the Cornwell well in Ypsilanti, some 7½, miles, the rock surface drops 74 feet, but there still remain some 241 feet which are to be considered as belonging to this same formation. In the Atlantis well and that of the Banner Oil and Gas Company, the sandstone stratum, marking the base of the Coldwater series, is not recognizable with certainty. Lithologically this formation is very similar to the Cuyahoga formation of Ohio, named by Newberry in 1870,[6] and as restricted by Orton[7] and later by Prosser[8] is very nearly its geological equivalent. The Berea shale, or Sunbury shale, however, is separated from the Cuyahoga in Ohio while it is intended to be included in the Coldwater of Michigan.[9] Lane in his latest discussion of the formation (1909) makes it the equivalent of the Sunbury, Cuyahoga, Buena Vista and Raccoon, of the Ohio series, and the lithological equivalent of the Portage and Chemung of New York.

Berea sandstone. This formation was originally defined by Lane[10] as the Richmondville sandstone and was regarded as the geological equivalent of the Berea grit of the Ohio series. Since then, however, he concluded that the "Richmondville" is not the exact equivalent of the Berea "but a stray sandstone somewhat 'higher up."[11] It constitutes the base of the Coldwater series ah though the two can not always be separated with certainty in the well records because of the frequent occurrence of sandstone strata in the Coldwater. In southeastern Michigan, the formation is a coarse, gray sandstone, 100 or more feet in thickness. Farther north in Huron County and at Tawas and Oscoda this sandrock supplies brine and in Wayne County what appears to be the course of the formation is marked by a belt of brackish to salty wells, some of them so heavily charged as to be unfit for use. The records of the character of the rock encountered by the farmers, in the comparatively few wells available, are so incomplete and often conflicting that the stratum can be traced only with difficulty. It lies in Wayne County under a cover of 50 to 100 feet of drift and is seldom penetrated or entered to any considerable depth. In the Ann Arbor Court House well, Rominger identified 92 feet of coarse, gray sandstone, charged with brine, as the correlative of the Berea and suggested that the overlying 28 feet of black, bituminous shale would correspond with the shales found in Ohio above the Berea.[12] These have been known variously as the Waverly black slate, Berea shale and Sunbury shale.[13] In the Campus well. Lane includes under "Berea sandstone" 15 feet of fine, gray sandstone and 115 feet of more or less sandy shale, above which are recognized 45 feet of dark shale with the suggestion that this may represent the Sunbury. The not infrequent references to black shale and "slate" in the townships of Canton, Nankin, Livonia and Bedford suggest strongly that this stratum extends across Wayne County also, although it is difficult to distinguish between it and the Antrim shale, beneath the Berea. The record of the deep well at Pontiac, 11 miles north of the Oakland—Wayfie county line, shows the rather surprising thickness of 273 feet (depth 535 to 808 feet), for the Berea sandstone,[14] above which lie 35 feet of "dark brown argillaceous shale," constituting the base of the Coldwater and the probable correlative of the Sunbury.

DEVONIAN SYSTEM.

Antrim shale. Beneath the Berea sandstone in southeastern Michigan, there lies a characteristic black shale formation, 150 to 275 feet in thickness,[15] which has been variously designated in the Michigan and Ohio Survey reports. In the Houghton survey, it was referred to as the "black strata", "black bituminous shale", "black aluminous slate". By Winchell, it constituted the main member of his "Huron Group" and was regarded as the correlative of the Genesee shale of New York. Newberry in 1871 applied the name "Huron shale" to the formation which up to that time in Ohio had been known as the "black slate," and this name is still retained in the latest Ohio bulletins. Rominger described the formation under the name "black shales of Ohio." Lane applied the name "St. Clair shales" in 1893[16] and, finding this name preoccupied for a Silurian limestone in Arkansas, in 1901 changed the name to "Antrim shales" from their typical exposure in that county.[17] The early names are suggestive of the black, bituminous character of the shale, so much organic matter often being present as to permit of their burning and to their being mistaken for coal.[18] An analysis of Antrim shale of Charlevoix County was made to test its possible fuel value and is given by Ries.[19] Although they do not ordinarily support combustion, beach fires on the shore of Sulphur Island, Thunder Bay, are said to have burned for many months. Upon the shores of this island these shales are black, very fissile, crisp and sharp, approaching slate when unweathered. They are finely laminated and very evenly bedded. Exposed to the weather they assume a gray, or rusty brown color, from the oxidation of the iron. Crystals of pyrite and nodules of marcasite are of common occurrence in these shales, which, upon suffering decomposition stain the shales with iron oxides and sulphur and impregnate the percolating waters. Spherical to ellipsoidal calcareous concretions, varying in. size from an inch to six feet in diameter, are found embedded in the shale. Toward the center of these there sometimes occur fragments of organic remains and crystals of calcite and siderite. It was from such concretions in this same formation that the remarkable fish remains of Ohio were obtained by Rev. H. Hertzer and later described by Newberry (see reference below, page 157). Concretions similar to those in Michigan have been described by Daly from Kettle Point; Ontario, where the same formation is exposed by the waves. This author calls attention to the deformation of the shale on all sides of each concretion and concludes that they were formed *in situ* that they antedate the period of joint development and final consolidation of the shale and that the deformation resulted from the change in volume when the original calcium bicarbonate was converted into the monocarbonate.[20]

TABLE XXXIII.—ANALYSIS OF ANTRIM SHALE, CHARLEVOIX COUNTY.

(Analyst W. H. Johnson.)

Volatile matter	17.96
Fixed carbon	6.49
Ash	75.55
Total	100.00

Analysis of ash.

Silica, (SiO_2)	70.54
Alumina, (Al_2O_3)	15.33
Ferric oxide, (Fe_2O_3)	5.31
Calcium oxide, (CaO)	2.38
Magnesium oxide, (MgO)	.78
Alkalies, etc., by difference	5.66
Total	100.00

Not infrequently these shales appear to be impregnated with oil, have a strong bituminous odor and have given off considerable quantities of "natural gas." When allowed to accumulate under a suitable cover of clay, "pockets" of such gas, under very great pressure, have occasionally been struck in well boring. It is likely that by entering the bed sufficiently more or less gas could always be procured which could be utilized in the homes situated over the formation, but the expectation can not be realized that any considerable flow can be long maintained. New wells could be drilled, or the former ones deepened when the supply ceased. The bituminous constituent in the shale is due very largely to the presence of enormous numbers of minute disc-like bodies, with relatively thick carbonaceous walls. These were discovered by Dawson in the shales of Kettle Point, Lake Huron, and described by him in 1871, under the name *Sporangites Huronensis*.[21] Remains of *Calamites* and *Lepidodendron* were found in association by Damson and he regarded them as spore cases belonging to the latter type of tree. From material derived from Brazil two additional species of *Sporangites* were described in 1888 (*S. Braziliensis* and *S. bilobatus*) and the similarity noted to the macrospores of the boating fern of European rivers, Sylvania natans.[22] The generic name *Protosalvinia* was suggested to cover the former *Sporangites* which he then regarded as macrospores with their envelopes lost. Clarke found them abundant also in the Marcellus shale of Ontario County, New York,[23] associated with immense numbers of still smaller sub-spherical bodies which he regarded as the *microspores*. Newberry, as early as 1873, had called attention to the difficulty of conceiving of such widespread shallow water conditions, capable of furnishing the necessary shore vegetation, but with the evidence of the proximity of the shore so completely wanting.[24] He concluded his discussion as follows: "Waiting the demonstrative solution of the problem, which patient and exhaustive study will doubtless sometime furnish, I offer, as a possible explanation of the peculiar features of the Huron shale, the suggestion that its carbon was derived from vegetation which lined the shores and covered the surface of a quiet and almost land-surrounded sea."

Aside from the fossils above referred to, which are not serviceable for correlating these shales with the New York series, there is little help that palæontology can render. They rest upon undoubted Hamilton and are lithologically identical with the Genesee shales of central New York. They have been so referred by Winchell, Rominger, Newberry, Whiteaves and Orton. Lane made the Antrim the equivalent of both the Bedford and Ohio shales in Ohio and these he correlated with the Tully, Genesee and Portage of New York. In the report of 1908, Lane places the shales "somewhat later" than the Genesee, based upon the evidence of a Naples fauna at the base, bringing them into the Portage of the New York scale.

Although known that the general dip of the stratum is toward the northwest, sufficient data are not available for the determination of the amount of such dip. Since these shales so nearly conform with those underlying, it may be assumed that the dip is practically the same as that of the Dundee and Upper Monroe and amounts to about 25 feet to the mile. Comparing the Ann Arbor Campus well with that at Pontiac, it is noted that the base of the Antrim at the latter place is 231 feet lower than at Ann Arbor giving an average drop in the 34 miles of about 7 feet to the mile, towards the northeast. In almost the opposite direction and in approximately the same distance, Ann Arbor to Adrian, the drop is 195 feet, or about 5¾ feet to the mile. Measured upon the top of the Antrim, or what is the same thing, the base of the Berea, at Ann Arbor, the formation is 134 feet higher than at Adrian and 234 feet higher than at Pontiac. This indicates the existence of a great arch in these strata, what is known in geology as an anticlinal fold, which might have been reasonably expected to have yielded gas or oil. The sandstone could have served as a suitable reservoir, the gas or oil under pressure displacing the brines and the overlying impervious shale acting as an ideal cover to prevent the escape to the surface. In explanation of why no considerable quantities of these desired commodities were struck in either the Ann Arbor, or Ypsilanti wells, attention may be drawn to the fact that the longitudinal crest of this broad fold is tilted downward toward the northwest and this may have allowed the gas and oil that were slowly distilled from the Antrim shales to work their way upward and southeastward until a means of escape to the surface was found. In attempting to locate these shales upon the geological map, help is furnished by the records of gas in the wells and by the amount of drift cover. The greatest de-depressions in the rock surface seem to correspond with the belt of Antrim shales, as though it had suffered greater glacial, or preglacial erosion, than the limestones beneath or the sandstones immediately above.

Traverse group. The next member of the Devonian system, as we descend in the geological scale, is the *Traverse*, originally described by Winchell as the "Hamilton group" in his First Biennial Report (1861, page 69), and subsequently as the "Little Traverse." This latter name was shortened to Traverse in 1895 by Lane[25] by which it is still known in the state reports. The formation was quite fully described by Rominger[26] under the name "Hamilton group" and its fossil contents carefully studied. With no outcrops in the southeastern part of the state he did not recognize its presence in the well records and denied its existence. In northern Ohio, Newberry identified some 15 to 20 feet of highly fossiliferous blue shale with the Hamilton, which formation is now regarded as the "Olentangy shale" of N. H. Winchell. In western Ontario, the same formation is readily recognized in outcrop and well sections, showing a thickness of 225 to 350 feet, and, as in Michigan, consisting of alternating layers of limestone and shale. During the last decade a very complete study of the Traverse has been made by Grabau, his paper upon the "Stratigraphy of the Traverse Group of Michigan" appearing in 1902.[27] These and subsequent studies were made upon the numerous exposures in the eastern part of the peninsula, in the Alpena region and upon those on the opposite side of the state in the Traverse Bay region.

Lithologically considered the Traverse Group of Michigan, and western Ontario is transitional between the underlying Dundee limestone formation and the overlying Antrim shale, in that it consists of alternating layers of limestone and bluish, calcareous shale, often referred to in the well records as "soapstone." In the Alpena and Traverse regions, the thickness is believed to be about 600 feet, diminishing to near 300 feet in the St. Clair River region and to less than 200 feet in the southeastern corner of the state. In the Campus well at Ann Arbor, Lane refers 65 feet of "gray, calcareous shale" to this formation and it seems probable that the last 70 feet of "bluish, cherty limestone" in the Court House well may also be so referred. The deep well at Pontiac gives the following series of Traverse strata:

TABLE XXXIV.—TRAVERSE STRATA, PONTIAC WELL.

Dark drab, coarse-grained, argillaceous limestone	25 feet.
Light drab, fine-grained limestone; 2% insoluble residue	10 feet.
Light drab, greyish white limestone; 8% insoluble residue	7 feet.
Light grey limestone; 20% insoluble residue	8 feet.
Sandy limestone, dark drab; 20% insoluble residue	35 feet.
Argillaceous limestone; 10% insoluble residue	15 feet.
Light blue, calcareous clay; 90% insoluble residue	50 feet.
	150 feet.

In this section there occur 100 feet of rather impure limestone and 50 feet of calcareous clay, which throw light upon the Wayne County records and show what may be expected in the case of new wells penetrating the formation. In the case of the Milan deep well (14 miles south-southeast from Ann Arbor) the Traverse series is as follows:

TABLE XXXV.—TRAVERSE STRATA, MILAN WELL.

Cherty limestone	30 feet.
Blue shale	45 feet.
Blue, shaly limestone	65 feet.
Limestone	28 feet.
	168 feet.

Although some of the limestone strata pass into dolomite, with the introduction of magnesium, others are of high grade, as indicated by the following table of analyses from the Alpena region.[28]

TABLE XXXVI.—ANALYSES OF TRAVERSE LIMESTONE, ALPENA PORTLAND CEMENT COMPANY.

Calcium carbonate ($CaCO_3$)	89.10% to 98.37%
Magnesium carbonate ($MgCO_3$)	.92% to 8.67%
Silica (SiO_2)	.33% to 1.77%
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	.13% to 1.21%

The clays and shales of the same formation in the Alpena region show the following composition:

TABLE XXXVII.—ANALYSES OF TRAVERSE SHALES AND CLAYS, NEAR ALPENA.

	(1)	(2)	(3)
Silica (SiO_2)	55.80	54.46	55.68
Alumina (Al_2O_3)	20.93	17.26	20.68
Ferric oxide (Fe_2O_3)	5.11	4.66	
Calcium oxide (CaO)	1.98	6.60	9.69
Magnesium oxide (MgO)	1.23	2.82	2.35
Alkalies (K_2O, Na_2O)	5.55	14.20	3 60
Loss by ignition	7.78		.....
	98.38	100.00	92.00

(1) Dock street clay; 5 feet below surface.
(2) Warner brick yard, blue shale.
(3) Fletcher dam, Thunder Bay River, blue shale.

From the same locality, Ries (*loc. cit.*, foot note 19) gives an analysis of a shale outcropping to the north of Alpena, belonging to the Alpena Portland Cement Company.

TABLE XXXVIII.—ANALYSIS OF TRAVERSE SHALE NORTH OF ALPENA.

Silica (SiO_2)	61.09%
Alumina (Al_2O_3)	19.19
Ferric oxide (Fe_2O_3)	6.78
Calcium oxide (CaO)	2.51
Magnesium oxide (MgO)	.65
Potassium oxide (K_2O)	1.80
Sodium oxide (Na_2O)	1.36
Sulphuric anhydride (SO_3)	1.42
Water (H_2O) and carbon dioxide (CO_2)	5.13
	99.93

As used by Lane, the Traverse Group of Michigan includes both the Hamilton and lower lying Marcellus of the New York series, and hence is the western equivalent of the Erian of Clarke and Schuchert. It carries an abundance of fossils which are often in splendid state of preservation and easily separated from the shales. In southeastern Michigan, these fossils are often found in the glacial gravels and fragments may be obtained in well drilling.[29] The formation forms a belt from two to five miles broad, extending northeast to southwest across the county of Wayne. It is covered by some 50 to 150 feet of drift and has approximately the same northwesterly dip as the overlying Antrim shale. The main body of Traverse shale is separated from the Antrim by the layers of limestone and is readily distinguished from it by its bluish color and soapy character when wet. The conditions favorable for the remarkable growth of marine vegetation that characterized the Antrim had not yet been established in the west during Traverse time. Highly mineralized water is sometimes met with from this formation but too impure to be utilized as a brine, in this respect differing from that of the Berea sandstone. The relatively small amount of organic matter preserved in the strata has given rise to very little or no gas and oil.

Dundee limestone. Under a heavy burden of drift, the preceding geological formations are but imperfectly known in Wayne County. We come now to a series of strata which have been carefully studied in outcrop, were penetrated in the Oakwood salt shaft and of which we have numerous well records, based upon actual samples of the drillings. The first of these is the Dundee limestone, one of the first to be recognized in the stare and utilized for building purposes and in the manufacture of lime. In every direction from southeastern Michigan, it extends persistently for great distances and underlies hundreds of thousands of square miles of the lake region, the Ohio and Mississippi basins. It represents the upper member of a group of strata found well exposed in the Helderberg Mountains of eastern New York, to which group the name "Helderberg" was given by Conrad, the early palæontologist of the New York Survey. Under the names "Helderberg series" or "Helderberg division" these strata were described in the Final Reports of the various districts prepared by Mather, Emmoris, Vanuxem and Hall (1842-3). It was soon found that this and the other geographic names there used were entirely arbitrary and ill suited for group divisions until they had been subdivided upon the basis of their carefully studied fossil contents. In his review of these New York reports, Owen suggested a regrouping of the minor divisions and a renaming of the main divisions. Attracted by this work in the United States, the able French palæontologist M. Ed. de Verneuil made a season's study of the formations with a view to correlating them with those of Europe and suggested the grouping together of the lower strata of the Helderberg series, found to be of Silurian age, under the name "Lower Helderberg." This placed the upper members in the Devonian and suggested the use of the term "Upper Helderberg." In his translation and review of the paper of de Verneuil, Hall refers to the "upper limestone series of the Helderberg"[30] and in 1851 uses the term "Upper

Helderberg series" to include the Corniferous limestone, Onondaga limestone, Schoharie grit and Caudagalli grit.[31] De Verneuil expressed the opinion that the Oriskany sandstone should also be included in the series as marking the base of the Devonian and, in this view, Hall promptly concurred (page 302). The French scientist also proposed to unite the Caudagalli and Schoharie grits and the Onondaga and Corniferous limestones. The Corniferous had been originally named by Eaton, "the Cornitiferous limestone" in allusion to its content of *hornstone*, or chert, and made to include both the Upper and Lower Helderberg formations.[32] The propriety of uniting the Corniferous and Onondaga limestones of the Upper Helderberg series, was early admitted because of their lithologic similarity, their content of hornstone mid the close similarity in fossils. As early as 1841 Hall had traced the main limestones of the Upper and Lower Helderberg groups into the middle west and had observed the disappearance to the westward of many of the intermediate formations.[33] But C. C. Douglass, assistant upon the early Michigan survey, had already recognized the Corniferous equivalency of the limestone of Monguagon township and subdivided them as follows:[34]

Limerocks of Lake Erie.

a. Corniferous (Dundee).
b. Silicious limestones, parsing into sand (Sylvania).
c. Compact gray or blue limestone (Monroe).

The term Corniferous for this limestone formation was very generally used in the earlier reports of the Ontario, Michigan, Ohio and Indiana surveys; "Upper Helderberg" being sometimes substituted. In 1894, Hall proposed to revive the term "*Onondaga*" for this formation[35] and this term has come into general use in the recent geological literature. In Ohio, Prosser recognizes a double division—the Delaware and Columbus limestones.36 Owing to the difficulty of establishing exact correlations across distant areas, especially where gaps occur in the aeries, Lane defined the *Dundee* in 1895, as "extending down from the bluish beds of the Hamilton (Traverse) so long as the formation continues to be limestone, stopping with the appearance of dolomite or of gypsiferous shales."[37] Although much better exposed near Trenton than at Dundee and on the Macon, this name had long been preoccupied, and the village of Sibley had not then come into existence. The base of the Dundee (Devonian) was thus intended to be placed at the top of the Monroe formation (Silurian), the uppermost strata of which are so generally dolomite. The discovery of the Anderdon limestone, of high grade and carrying *Devonian* fossils, embedded in the Upper Monroe[38] and that the superposed dolomite strata may be absent enables the Dundee to rest directly upon this Anderdon, or to be separated from it by a very thin stratum of sand. Such is the case at the Hibley quarry near Trenton and at the Anderdon quarry near Ambertsburg, Essex County, Ontario, where the original definition of the base of the Dundee becomes inapplicable and the separation between it and the Anderdon can be made only upon a palæontological basis. As thus defined by Lane it was intended to cover the entire time of the Upper Helderberg; Oriskany to Corniferous, inclusive.[39].

As seen in southeastern Michigan and western Ontario, the Dundee is essentially a pure limestone formation with occasional nodules, seams and thin strata of chert, an impure variety of quartz. The limestone varies in color from light gray to drab, buff to yellow, in some cases merging into blue. The purer varieties show numerous cleavage faces of calcite, or crystallized lime carbonate, and are heavily charged with fossil fragments. The argillaceous ingredient, abundant in the Traverse limestones, is usually small in amount, generally less than one per cent but may run up to 6 or 7% in certain beds. The iron content is also small but the silica and magnesium carbonate are subject to considerable variation. With dilute hydrochloric acid, the Dundee always gives vigorous effervescence by which it may be distinguished from the underlying Monroe dolomites. The beds not infrequently give a strong odor of oil and show drops of thick, black, bituminous matter in the small cavities. In Ontario and near Port Huron, the formation yields oil and gas where the structural conditions have been favorable.[40] It is also the source of a highly mineralized water, too impure for salt manufacture but valuable for medicinal and! chemical uses. The composition of such a "mother liquor" from a deep well[41] at Port Huron is shown in the following analysis. The well is 750 feet deep and enters the Dundee 100 feet.

TABLE XXXIX.—ANALYSIS OF DUNDEE MINERAL WATER. "DEEP SPRINGS MINERAL WATER," PORT HURON, MICHIGAN.

(Analysts Dr. E. Ristenpart and Prof. R. C. Kedzie.)

	Parts per 1000.
Sodium chloride ($NaCl$)	66.6832
Potassium chloride (KCl)	2.8181
Ammonium chloride (NH_4Cl)	0.1431
Calcium chloride ($CaCl_2$)	5.2492
Magnesium chloride ($MgCl_2$)	6.7846
Magnesium bromide ($MgBr_2$)	0.0488
Magnesium iodide (MgI_2)	0.0003
Calcium bicarbonate $Ca(HCO_3)_2$	1.7600
Iron bicarbonate $Fe(HCO_3)_2$	0.0140
Calcium sulphate ($CaSO_4$)	3.7721
Sodium hyposulphite ($Na_2S_2O_4$)	0.0177
Sodium hydrosulphate (Na_2SO_4)	0.0136
Sodium carbonate (Na_2CO_3)	......
Lithium chloride ($LiCl$)	......
Alumina (Al_2O_3)	0.0033
Silica (SiO_2)	0.0085
Sulphuretted hydrogen gas (H_2S)	0.3146
Carbonic acid gas (CO_2)	0.7147

Studies upon the various layers of the Dundee as exposed in the Sibley quarry, near Trenton, were begun by the writer 15 years ago (June 1896), when there were recognized for commercial purposes the following series of strata; which for convenience of reference were assigned letters.

TABLE XL.—STRATA OF THE SIBLEY QUARRY, NEAR TRENTON.

A. "6 foot top." Yellow, brown to gray; thin-bedded; very fossiliferous.
B. "7 foot limestone." Thin-bedded, gray to bluish.
C. "2 foot limestone." Compact, gray, rich in fossils.
D. "5 foot limestone." Compact, crystalline, bluish where unweathered.
E. "6 foot limestone." Compact, gray to blue, fossil fragments abundant.
F. "14 inch flint." Brittle, bluish gray chert, some fossils.
G. "6 foot limestone." Gray to bluish, more heavily bedded.
H. "2 foot flint." Very brittle impure chert, some fossils.
I. "9 foot limestone." Compact, heavily bedded, blue to gray.
J. "6 foot magnesian." Similar to I but oily and fewer fossils.
K. "8 foot limestone." Gray, thin-bedded, fossiliferous.
L. "12 foot lower magnesian." Light to dark gray, fossiliferous.
M. "7 foot silicious." Thin-bedded, firm, poor in fossils.

Aside from the splendid exposure of the Dundee strata now seen at the Sibley quarry, the only other known locality, in south-eastern Michigan lies some 27-28 miles to the southwest at Dundee and the mouth of the Macon.[42] Four separate beds may be recognized at the Christiancy quarry, the second and third of which are separated by a thin stratum of chert, which from its fossil contents agrees with that designated "Bed F" in the Sibley quarry. If this correlation is correct, and there is much opportunity for uncertainty, the "2 foot flint" has disappeared and the four Macon beds exposed represents beds D, E, G and I of the Sibley quarry. Lithologically the beds seem to correspond, their combined thickness is 21 to 22 feet on the Macon and 26 feet at the Sibley quarry, and they seem to lie at about the same horizon, measured from the top of the dolomite (Flat Rock?). The base of "Bed I" at the Sibley quarry is some 48 feet (including the Anderdon) above the dolomite while in the Christiancy quarry, the Nogard well record indicates that the base of the lowest stratum there is about 38 feet above the corresponding horizon. These variations in the thickness of the strata at these two localities harmonize with the apparent increase in the thickness of the entire formation to the northward. In actual elevation, the Sibley bed is about 18 feet lower, this representing the drop in the direction of the strike. The following analyses will be of interest for comparison with those of the Sibley and Anderdon limestones.

TABLE XLI.—ANALYSES OF DUNDEE LIMESTONE, CHRISTIANCY QUARRY.

(Analyst G. A. Kirchmeier.)

	Upper.	Second.	Third.	Lowest.
Calcium carbonate ($CaCO_3$)	90.80%	86.80%	77.60%	95.00%
Magnesium carbonate ($MgCO^8$)	6.87	11.60	17.41	3.86
Silica (SiO_2)	0.48	1.10	2.78	0.81
Iron (Fe_2O_3?)	0.16	0.12	0.56	0.41
Organic matter	1.69	......	1.63	......
Difference	0.00	0.38	0.02	—0.08
	100.00	100.00	100.00	100.00

In a brief report upon the limestone of the Anderdon quarry,[43] Rev. Nattress gives the following average composition of certain of the richer beds, the analyses having been made by the Solvay Process Company of Detroit. It seems very probable that the samples covered both the Dundee and Anderdon formations, the latter of which had not yet been recognized and separated from the former. In the case of the former, recent determinations of the lime carbonate ingredient alone shows quite a wide range in amount, depending upon the presence mainly of magnesium carbonate and silica. The 76 analyses supplied by Rev. Nattress give an average of 62.49% and an extreme range of 40.34%. to 95.26%. The samples were taken from drill cores through the beds believed to represent the basal layers of the Dundee, just above the Anderdon, which is still richer in lime carbonate (see Pl. XXIII for these beds now exposed in the quarry).

TABLE XLII.—AVERAGE COMPOSITION OF DUNDEE BEDS, ANDERDON QUARRY.

(Laboratory Solvay Process Co.)

Calcium carbonate ($CaCO_3$)	97.50%
Magnesium carbonate ($MgCO_3$)	1.50
Calcium sulphate ($CaSO_4$)	0.03
Silica (SiO_2)	0.80
Ferric oxide (Fe_2O_3) and Alumina (Al_2O_3)	0.09

In the summer of 1905 two drill cores were removed from the eastern and western sides of the Sibley quarry for the purpose of discovering the nature and thickness of the underlying beds. '"No. 2," farthest west, started upon "Bed 1" elevation about 583 feet above sea level, and extended to a depth of 83 feet. Through the kindness of Mr. Sundstrom, the writer was permitted to study these cores and was given the following set of analyses, which, taken in connection with the series of strata in the quarry, bring out admirably the essential nature of this economically important formation.

TABLE XLIII.—ANALYSES OF DRILL CORES, PROSPECT HOLE NO. 2, SIBLEY QUARRY.

(Laboratory Church and Co.)

Sample.	Depth.	Elevation.	$CaCO_3$	$MgCO_3$	SiO_2	Difference.	Remarks.
1	5	578	87.63	8.72	1.98	1.67	Bed I.
2	10	573	87.26	9.02	1.90	1.82	Bed J.
3	16	567	83.99	11.56	2.78	1.67	Bed K?
4	20	563	81.08	14.63	2.39	1.89	Bed K.
5	25	558	93.26	4.82	0.73	1.19	Fossils.
6	27	556	81.81	14.02	2.21	1.96	
7	33	550	75.99	15.13	8.16	0.72	
8	35	548	82.72	9.06	7.24	0.99	
9	40	543	92.54	4.17	2.63	0.66	Base of Dundee.
10	42	541	87.79	2.49	9.50	0.22	Anderdon.
11	45	538	79.99	15.55	2.89	1.57	"
12	48	535	87.08	7.91	4.95	0.06	"
13	53	530	68.36	23.64	1.50	6.50	"
14	55	528	70.54	23.49	0.96	5.01	"
15	58	525	59.99	35.70	0.54	3.76	Flat Rock?
16	62	521	64.72	32.57	0.49	2.21	" "
17	65	518	62.36	33.34	0.29	4.01	" "
18	70	513	59.45	37.00	0.68	2.87	" "
19	78	505	54.27	43.04	0.22	2.54	" "
20	80	503	59.15	37.88	1.05	1.92	" "
21	83	500	58.09	40.04	0.31	0.56	" "

The "differences" consisted mainly of alumina, iron oxide, and organic matter and were not determined.

In August, 1907, Prof. A. W. Grabau examined these cores with the writer and was able to recognize the Anderdon character of the fossils seen in the cores from depth (Hole No. 2) 46.5 feet to about 51 feet. From a depth of 41 to 43 feet, there occurs a light brown limerock in which are thickly embedded quantities of fine, rounded, pure white, quartz granules, not to be distinguished from those derived from the Sylvania. At what appears to be the same horizon in the Anderdon quarry, upon the opposite side of Detroit River, Rev. Thomas Nattress, found a few inches of sand, or an incoherent sandstone. This occurrence is of interest since it marks the horizon of the Oriskany sandstone of the New York series and the base of the Dundee. It probably resulted from transportation of Sylvania sand by the wind during a land interval between the Silurian and Devonian. In the table of analyses above given, the 15 to 16 feet (elevation 541 to 525) of limestone lying just beneath the sandy stratum are to be referred to the Anderdon. Beneath this lies some 25 feet of rock approaching normal dolomite in its composition and presumably representing the Flat Rock formation yet to be described. The strata of the Anderdon quarry have been made the subject of study for a number of years by Rev. Nattress and reported upon from time to time.[44] During the past summer and fall (1911), he has conducted a series of investigations for the Solvay Process Company in the district immediately to the west of the Sibley quarry.

The total thickness of the Dundee formation at the Sibley quarry appears to be about 90 to 100 feet where it has been pushed up to form a knoll, across which the earliest ice sheet moved with considerable vigor. How much was removed by glacial, or other agencies we may only surmise by ascertaining the total thickness at neighboring localities. At the Oakwood salt shaft the Dundee was found to have a thickness of 63 feet, but here again we have but a partial record, since it lies next to the drift cover of 83 feet. In Ohio, the maximum thickness of the formation is given as 100 feet, which thickness it retains for a few miles into Michigan. In the Adrian well record the separation of the Dundee and Monroe was not made but at Britton, Lenawee County, there were 100 feet of "white or brownish crinoidal limestone with water and traces of oil and gas," which are referred by Lane to the Dundee. At Milan, Monroe County, there occur 97 feet of the same formation. In the next dozen miles to the northward a rapid thickening seems to take place as indicated by the Ann Arbor and Ypsilanti records, the Campus well giving 185 feet and the Cornwell well at least 200 feet referable to this formation. The Pontiac and Royal Oak records, unfortunately, are not complete enough to be of service in this connection. At Petrolea, Ontario, the thickness is about 200 feet, according to the Canadian records. Judging from these records in the surrounding districts, the Dundee in Wayne County would have to be assigned an original thickness of about 100 feet, in the southwestern corner, to about 200 feet along the northern border. In the numerous wells along Detroit River, the records are either incomplete, or penetrate only a portion of the formation. The Stroh Brewery well, on Gratiot Avenue, Detroit, shows 400 feet of "limestone," from the base of the Traverse to the top of the Sylvania, two very well defined horizons. This includes the Dundee and Upper Monroe, the latter of which in the Oakwood salt shaft has a thickness of 274 feet, leaving some 126 feet for the Dundee.

Between the outcrop at the mouth of the Macon, in Monroe County, and that at Sibley, the drift cover is relatively light, but still amounting to 30 to 80 feet, hopelessly covering a rock for which there is now great demand. Towards the north, this burden of drift increases until it exceeds 100 feet. The breadth of the outcrop, *beneath this cover*, ranges from four to twelve miles (see Pl. XXV) and the strike of the formation is toward northeast as it enters the county, curving around to the eastward and apparently shifting the direction of dip from northwest around towards the north. At the Sibley quarry, the rock strata have been disturbed and both the strike, amount and direction of dip are abnormal. At the time of their study by the writer in 1896 the dip as carefully determined by transit was found to be 5° south of west and equal to 4.4 feet per hundred, measured along the top of "Bed J." The surface of "Bed I" showed a drop per hundred feet of 3.9 feet. In the old Christiancy quarry upon the Macon, the former foreman, Mr. T. J. Brandt estimated the direction of dip as W. NW. and the amount as about .45 feet to the 100 feet. In the Dundee quarry it was found to be approximately 2.25 feet to the hundred. The average dip of the strata for the county can be determined only by an examination of the well records for which we have reliable data, the base of the Dundee in the salt shaft being known to have been reached at a depth of 146 feet (elevation of mouth 575.2 feet above sea level) or at an elevation of 429 feet. In the Campus well at Ann Arbor the base of the Dundee is 50 feet *below* sea level, giving a drop in the 32.5 miles from Detroit to Ann Arbor of 479 feet, or an average of 14.74 feet to the mile. This is in a direction, however, almost due west and hence does not indicate the real dip of the beds. From Detroit towards Royal Oak, or Pontiac, would more nearly furnish the desired data but, unfortunately, the separation of the Dundee from the Monroe can not be made in the well records at these two places. Dropping to the level of the top of the Sylvania, the dip from Detroit to Ann Arbor is found to be 15.7 feet to the mile. In the Pontiac well, N. NW. from Detroit, there occurs an arenaceous limestone which probably marks the horizon of the Sylvania. If we make this assumption, the dip in this direction is about 21.2 feet to the mile. The top of the Sylvania is much better defined in the Royal Oak deep well (SW. ¼ sec. 19), at a depth of 836 feet, but unfortunately the elevation of the mouth of the well is not given with the record. If we take this from the topographic map as about 678 feet above sea level, then we have an average dip indicated in almost due north direction of about 22 feet to the mile. Until more reliable data are at hand we may assume that the average dip is not far from 25 feet to the mile and in a direction north-northwest.

In connection with the Antrim shales, attention was called to an anticlinal fold with its crest near Ann Arbor and the economic importance of such structural features was there pointed out. When the Dundee is similarly examined it is found that the base of this formation at Ann Arbor (—50 feet) is *lower* than at Milan (+290 feet), or at Royal Oak (about sea level), indicating the presence of a synclinal trough in the surface of the Upper Monroe. In private conversation Prof. I. C. Russell called attention to the fact that the production of the great basin-like depression over central Michigan must have produced a series of such wrinkles in the strata radiating from the center. The suggestion has value in the search for oil and gas in that if a series of test wells is being put down their direction should be *tangential* to the basin; i.e., northeast to southwest in southeastern Michigan. If a successful well is once reached a *radial* position for new ones is to be recommended with reference to the central basin; i.e., so placed that the line will point toward the center of the basin.

A full suite of fossils was collected from the Sibley strata and these have been made the subject of study by Prof A. W. Grabau, whose preliminary report upon the same is found in Chapter X. Dr. Carl Rominger had also collected extensively from the same beds and his lists are given in Vol. III, issued in 1876, with photographic views of the corals. Most of the strata are surprisingly rich in fossil forms, often proving to be a solid, coquina-like mass of shells, corals and crinoid joints. Even when the limestone appears quite compact, the weathered portions reveal more or less of this structure. The discussion of the conditions under which this material accumulated and resulted in the formation of limestone and chert will be found in the writer's report upon Monroe County.[45] It may be stated here simply that warm, open, shallow sea conditions prevailed, far enough removed from land to escape deposits of mud and sand. Floating vegetation, so abundant later, had not yet invaded the sea and the oil and gas were probably very largely of animal origin. The Michigan basin as far north as James Bay was covered by this epicontinental sea which communicated eastward with the Atlantic and southward with the Gulf of Mexico from which came a rich fauna of corals and brachiopods which gave rise to extensive reefs.

SILURIAN SYSTEM.

The establishment of this world-wide system dates back to 1839 and was made by Murchison as the result of his extended studies upon the formations of the region of Great Britain, formerly occupied by the ancient tribe of *Silures*.[46] Two main divisions were recognized, an Upper and a Lower Silurian (p. 265). Almost immediately, the system received recognition in tins country by Conrad who endeavored to correlate the New York strata with their English equivalents upon the basis of fossil similarity.[47] Owing to the pronounced break between the upper and lower divisions, it was proposed in 1879 by Lapworth to recognise each division as a *system*, retaining *Silurian* for the upper and using *Ordovician* for the lower, the name derived as the other had been from an ancient tribe of Wales, the *Ordovices*.[48] This suggestion has been largely adopted in the recent English and American texts on geology arid has much to commend it. In Wayne County, the Silurian System only has been completely penetrated by the wells and only the uppermost formations are to be seen in outcrop. The Ordovician is reached in the deeper wells in Wayne and Monroe counties and is seen in outcrop towards Ohio River.

Monroe formation. The formation to which this term is now applied has been known in the state reports under a variety of names, as an effort has been, made to correlate its strata with those of the standard New York series. It has recently been made the subject of joint study by Prof. A. W. Grabau and the writer and described in a special report[49] to which those especially interested may be referred. Three main divisions are readily recognized; an upper and a lower set of dolomitic limestones, separated by a stratum of incoherent sandrock known as the Sylvania. Only the upper member of the entire series is believed to extend into New York, where it makes up the lower portion of the original Helderberg division and constitutes a portion of that which was set off by De Verneuil as the "Lower Helderberg." In his western trip, taken in 1841, for the purpose of correlating the strata of the middle states with those of New York, Hall referred certain limestones in the vicinity of Mackinac to the Onondaga Salt Group and the Waterlime.[50] The first recognition of Lower Helderberg strata in the Lake Erie region was made by Chapman in 1864, who suggested. for it the name "Bertie dolomite."[51] The Waterlime equivalency of the Lake Erie dolomites was announced by Newberry and Winchell in 1871 and recognized, more or less generally, in the Ohio, Michigan and Ontario survey reports. In Ohio, the term. "Lower Helderberg" was contracted to *Helderberg*, which was believed to be represented by the Waterlime alone with a thickness of 100 feet. Rominger in Michigan used the name "Helderberg Group" and extended its meaning to more nearly that of the early New York reports, making it include both the Dundee and Monroe and not endeavoring to separate them upon his geological map. The sandrock stratum (Sylvania) was supposed to separate the two members and had been regarded generally as the correlative of the Oriskany. In 1873 it was noted by N. H. Winchell that this formation is *embedded* in the dolomites, instead of being at the top of the series, which observation was later confirmed by Orton in Ohio and the writer in Michigan.[52] Because of its exposure and utilization near the village of Sylvania, Ohio, Orton suggested this name for the formation (*loc. cit*., p. 18). It must be regarded, of course, as of the same geological age as that of the dolomites themselves.

Owing to the difficulty of separating this entire series, upon which rests the Dundee, from the underlying Salina formation, it was proposed in 1893 by Lane to use the name "Monroe beds" for the series intervening between the base of the Dundee and the top of the Niagara.[53] The formation was not defined until 1895, "as extending from the limestones of the overlying Dundee down to the lowest gypsiferous beds, and to consist mainly of buff dolomites and of calcareous and argillaceous marls, associated with anhydrite and rock salt."[54] Based upon the evidence of the well records the thickness was placed at 1200 feet and the beds were believed to have been deposited in an excessively salt interior sea, extending from New York to eastern Wisconsin, exposed to a hot sun and receiving little accession of fresh water from rivers. Shallow water conditions prevailed in places, particularly in Ohio, where there was a great bar, reef or flat, permitting the formation of ripple-marks and mud-cracks. In southeastern Michigan, three periods of dessication were recognized, the first and greatest of which gave rise to the heavy beds of rock salt, aggregating in thickness some 600 feet; the second preceded the formation of the Sylvania (Middle Monroe) and resulted in the formation of gypsums, or salty dolomites, and occasional beds of oölite. The third period of dessication occurred during the deposition of the Upper Monroe series. The name "Monroe Group" for this series was approved in May, 1903, by the Committee on Geological Names of the United States Geological Survey.

In 1908 Grabau proposed to subdivide the Monroe into an upper, middle and lower division and to remove from it the Salina formation,[55] which in the New' York series had been known as the Onondaga Salt Group. In a joint paper by Grabau, Lane, Prosser and Sherzer, presented at the same time before the Albuquerque meeting of the Geological Society of America and the Chicago meeting of the American Association for the Advancement of Science, this subdivision and restriction of the Monroe was recognized.[56] The upper and lower divisions were further subdivided as shown in the accompanying table, with the approximate thickness of each member.

TABLE XLIV.—THE MONROE FORMATION OF MICHIGAN.

Dundee Formation.

Monroe Formation.		disconformity.		
	C. Upper Monroe or Detroit River Series.	Lucas dolomite	200 ft. +
		Amherstburg dolomite	20–50
		Anderdon limestone	35–60
		Flat Rock dolomite	40–100
		disconformity.	
	B. Sylvania sandstone and dolomites		30–300
		disconformity.	
	A. Lower Monroe or Bass Islands Series.	Raisin River dolomite	200
		Put-in-Bay dolomite	100
		Tymochtee shales	90
		Greenfield dolomite	100
		disconformity.	

Salina Formation.

In the typical locality, the Upper Monroe, or Detroit River Series, shows a thickness of about 100 feet at Wyandotte, to 350 feet at Windsor, Ontario, including the series of dolomites and limestone that intervene between the base of the Dundee and the top of the Sylvania sandstone. Extensive erosion of these beds seems to have taken place in the present vicinity of the lower Detroit River region previous to the deposition of the Dundee. The Middle Monroe, or Sylvania member, consists, in the main, of a pure, incoherent sandrock, not infrequently divided by a bed of silicious dolomite, sometimes, by two such beds. In the upper Detroit River region, the average thickness of this member is about 100 feet, but is found to be variable and to entirely disappear in some well sections. The thickness grows less to the southward and greater toward the northwest. The Lower Monroe, or Bass Islands Series (from the islands in the western end of Lake Erie), extends from the base of the Sylvania to the top of the Salina, which may be regarded in well records as the first bed of salt, or first heavy bed of gypsum. A comparison of the logs of adjacent wells, as for instance those of Wyandotte and Trenton, shows that some of the upper rock salt strata are replaced to the southward by deposits of gypsum. Without doubt, some of the strata lying above these salt and gypsum deposits are referable to the Salina and it was hoped that the record of the salt shaft at Oakwood would enable us to ascertain the thickness of these strata for that region. Unfortunately for this purpose, these beds proved unfossiliferous and with no structural break that could be observed it seems necessary to place the base of the Monroe at, or near the heavy salt or gypsum deposits. Thus limited, the Lower Monroe in the 17 wells of the Solvay Process Company, Delray, gives an average thickness of 360 feet and the entire Monroe formation of southeastern Michigan and western Ontario has a development ranging variously from 500 to 900 feet.

The best exposures, both natural and artificial, are to be found in Monroe County of each of the three main divisions of the formation. The Upper Monroe strata in Wayne County have been best seen in the quarry west of Gibraltar, now abandoned, and were formerly exposed in the shallow quarries on Stony Island and Grosse Isle. The Middle Monroe, or Sylvania member, may be seen in the pit of the American Silica Company, just east of Rock-wood, where it was covered; by some 15 to- 20 feet of glacial clay. The Lower Monroe is not exposed in the county but a very good section and suites of specimens were obtained at the Oakwood salt shaft.

Rev. Thomas Nattress has recently endeavored to show[57] that the dolomites which constitute the bed of Detroit River, in the vicinity of Stony Island are of Lower Monroe age and that the Sylvania sandstone, or Middle Monroe, swings in a sharp, horse-shoe shaped curve from the vicinity of Gibraltar, northward about the head of Grosse Isle and back to Bois Blanc Island, opposite Amherstburg; the respective exposures being upon "opposite sides of the *Cincinnati anticline*," and with a possible distance across of but about three miles at the broadest place. The conception was that the Sylvania represents a shore deposit about this very narrow peninsula of early Monroe dolomite and the argument was based upon theoretic considerations of dip and strike and the supposed absence of the Sylvania in the lower Trenton channel of Detroit River. Against this view many objections may be urged; first of which is that the crest of the Cincinnati anticline lies some 25 to 30 miles to the eastward; that it is not a narrow ridge, having "little or nothing of the character of an anticlinal or arch, * * * * no roof-shaped arrangement of the strata whatever, * * * * but a nearly level tract," (Orton) that could not be set down in Detroit River and still leave room for the thick Sylvania deposit upon either side. Furthermore, the "Cincinnati anticline" was formed before any of these Detroit River strata came into existence and not between Lower and Middle Monroe time, as would have had to be the case if the above arrangement held. But, if not the "Cincinnati anticline" could there have been a similar, but younger wrinkle in these strata that would satisfactorily account for all the phenomena? The Sylvania formation at Rockwood is 75 feet thick, 90 and 180 feet thick at Trenton, 60 and 100 feet at Wyandotte; and, although growing thinner to the eastward, unless we assume that it possesses a very much greater dip than it, or any contiguous strata are known to have, there would not be room in the area assigned to have the formation describe such a curve about a ridge of dolomite (see Pl. XXV). Outcropping (beneath the drift) at the mouth of the Huron with a breadth of two to three miles, by the time the Sylvania reaches Trenton it has dropped to a depth of 285 feet, while at Wyandotte its average depth is 213 feet, at both of which places we should expect to find the formation at, or very near the base of the drift. Furthermore, we should expect to find some trace of the formation in the channel bed passing either side of Grosse Isle, but nothing of the kind has ever been noted. Near the southern end of Bois Blanc Island a well belonging to Capt. Walter Campbell was abandoned because of the great quantity of this sand pumped from it. At Elliott's Point, upon the Canadian mainland, there are reported 44 feet of glacial clay, 25 feet of dolomite and then the Sylvania sandstone entered to a depth of 14 feet. At the adjoining farm to the north the depth to rock was 41 feet, with but a foot of "shale" overlying the Sylvania, which was reported as but 20 feet thick. Many reasons have been given for thinking that the Sylvania is not a shore deposit at all but a wind blown and wind deposited mass of sand, in which case it would sustain no such relation to the peninsular fold assumed by Nattress to have been dry land at the time of its formation. Its supposed absence from the bed of the river, where it has been assumed to cross to the southward of Celeron, Island, where not still covered by till, may be readily accounted for by the action of the present, or early Detroit River, at one stage of which it flowed to a considerably lower level (560 feet above sea level). Furthermore, if the Sylvania is an aeolian deposit there is no reason to expect that it must be continuous from one point to another.

As to the Lower Monroe age of the dolomites of the Detroit River bed and adjacent islands, structural and stratigraphic relations can furnish only a very uncertain guide. If fossils were absent, we should be compelled to rely upon lithological characters and these all point to the Upper Monroe age of the strata ex-posed in the Livingstone Channel (Pl. XXIV). But, unlimited quantities of excellently preserved fossils, corals being especially abundant, are available and will continue to be until the tremendous pile of dump is removed from the river. A large box of such material was submitted to Prof. A. W. Grabau, during the summer of 1911, and he unhesitatingly pronounces the strata of Upper Monroe age (Lucas and Amherstburg), which means that the Sylvania underlies Grosse Isle. It should be noted that corals are entirely absent from the Lower Monroe of southeastern Michigan, but are so abundant in the Livingstone Channel region as to almost constitute a reef. In the case of the Swan well, at the southwestern corner of this island, the owner Judge Swan feels confident that the Sylvania was penetrated early in the drilling, the drill requiring very frequent sharpening. While the drilling was in progress by the West Virginia Drilling Company (St. Marys, West Virginia) the well was visited by Forest B. H. Brown for the State Survey. A depth of 785 feet had been reached (July, 1903) which gave 14 feet of clay, 300 feet of "limestone" and 70 + feet of sand. These figures would give an elevation here of the surface of the Sylvania of 266 feet above sea level as compared with 290 and 300 feet at Trenton (Church and Co).

The fossils collected from the exposure at the southeastern corner of Celeron Island prove to be of *Lucas* age. Being so near the outcrop of the Sylvania. we should expect these beds to represent the Flat Rock division of the Upper Monroe, which was next in age to the Sylvania. This indicates that the Amherstburg, Anderdon and Flat Rock are either absent, or greatly attenuated at the mouth of Detroit River. Instead, then, of a dolomitic *ridge* of Lower Monroe age, as made out by Rev. Nattress, the evidence indicates that there existed a sandstone *basin* of Upper Monroe age in which the Detroit River beds were deposited.

In conformity with the overlying strata already described, the Monroe strata have a general northwesterly dip, swinging towards the north in the northern part of Wayne County, amounting probably to about 25 feet to the mile. In the lower Detroit River region, local disturbances have rendered the strike and dip irregular. At the Patrick quarry, south end of Grosse Isle, the strata were observed to dip S. 30° W. and to range in amount from 1½ to 2°. In the bed of Detroit River, opposite Stony Island, while the excavation for the Livingstone Channel was in progress, the average dip of the strata (seven determinations) was found to be S. 50° W. and to be equal to 1° 58', or about 3.438 feet to the hundred. In the northern part of the area exposed, the strata showed a pronounced anticlinal fold, extending in an east-west direction across the river bed. The strata dip rather rapidly upon the southern slope of the fold, having been eroded along the plane of the river bed and indicate that the fold is one of considerable magnitude. Upon the eastern face of the channel wall, Rev. Nattress and the writer counted 32 strata which had an average thickness of 38.3 inches and a total maximum thickness of 102 feet. Bench marks in use in the construction of the channel and located upon the surface ledges have elevations of 566.16, 568.61 and 568.69 feet, above sea level, respectively. In the Anderdon quarry, upon the Canadian side to the eastward, the foreman, Patrick Hancock, in 1907, reported the dip of the beds as 6 feet to the hundred and about S. 23° W. in direction.

Recurring to the geological equivalency of the Monroe formation, it is believed by Grabau that only the three younger members of the Upper Monroe are represented in eastern New York by the Manlius, Rondout, Cobleskill and Rosendale formations. In western New York, the representation is still more meager, only the Amherstburg and Anderdon being correlated with the Akron and Bertie dolomites. A rather full discussion of these correlations and description of the fossils of the Monroe will be found in the bulletin cited in foot note 49. To this same report also may be referred the reader interested in the lithological and structural details of the various divisions of the Monroe. In the 1908 report previously cited (foot note 37), Lane refers to the Upper Monroe, or Detroit River series, as "Eo-Devonian" implying a very close relationship with the Devonian as indicated by the remarkable fauna of the Anderdon and Amherstburg strata. To account for these forms it is necessary to assume that a Devonian fauna had already developed, probably to the northward, and migrated into southeastern Michigan before Silurian conditions had been entirely effaced, an arm from the Cordilleran sea giving temporary communication with the interior basin. These forms began to arrive in the Flat Rock, reached their culmination in the Anderdon during the existence of normal marine conditions and some of them continued to exist side by side in the Lucas with typical Siluric forms from the North Atlantic.

Salina formation. Originally known in the New York series as the "Onondaga Salt Group," this formation is now very generally referred to as the Salina, on account of its large content of salt, either in the form of rock salt, or in solution as brine. In southeastern Michigan, it consists of alternating layers of compact, brown to drab dolomite; anhydrite, more or less converted into gypsum and pure to impure strata of rock salt. In the deep well at Royal Oak (Oakland County), there is indicated the surprising development of 932 feet of this formation, of which 609 feet are reported as salt. Along Detroit River, the thickness is considerable, although less and diminishes gradually to the southward. With the disappearance of the beds of rock salt in the Church and Company wells, just north of Trenton, there is no means of distinguishing the Salina dolomites from those of the overlying Monroe in the well records to the south. In the Ohio scale, the formation is not now recognized as was originally done by Newberry.[58]

The wells of the Solvay Process Company, near Detroit, furnish a thickness of 709 to 748 feet, and an average of 732 feet, but with no certain knowledge that the entire series was penetrated. Similarly at the Oakwood salt shaft, the preliminary test well showed 792 feet that should be referred to the Salina. The shaft itself has thus far penetrated but 150 feet of the series and with the drill cores of the preliminary test well, gives us the first definite information relative to the stratigraphy of this portion of the formation. The revelations of this difficult and expensive piece of engineering are of such geological interest and of such economic importance that a description and complete log of the shaft will be given upon a subsequent page of this report. Reference to this log shows a succession of dolomites, salt and a mixture of these two materials, in some instances the dolomitic slime simply clouding the salt, in other cases with only a few disconnected crystals of salt embedded in the dolomitic matrix. Exposed to the weather upon the dump, the salt is soon dissolved and a honey-combed mass of brown or drab dolomite remains. Thin seams of greenish shale occur at certain horizons, becoming black and carbonaceous at times. Whereas the Monroe beds are characterized by heavy flows of water highly charged with hydrogen sulphide, the Salina is absolutely free from such flows and the tunnels radiating from the shaft are almost dusty. What are believed to be marketable strata of salt give a total of 454 feet, the heaviest bed having the enormous thickness of 869 feet. When entered, it will probably be found that this bed is really divided into two, or more, by thin layers of dolomite, as seen in a number of the Solvay wells. Careful search of the rock fragments brought up from the shaft failed to reveal any trace of fossils, plant or animal.

Passing southward from the Detroit region the deep well of the River Rouge Improvement Company, shows, at least, 723 feet of Salina, of which 378 feet are rock salt. At the bottom of the series, two beds, 120 feet and 78 feet in thickness respectively, are separated by 15 feet of a, salty shale. Just above lie 125 feet of what is described by the driller also as "salt shale." The well record of the Eureka Iron Company at Wyandotte is interpreted by Lane as showing some 770 feet of Salina, but with the salt strata aggregating only 160 feet. The lowest bed of the series has a thickness of 110 feet and is the correlative, presumably, of the very heavy bed to the north. Here it is underlain by 310 feet of strata also referred to the same formation before the Niagara is reached. If this reference is correct, the heavy salt bed lies near the middle of the series and the wells in the vicinity of Detroit give only partial sections of the Salina formation, although there is, as yet, no means of knowing how rapidly these lower beds may vary in thickness to the northward. The series of six wells of the. Church and Company, just north of Trenton, enable us apparently to mark the southern limit of the rock salt in southeastern Michigan. The four wells numbered 1, 3, 4 and 6 lie in an east-west line and show but a single salt stratum 26 feet, 25 feet, 30 feet and 33 feet, respectively, in thickness. Well No. 2 lies 300 feet-due south of No. 1 and gives but two feet of salt, while No. 5 lying 1350 feet to the southwest of No. 1 gave no rock salt whatever. Well No. 4 gives 650 feet for the entire Salina; gypsum (probably anhydrite) very largely replacing the salt.

The frequent association of calcium and magnesium carbonate, calcium sulphate and the strong bitter brines with rock salt, as in the region just described, gave rise more than a century ago to the theory that they must all have originated from the evaporation, under arid conditions, of detached arms of the sea. To account, however, for such extensive beds of salt, gypsum and dolomite demanded depths for these inland seas which overtaxed ones belief. Furthermore, the deposits alternated in succession and were often interstratified with shale and sandstone, so that the simple evaporation of such a sea could furnish no adequate explanation. Laboratory experiments have shown that, when sea water is evaporated, there are first thrown down the calcium carbonate ($CaCO_3$) and hydrous oxide of iron (2 Fe_2O_3+3 H_2O; next about 84% of the calcium sulphate ($CaSO_4$) in solution. There is next precipitated upon further concentration about 54% of the salt (NaCl) along with the balance of the calcium sulphate, followed by 8.5% of salt free from this sulphate. The remaining salt with the more soluble compounds of magnesium, potassium, bromine and iodine, finally crystallized in various combinations, or constituted the *bittern* in case evaporation was not complete. As pointed out by Hubbard (foot note 60), when such simple concentration of an inland sea takes place, the bottom and sides would be coated with calcium carbonate, more or less stained with iron, upon which would be deposited a layer of gypsum or anhydrite. The concentrated brine would shrink to the deeper portions of the basin and there be precipitated along with more gypsum, the final salt layers being practically pure. If the evaporation were not completed the bittern, or "mother liquor," would remain as a concentrated mineral water, to be incorporated into subsequent deposits. To account for a succession of the above series, for irregularities and for shale and sandstone, it has been supposed that influxes of the sea took place, as during storm, or exceptionally high tides, bringing in fresh supplies of sea water and incidentally mud and sand.[59] The enormous thickness of any single deposit, however can not be so explained.

In 1877 Ochsenius proposed a modification of this theory by as-sinning a basin of sufficient depth which continuously maintained its connection with the adjacent ocean, the water of the basin evaporating and allowing a constant inflow of sea water. The concentrated surface layers will sink, encountering layers differently charged and giving rise to the deposition of various compounds, chiefly salt and gypsum. Given sufficient time, a basin of sufficient original depth or in process of slow subsidence, the continuance of uniform conditions and an extensive bed of any of the above substances might take place. This is the theory accepted by Hubbard as explaining most satisfactorily the Salina series of Michigan.[60] Grabau has recently pointed out that according to this theory there should be found abundant remains of marine organisms in, the strata enclosing the salt, and it would seem, even in the salt itself. The constant influx of sea water would sweep in countless forms whose remains would settle to the bottom, whether or not they had been able to maintain themselves alive for any considerable time in the water undergoing concentration. It has already been pointed out that the Salina strata are practically barren of fossils. Grabau further calls attention to the absence of marine strata, outside of the Salina area of Michigan, Ontario and New York, which might be regarded as contemporary with the salt and gypsum strata.[61] The complete absence of such strata, this author convincingly argues, indicates a land-locked basin, or series of such in which the Salina beds are to be laid down. Widespread desert conditions with intermittent streams; long continued erosion of pre-Salina strata containing imprisoned sea-salts; the solution, transportation and final concentration of these salts in the various basins, he believes most satisfactorily explains all the phenomena of the Salina. From computations, this author concludes that the erosion of 400 feet of Niagara limestone from Minnesota, Wisconsin, the upper Great Lake region and western Ontario would be sufficient to yield 100 feet of pure rock salt distributed over an area of 25,000 square miles.

The very general absence of fossils makes it rather difficult to account for the dolomitic strata which make up the bulk of this series and the Lower Monroe as well. Some of this may have originally deposited as dolomitic slime resulting from the destruction of earlier dolomitic strata, but the fact that the oolitic particles and brachiopods were certainly transformed from calcium carbonate into the calcium-magnesium carbonate, known as dolomite, makes it appear that the alteration was possible in the sea itself or subsequently. In the process of dolomitization, there is a theoretical shrinkage of 13.3 per cent, but most of the Monroe and Salina dolomites of this region are exceedingly compact, indicating that the conversion took place either just before or at the time of deposition of the slime. The theory which best explains the various facts observed in this locality is that much of the dolomite resulted from the alteration of chemically precipitated calcium carbonate, this change occurring at the time of deposition. The unusual conditions which permitted this change were attained in the land-locked basins of Monroe and Salina time. During Anderdon time (Upper Monroe), normal marine conditions seem to have prevailed and the organisms furnished the great bulk of the calcium carbonate that was then deposited over the sea bottom. There occurs one very compact stratum, however, in the Sibley and Anderdon quarries, in which fossils are absent, the rock delicately laminated and which furnished an analysis of 100 per cent calcium carbonate. It seems quite probable that this stratum was chemically precipitated from the sea water directly from the breaking down of the very unstable calcium bicarbonate ($CaH_2C_2O_6$), a change now known to be taking place at the present time in connection with some of the Florida keys.

Niagara formation. This formation, named and well known because of the role which it plays in the production of the celebrated cataract, is penetrated in the deeper wells of southeastern Michigan. The log of the deep Wyandotte well shows some 360 feet of "limestone," underlain by 10 feet of "slate," which are referred by Lane to the Niagara. The so-called limestone is in reality a dolomite; compact, fine grained, light colored and hard. In color, it is thus in contrast with the drab colored dolomites of the Salina series and is not interrupted with seams of shale, salt or gypsum. There is but little content of argillaceous matter, suggesting the absence of ordinary sediment while it was forming and permitting the inference of Lane that the arid conditions of Salina time had already made their appearance.[62] This inference relative to the climate receives confirmation from the very low percentage of iron present in the rock, the occasional presence of apparently wind-blown sand grains and the fact that the strata are overlain by the salt and gypsum deposits of the Lower Monroe.

In Ohio the Niagara formation is known in outcrop, giving an opportunity for the study of its characteristic fossils and its subdivision.[63] Four groups of strata are there recognized; a sandstone, two series of dolomites and a basal shale layer. The sandstone (Hillsboro) has no representative in Michigan but the Guelph— from the typical locality in Ontario—maintains a development of some 200 feet across Ohio to the northward. Beneath the Guelph, lies the so-called "Niagara limestone," or Lockport, an even-bedded, blue to drab dolomite which is best developed in southern Ohio and thins out and is unrecognizable toward the north, even in its outcrop. For this reason, as well as from its color, it seems probable that the Michigan representative is the Guelph. The lowest member of the series is the Niagara shale, a mass of light-colored clays with numerous calcareous bands, showing a thickness of 100 feet in southern Ohio, but thinning towards the north to but a few feet, or being entirely absent. In the Wyandotte well, this division of the Niagara is represented by 10 feet of "slate." There is reason for believing that the dolomitic member, or members, of the Niagara underlie the entire Lower Peninsula and that it will be reached in all wells that penetrate its horizon. Its outcrop in Michigan is seen only along the northern border of lakes Michigan and Huron, in the southern margin of the Upper Peninsula, where at a few localities it is utilized in the manufacture of lime. Unusually fine exposures occur upon Drummonds Island, affording a choice series of fossils, especially corals. Rominger made the fullest study of the group in this northern localities and recognized three divisions, all dolomitic except a few thin layers, or irregular patches of limestone.[64] The uppermost division consists of a series of thin, uneven layers, carrying seams and nodules of chert, and containing the greatest abundance of fossils. The middle division consists of massive, highly crystalline ledges with casts or poorly preserved fossils. The lowest division shows fossils but rarely, is very regular and even-bedded, but composed of thin layers of fine, crystalline grains. This author expresses no opinion as to the approximate total thickness of the group. The logs of two deep wells at St. Ignace are now available giving two complete sections of the formation.[65] In the older of the two, there is shown 300 feet of Niagara (depth 504 to 804 feet) and in the second, which lies about two miles north, a thickness of 510 feet (depth 510 to 1020 feet). Rominger published the analyses of 10 specimens of the Niagara dolomite, showing a range of 52 to 62% of calcium carbonate, 32 to 43% of magnesium carbonate, 1 to 3% of alumina and iron and 1 to 9% of insoluble residue (*loc. cit.*, p. 48). In the limestone layers, the calcium carbonate ran as high as 95%, indicating a true limestone.

DEEPER BEDS REACHED BY BORINGS.

Beneath the Niagara formation and between it and the much sought for Trenton limestone, there intervene approximately 600 feet of sedimentary strata, mostly shale, with some sand. These layers are believed to represent in part the Clinton and Medina formations, often highly stained with iron and belonging to the Silurian System. In the Wyandotte well, which alone furnishes a section of these strata in Wayne County, it is difficult to draw any line of division between them. Beneath these lie the Hudson River and Utica shales, grayish to bluish, more or less dolomitic, or calcareous, and passing below into black. These two, with the underlying Trenton, represent the Ordovician System in Michigan. Along with the Clinton and Medina they are only imperfectly known in outcrop in the Upper Peninsula, skirting on the northward the belt of Niagara, Over the Lower Peninsula they are deeply buried and reached only in the deeper wells along the northern and southern portions, outcropping again in southern Ohio. Southward the carbonates become more prominent than in Michigan, indicating their formation under off-shore conditions. The entire series indicates a shallowing of the Palaeozoic sea in this region, and an increase in the erosion of neighboring land areas and consequent sedimentation, an intermediate stage between the open sea conditions of Trenton and Niagara time. For a fuller discussion of these strata in Michigan, the reader is referred to recent papers in the Report of the State Board of Geological Survey of Michigan for the year 1908, pp. 23 to 105.

Notes on the Geological Section of Michigan for geologists, teachers and drillers.

Part I. The Preordovician, by A. C. Lane and A. E. Seaman, p. 23.

Part II. From the St. Peters up, by A. C. Lane, p. 43.

1. Report of a Geological Reconnaissance of the State of Indiana; made in 1837; 1838, pp. 12 and 13.

2. Correlation Papers, Devonian and Carboniferous: Bulletin No. 80, U. S. Geological Survey, 1891, p. 135. To this bulletin is referred the reader who is interested especially in the nomenclature and correlation of the various formations described in this chapter.

3. The Marshall group: Proceedings of the American Philosophical Society, vol. XI, 1879, p. 79.

4. Lane, The Geological Formations of the Lower Peninsula and their Economic Products: Geological Survey of Michigan, vol. V, pt. II, 1895, p. 19. See also by same author Notes on the Geological Section of Michigan, Pt. II, From the St. Peters up: Annual Report of the State Board of Geological Survey of Michigan for the year 1908, p. 43.

5. Russell, The Portland Cement Industry in Michigan: Twenty-second Annual Report of the Director of the U. S. Geological Survey, part III, 1902, p. 666.
Ries, Clays and Shales of Michigan, their Properties and Uses: Geological Survey of Michigan, vol. VIII, pt. I, 1900, p. 42.

6. Newberry, Geological Survey of Ohio, Report of Progress in 1869, pt. I, 1871, p. 22 Also Report of Progress in 1870; 1871, p. 469.

7. Orton, Geological Survey of Ohio, vol. VI, 1888, p. 37. Vol. VII, 1893, p. 31.

8. Prosser, The Nomenclature of the Ohio Geological Formations: Journal of Geology, vol. XI, 1903, p. 519. See also The American Geologist, vol. XXXIV, 1904, p. 335, and Bulletin No. 7, Fourth Series, Geological Survey of Ohio, 1905.

9. Lane, Communication of Nov. 11, 1907, to George W. Stose, Editor of Maps, U. S. Geological Survey.

10. Geological Survey of Michigan, vol. V., pt. II, 1895, p. 20.

11. Communication of Apr. 20, 1903 to Prof. Charles S. Prosser. In his latest discussion of this sandstone Lane uses the term "Berea Grit" (Michigan Geological Report for 1908, p. 74) for the sandstone, regarding it as the base of the Carboniferous and the equivalent of the Catskill of New York.

12. Geological Survey of Michigan, vol. III, pt. I, 1876, p. 92.

13. Hicks, The Waverly Group in Central Ohio: American Journal of Science, 3rd series, vol. XVI, 1878, p. 216.

14. Geological Survey of Michigan, vol. V, pt. II, 1895, pl. XLVII.

15. In the Campus well, Ann Arbor, 160 ft. (Lane). Court House well, Ann Arbor, 275 ft. (Rominger). Pontiac deep well, 157 ft. (Wright). Adrian well, 221 ft. (Lane).

16. Michigan Geological Survey, Report for 1891 and 1892; 1893, p. 66. See also vol. V pt. II, 1895, p. 21.

17. Michigan Miner, Sept. 1, 1901. Also Report of the State Board of Geological Survey for the year 1901; 1902, p. 209.

18. Lane, Deep Wells and Prospects for Oil and Gas: Report of the State Board of Geological Survey for the year 1901; 1902, p. 212.

19. Ries, Clays and Shales of Michigan: Geological Survey of Michigan, vol. VIII, pt. I, 1900, p. 47.

20. Daly, The Calcareous Concretions of Kettle Point, Lambton County, Ontario: Journal of Geology; vol. VIII, No. 2, p. 135. See also Newberry, Geological Survey of Ohio, vol. I, pt. I, 1873, p. 155.

21. American Journal of Science, 3rd series, vol. I, 1871, p. 256. See also Orton. A Source of the Bituminous Matter in the Devonian and Sub-Carboniferous Black Shales of Ohio: same journal, 3rd series, vol. XXIV, 1882, p. 171.

22. Dawson, On Rhizocarps in the Paleozoic Period: Proceedings of the American Association for the Advancement of Science, 1883, p. 260.

23. Clarke, On Devonian Spores: American Journal of Science, 3rd series, vol. XXIX, 1885, p. 284.

24. Geological Survey of Ohio, vol. I, pt. 1, 1873, p. 156.

25. Geological Survey of Michigan, vol. V, pt. II, 1895, p. 24.

26. Geological Survey of Michigan, vol. Ill, pt. I, 1876, pp. 38 to 63.

27. Report of the State Board of Geological Survey of Michigan, for the year 1901, pp, 163 to 210.

28. For fuller data see Grabau's paper, Report of the State Board of Geological Survey of Michigan for the year 1901; 1902, p. 181.

29. For descriptions and figures of Traverse fossils see vol. Ill, Geological Survey of Michigan, 1876, pt. II, Fossil Corals by Rominger.

30. The American Journal of Science and Arts, second series, vol. VII, 1849, p. 230.

31. Report on the Geology of the Lake Superior Land District; Foster and Whitney, part II. 1851, p. 288.

32. Geological Nomenclature Exhibited in a Synopsis of North American Rocks and Detritus: The American Journal of Science and Arts, vol. XIII, 1828, p. 385.

33. Hall, Notes upon the Geology of the Western States: The American Journal of Science, vol. XLII, 1842, p. 51. See also Report on the Geology of the Lake Superior Land District, Foster and Whitney, pt. II, 1851, p. 307.

34. Fourth Annual Report of the State Geologist (Michigan), 1841, p. 109.

35. Thirteenth Annual Report of the State Geologist (New York) for the year 1893, vol. I, 1894, p. 207.

36. Revised Nomenclature of the Ohio Geological Formations: Geological Survey of Ohio, fourth series, Bulletin No. 7, 1905, p. 4.

37. Geological Survey of Michigan, vol. V, pt. II, 1895, p. 25. See also Annual Report for 1908, p. 70, in which the occurrence of magnesian beds is noted near Mackinaw City, near the base of the Dundee.

38. Grabau and Sherzer, The Monroe Formation of Southern Michigan and Adjoining Regions: Michigan Geological and Biological Survey, Geological Series 1, 1910, p. 42.

39. Geological Survey of Michigan, vol. VII, pt. I, 1900, foot note, p. 37.

40. Gordon, The Port Huron Oil Field: Geological Survey of Michigan, Report for the year 1901; 1902, p. 269.

41. Annual Report for the year 1903; 1905, p. 109.

42. See author's Geological Report on Monroe County: Geological Survey of Michigan, vol. VII, pt. I, 1900, p. 75.

43. The Limestones of Ontario: Report of the Bureau of Mines, 1904, pt. II, p. 41.

44. The Corniferous Exposure in Anderdon: Eleventh Report of the Bureau of Mines (Ontario), 1902, p. 123.

The Limestones of Ontario: Report of the Bureau of Mines, 1904, pt. II, p. 41. See also papers in the annual reports of the Michigan Academy of Science:

The Contour of the Sylvania Sandrock and related strata in the Detroit River Area: 12th Report, 1910, p. 47.

The Extent of the Anderdon Beds of Essex County, Ontario, and their place in the Geologic Column: 13th Report, 1911, p. 87.

45. Geological Survey of Michigan, vol. VII, 1900, pt. I, p. 40.

46. The Silurian System, founded on Geological Researches in the Counties of Salop, Hereford, Radnor, etc., with descriptions of the Coal fields and overlying formations. R. J. Murchison, London, 1839.

47. On the Silurian System, with a Table of Strata, and Characteristic Fossils: American Journal of Science, vol. 38, 1840, p. 86.

48. Lapworth, On the Tripartite Classification of the Lower Palaeozoic Rocks: The Geological Magazine, New Series, vol. VI, 1879, p. 13.

49. Grabau and Sherzer, The Monroe Formation of Southern Michigan and Adjoining Regions: Michigan Geological arid Biological Survey, Publication 2, Geological Series 1, 1910.

50. Geology of New York, pt. IV. 1843, p. 512. Also Report on the Geology of the Lake Superior Land District, Foster and Whitney, pt. II, 1851, pp. 162-3.

51. A Popular and Practical Exposition of the Minerals and Geology of Canada, E. J. Chapman, 1864, p. 190.

52. Winchell, Geological Survey of Ohio, vol. I, 1873, p. 603.

Orton, Geological Survey of Ohio, vol. VI, 1888, p. 18. Also vol. VII, 1893, p. 17.

Sherzer, Geological Survey of Michigan, vol. VII, pt. I, 1900, p. 60.

53. Report of the State Board of the Geological Survey of Michigan for 1891 and 1892; 1893, p. 66. This name was selected because of the excellent exposures of the strata in Monroe County.

54. Geological Survey of Michigan, vol. V, 1895, pt. II, p. 27.

55. Science, new series, vol. XXVII, 1908, p. 622.

56. Nomenclature and Subdivision of the Upper Siluric Strata of Michigan, Ohio, and Western New York: Bulletin of the Geological Society of America, vol. XIX, 1909, p. 556.

57. The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area: Twelfth Report of the Michigan Academy of Science, 1910, p. 47.

58. Newberry, Report of the Geological Survey of Ohio, vol. I, 1873, p. 132.

Orton, Report of the Geological Survey of Ohio, vol. VI, 1888, p. 15.

Prosser, Geological Survey of Ohio, Bulletin No. 7, 1905, p. 3.

59. See Winchell, Geological Studies, 1886, p. 186.

60. Hubbard, Geological Survey of Michigan, vol. V, part II, 1895, p. IX.

61. Grabau, Physical and Faunal Evolution of North America during Ordovicic, Siluric and Early Devonic Time: Journal of Geology, vol. XVII, 1909, p. 245. See also The Monroe Formation: Michigan Geological and Biological Survey, 1910, p. 226.

62. Annual Report for 1908, p. 57. Also vol. V, pt. II, p. 29.

63. Orton, Geological Survey of Ohio, vol. VI, 1888, p. 13.

64. Rominger, Geological Survey of Michigan, vol. I, pt. Ill, 1873, p. 37.

65. See vol. V, Geological Survey of Michigan, 1895, pl. LXIII. Annual Report for 1901 p. 228.

CHAPTER VII. WATER RESOURCES.

Rapid increase in the density of population of any section makes the problem of a wholesome and sufficient water supply more and more difficult of solution. This difficulty arises not only from the relatively greater consumption but from complicated factors connected with its distribution, disposal of sewage, protection from fire, etc. To supply with water the army of people making up the population of Wayne County, nearly one-fifth of that of the entire state, there are four chief sources available:

1. Surface waters: streams, lakes, ponds, reservoirs and cisterns.
2. Waters from former lake and river deposits.
3. Waters from deposits of the ancient ice sheets.
4. Waters from the bedrock.

As generally understood, the source of all these waters is the atmosphere, from which the moisture is condensed and precipitated as rain, snow, hail, etc. However, when subjected to various conditions after precipitation, the waters become essentially different and typical samples from each source may generally be readily distinguished.

SURFACE WATERS.

Reservoirs and cisterns. From data obtained from Prof. M. E. Cooley, of the University of Michigan, Lane calculated that 38% of the total precipitation of a region may be collected from roofs and secured in cisterns and that with a rainfall of 32 inches, practically the same as that of Detroit, every 100 square feet of horizontal surface may yield 100 cubic feet of water annually, or about 25 barrels.[1] This is but a little over one-third of what actually falls upon the area, the remainder being lost in wetting the roof, evaporation, overflow during heavy rains, blowing or sliding of snow, etc. Where limited quantities of practically pure water are desired, simple precautions would enable one to secure a greater yield. In addition to the dust, coal dirt and organic matter derived from the collecting surface and also from the atmosphere as well, this water contains appreciable quantities of ammonia, nitric and nitrous acid, sulphuric and sulphurous acid, nitrites, nitrates and sulphates, along with carbon dioxide and other gases of the atmosphere. For the laundry, and in some cases for full domestic use, this type of water is collected in cisterns or tanks and utilized. Where wells are especially difficult to obtain, these artificial reservoirs are connected with the barn and used in watering stock. Excavations in the old lake clays for the manufacture of brick serve as collecting basins for surface water and supply the necessary water for the softening of the stiff clays. These and other excavations made directly for the purpose often serve as ponds for ducks and geese.

Ponds and lakes. In striking contrast with Oakland to the north and Washtenaw to the west, the county of Wayne is surprisingly deficient in ponds and lakes. Aside from the small bayous found upon the river flats, the only natural lakelet in the county lies one mile east of Northville (Sec. 2, Northville township) and is known locally as Yerkes Lake (Pl. XXVI). It has a maximum diameter of about 1100 feet and is drained at higher stages than at present by a small stream into the Middle Rouge. Occupying a depression between the morainic knolls of the region, it receives considerable surface drainage and is said also to be fed with springs and to be well stocked with fish. Owing to its slight elevation (below 800 feet), it had to be rejected as the source of supply for the village of Northville.

A small artificial lakelet for ornamental purposes is maintained at Eloise, an excavation having been made into the glacial clay and supplied with water which is piped from the Rouge flats to the north. Although so poorly supplied with inland lakes, Wayne County reaches Lake St. Clair upon the north and extends to Lake Erie upon the south. The water of Lake St. Clair is utilized to a greater or less extent by the residents of Grosse Point township. Many of those who adjoin the lake, pump the water direct by means of windmills and distribute it over their grounds from elevated storage tanks. Drinking water is ordinarily derived from wells into the drift, or exceptionally from the bedrock. The village of Grosse Point Farms is supplied with water from the lake drawn at a point about 1¾miles from the shore, this distance being necessitated by the shallow condition of the lake. The water flows by gravity into a settling basin from which it is pumped direct.[2]

Surface streams. Aside from Detroit River, the surface streams of the county are utilized to but a slight extent as a source of water, except for the watering of stock and sprinkling of small truck farms. The very irregular flow of the Rouge and its usual turbid condition have prevented its utilization as a water resource. At Dearborn, the Arno Mills use the water of the Lower Branch in their dyeing business and the main branch for a time furnished water for the boilers in the power plant of the Detroit, Ypsilanti, Ann Arbor and Jackson Railway. At Eloise, the Rouge water is used for the boilers of the Wayne County House, for sprinkling, in flushing the sewers, etc. It was originally pumped direct from the Lower Rouge but is now obtained from the flats of the Middle Rouge near Perrinsville, 3¾ miles distant. A well 35 feet in diameter and 18 feet deep has been constructed (1902), which receives the flow from the river along with surface drainage and the latter necessitates a filtering plant at Eloise. The composition of the water of the Middle Rouge is shown in the following table, the analysis having been made by L. M. Gelston, then Assistant Director of the University of Michigan Laboratory of Hygiene, Ann Arbor.

TABLE XLV. ANALYSIS OF WATER FROM MIDDLE RIVER ROUGE.

(Parts per million).

Inorganic matter	732	Free ammonia	0.133
Organic matter	96	Albuminoid ammonia	.124
Chlorine	37	Total residue by evaporation	828.
Potassium	1.5		

Reaction neutral. Algae, protozoa, and bacteria present.

In a suit brought against the infirmary in 1898 for the pollution of the Lower Rouge, the following analyses were made by Prof. J. E. Clark, M. D., of the Detroit College of Medicine. It was then legally decided that the Rouge was being seriously contaminated, and the institution was required to put in settling basins for its sewage. A series of such basins is now in use, the sewage being treated with alum and lime and then filtered through gravel.

TABLE XLVI. ANALYSES OF WATER FROM LOWER BRANCH RIVER ROUGE SHOWING CONTAMINATION.

(Parts per million).

	Above sewer.	From sewer.	250 to 300 ft. below sewer.
Inorganic	280	740	720
Organic matter	150	380	370
Chlorine	5	105	95
Free ammonia	.302	48.8	1.512
Albuminoid ammonia	.366	32.58	1.44
Total solids	430	1,120	1,090
Bacteria	10,900	325,000	12,500

The table is of especial interest, since it shows the normal condition of the stream water as well as those substances indicating serious sewage contamination. The amount of chlorine, combined to form common salt, has been increased 19 fold, while the ammonia has not risen in proportion to the amount actually present in the sewage itself. A complete analysis of the water would have shown that much of this had been oxidized into nitrites and nitrates, which, along with the chlorine, furnish an index to the probable amount of sewage contamination. A comparison of the amount of inorganic matter in the waters of the Middle and Lower branches shows that the former is considerably harder, due undoubtedly to the fact that it is more abundantly fed by springs along its course.

Aside from the incidental use by the farmers along its course, the water of the Huron is utilized only at one place—French Landing, for the disposition of the garbage collected from the city of Detroit. Before entering the county, it has already received the sewage from Ann Arbor and Ypsilanti, with a combined population of 21,047. Owing to the rapid and tortuous course of the river, it is likely that this contamination is rendered harmless before entering the county, although none of the villages have thus far cared to utilize this supply. The following analysis of the Huron water has been very kindly supplied by Mr. Roy W. Pryer, of the Hygienic Laboratory of the University of Michigan.

TABLE XLVII. ANALYSIS OF HURON RIVER WATER.

Sample taken at Ann Arbor, Mich., June 22, 1911.

Analyst Roy W. Pryer, Ann Arbor, July, 1911.

(Parts per million).

Color	slight yellow.
Odor	fishy.
Reaction	alkaline.
Hardness	162.8
Total solids	390
Loss on Ignition	192
Inorganic residue	198
Of this	
Sodium chloride ($NaCl$)	15
Calcium sulphate ($CaSO_4$)	72.3
Calcium carbonate ($CaCO_3$)	41.3
Magnesium carbonate ($MgCO_3$)	69.4
Parts potassium permanganate reduced	
by organic matter	16.95
Free ammonia (as NH_3)	.25
Albuminoid ammonia (as NH_3)	.38
Nitrates as N_2O_5	.2
Nitrites as N_2O_3	.01

Water powers have been developed for grinding purposes at certain favorable points along the Middle and North branches of the Rouge and along the Huron. Owing to the irregular flow and great reduction during the summer months, the water power must be supplemented with steam, or the turbines operated but a portion of the time. The heavy floods in the spring, often with the help of the ice, occasionally lead to the destruction of the dams. Both of these difficulties will be obviated by establishing great storage reservoirs by which the surplus water may be held back and dealt out as needed.

At the Yerkes Flouring Mill, upon the Middle Rouge, at Northville, there is a head of 16 feet and an available horse power of 40. The Argo Mills at the same place have 12 feet head and 20 horse power available. Upon the same stream at Plymouth, there are also two mills in operation, the Phoenix and Plymouth mills, each with a head of about 16 feet and developing 80 and 45 horse power respectively. Between Northville and Plymouth, at Waterford, there is an abandoned mill and power. At Pikes Peak, the Nankin Mills have secured a fall of 14 feet and have developed 53 horse power, available the year around except during very dry, or very cold periods. Upon the North Branch of the Rouge, two powers have been developed—the Du Bois Mills, near Bedford, with an 8-foot head and 42 horse power and the Dearborn Mills, north of the village, having 9 feet of head and 44 horse power available. Under favoring conditions, there is thus being utilized some 324 horse power in connection with these two branches of the Rouge. Higher and stronger dams, and more of them would pond the water more effectually, increase the head, regulate the flow and greatly increase the available power. The system of storage reservoirs, planned for the Huron can not be so successfully applied to the Rouge because of the absence of the natural basins.

From Rawsonville to Lake Erie the fall in the Huron is about 71 feet, or measured along the valley, at the average rate of about 2.9 feet to the mile. With high banks favorable for ponding and with an average mean flow of 670 cubic feet per second, this means that much energy is going to waste within the limits of the county. If converted into electrical energy it could readily be delivered and utilized in the city of Detroit. At four places only have powers been developed for milling purposes—Flat Rock, New Boston, Belleville and Rawsonville. The last of these had a head of 7 feet and furnished a horse power varying from 150 to 175, but the dam was destroyed in 1899, has not been restored and the mill is abandoned. The dam at Belleville was built in 1836 and held for nearly 60 years, but finally gave way. The new dam gives an 8-foot head, creates a reservoir of 25 acres and yields 400 horse power. One-half mile up from New Boston is located the New Boston Flouring Mills, with 6-foot head and 125 horse power available. At Flat Rock the head is 8 feet and the power about 100, at ordinary stages of the water. Of the 71 feet of fall theoretically present, there is thus utilized but 22 feet and only a small percentage of the actual horse power.

Over nine-tenths of the entire population of Wayne County derive their entire water supply from Detroit River, naturally one of the most magnificent streams of potable water in the world, when volume, purity, temperature and constancy of flow are considered. Opposite the city of Detroit, the breadth is 2200 feet, the average depth 37 to 38 feet and there is maintained a rather constant velocity of two miles per hour. With the level of Lake Erie at its normal, it is calculated by the U. S. Engineers that there flow by Ft. Wayne, in the western part of the city, 209,900 cubic feet each second. In the American channel, opposite Belle Isle, the maximum velocity is 2½ miles an hour, and the average somewhat less than 2 miles. During July and August, 1897, detailed measurements of the flow were made by Clarence W. Hubbell, engineer of the Detroit waterworks. Float methods gave an average flow of 65,000 cubic feet a second and current meters one of 53,000 cubic feet for this channel. When the channel is covered with ice and the Canadian channel is open, the flow is reduced to 36,000 cubic feet a second. The temperature of the water ranges from 32° to 70° F., and the greatest vertical range between the top and bottom has never been observed to exceed one-half degree. Between shore and midstream, the temperature of the water may vary as much as 8° or 9°, and this fact may be used to detect possible contamination from tributary streams. Lake St. Clair, which extends practically to the city, has served for many centuries as a great settling basin, as is evidenced by its shallow condition and the delta at its head. The turbidity of the water is low, except immediately following storms, when the bottom of Lake St. Clair becomes more or less disturbed and the tributaries bring in sediment. The following analyses, made some eight years apart, are of interest in showing the nature and amount of mineral matter contained in this water. The total solids is thus seen to be small, well adapting the water to use in various manufacturing plants, a matter of great importance to such a rapidity growing city.

TABLE XLVIII. MINERAL ANALYSES OF DETROIT RIVER WATER.

(Parts per million).

Calcium (Ca)	[3]24.610	[4]23.800
Magnesium (Mg)	7.440	5.400
Aluminum (Al)	1.800	......
Iron (Fe)	Trace	......
Alumina (Al_2O_3) and Ferric oxide (Fe_2O_3)		11.100
Sodium (Na)	2.760	2.910
Potassium (K)	Trace	0.0576
Chlorine (Cl)	2.990	4.550
Silica (SiO_2)	1.590	7.500
Carbonate radical (CO_3)	50.850	CO_2 30.120
Sulphate radical (SO_4)	7.620	8.630
Organic and volatile matter	36.390	38.540
Total mineral matter	101.240	Total solids....109.640

3. Twenty-first Annual Report of the Michigan Board of Health, 1902, p. 63. (Recomputed to ionic form by the United States Geological Survey.)
4. Twenty-eighth Annual Report of the Board of Health of the City of Detroit, 1909, p. 97. For other analyses see Lane, Lower Michigan Mineral Waters: Water-Supply and Irrigation Paper No. 31, 1899, pp. 18 and 19.

The city of Detroit, with its population of 465,766 souls (1910) and area of approximately 42 square miles, is supplied with this water from a single pumping station, believed to be the largest in the world. This station is located in the extreme eastern part of the city, opposite Belle Isle, and the water is taken from the head of the island through a tunnel of recent construction.[5] In addition to the city itself, this station also supplies water to the suburban villages of Hamtramck (population 3,559), Highland Park (4,120), River Rouge (4,163) and Oakwood (781); with a combined population of 12,623. This water is all metered and double the city rates are charged. With the system of direct pressure, it has been found impracticable to force the water to all parts of the city, portions of which are 60 to 70 feet above the river, and to the upper floors of the taller buildings. Accordingly, in 1898, a double system was installed each with its own set of pumps and mains, one operated under low and the other under high pressure. However, buildings over five stories high are provided with their own private pumps.

TABLE XLIX.—SANITARY ANALYSES OF DETROIT RIVER WATER.

(Parts per million.)

	July, 1901.	August, 1901.	Sept., 1901.	Oct., 1901.	Nov., 1901.	Dec., 1901.	Jan., 1902.	Feb., 1902.	March, 1902.	April, 1902.	May, 1902.	June, 1902.
Appearance	C.	C.	C.	C.	C.	C.	C.	N. C.	N. C.	S. T.	S. T.	N. C.
Total Solids	108.4	104.2	103.0	111.0	104.0	111.0	106.2	115.0	116.4	116.0	118.2	112.0
Volatile matter	41.4	36.4	44.4	41.8	34.8	41.6	39.6	39.0	36.8	39.0	40.0	40.0
Non-volatile matter	67.0	67.8	58.6	69.2	69.2	69.4	66.6	76.0	79.6	77.0	78.2	72.0
Free ammonia	.008	.006	.020	.016	.024	.012	.026	.028	.024	.016	.022	.020
Albuminoid ammonia	.074	.080	.126	.116	.092	.102	.082	.086	.092	.086	.082	.118
Nitrogen as nitrates	.115	.082	.164	.210	.099	.198	.230	.148	.115	.164	.198	.165
Nitrogen as nitrites	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Chlorine	2.80	2.90	2.60	2.80	2.70	3.15	2.70	3.15	2.50	2.75	3.10	2.70
Oxygen absorbed in 15 minutes	.40	.32	.44	.48	.44	.48	.40	.36	.44	.40	.32	.28
Oxygen absorbed in 4 hours	.76	.72	.88	.96	.84	.72	.76	.84	.88	.80	.84	.88
Bacteria per cubic centimeter	98	106	37	37	103	104	87	124	170	105	31	398
Bacteria per cubic centimeter	43	84	98	104	170	199	132	353	105	190	48	34
Bacteria per cubic centimeter	116	192	160	82	89	265	26	197	266	235	66	140
Bacteria per cubic centimeter	62	47	52	206	204	99	204	402	333	302	115	69
Growth in .2 per ct. carbolic-acid gelatin	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.

C.—Clear. N. C.—Nearly Clear. S. T.—Slightly Turbid.

Although naturally of most excellent quality, this abundant water supply is subject to more or less contamination from surface drainage. Not far from 400,000 people reside in the St. Clair drainage basin between Detroit and Port Huron. There are many truck farms, rich in compost, the drainage from which in the early spring and after heavy rains is a menace to the city's health. Prof. Gardner S. Williams, lately of the University of Michigan, has demonstrated that the dredging of the delta of Black River, Port Huron, by the United States Government in 1892 was responsible for the outbreak of typhoid in Detroit during June of that year.[6] Compared with many other cities, the city of Detroit has a very low death rate from this disease, averaging during the past five years 87 deaths or from 4 to 5 deaths for each thousand inhabitants. In view of this low rate, there is little reason to suspect that the germs are ordinarily derived from the river, although there is the possibility that they may be at any time. A number of local outbreaks during the past two years have been traced to the milk supply, the contamination occurring in the dairies and, undoubtedly, numerous cases each summer are contracted outside, and imported into the city. The officials of the city Board of Health are fully awake to the danger and are doing all in their power to guard the public health, making frequent sanitary analyses of the river water and each year recommending strongly the establishment of a municipal filtering plant. The preceding analyses, taken from their Twenty-first Annual Report, 1902, are of interest as showing the monthly variations in the character of the water.

Below Detroit, the city of Wyandotte and the, villages of Ford and Trenton also draw their water supply from the river by separate pumping plants. Upon Grosse Isle, this water is also pumped by means of wind mills into storage tanks, from which it is distributed by gravity. Since practically all the water pumped by the Detroit plant finds its way sooner or later into the river again as sewage, or surface drainage, this means that some 85,000,000 gallons of polluted water are returned daily. If we assume that 50% of the rainfall, after collecting the filth from the roofs, streets, walks and gutters, also reaches the river, we have some 22,000,000 of gallons as a daily average from this source. The Canadian towns opposite Detroit—Walkerville, Windsor and Sandwich, with a combined population of some 20,000, contribute to the river some 6.000,-000 additional gallons of sewage. The grand total of this unsavory beverage gives about 17.5 cubic feet a second, or about one gallon for every 12,000, on the supposition that it is evenly distributed. However, the Detroit drainage hugs the western bank from the mouth of the sewers to the intake pipes and in five to six hours the contents of Detroit sewers may be delivered to unsuspecting victims farther down the river. This gives insufficient time for the process of oxidation to complete its work of purification of organic refuse and bring about the death of the disease germs. Then, too, it must be remembered that it is not a matter of the *quantity* of contaminating material, but rather of its *quality* and that Detroit has upon an average some 1000 to 1500 cases of typhoid annually. Below Wyandotte the conditions are still more serious as further pollution has occurred from its sewers and the water is confined in the relatively narrow western channel. One resident of the region informed the writer that he was cured of wanting to drink this water by observing the nature of the spray tossed upon the deck of a motor boat in which he was riding. Another had noted the appearance of the water when seen through thin, clear ice in the winter.

The question of water supply for the lower Detroit River section is one for the trained engineers to settle. To the geologist, several solutions are in sight—a municipal filtering plant for each, or a single one for all; the extension of the Detroit mains to Trenton; the use of deep wells such as that upon Grosse Isle for household use, the river water still being used for manufacturing, laundry, fire and lawn purposes. In the Free Press of June 11, 1911, the suggestion of Richard P. Joy is worth consideration by those interested. This involves the construction of a canal, or aqueduct, from Port Huron to Lake Erie which would furnish the entire series of cities and villages with a wholesome and adequate water supply, well adapted to the various uses. Until some feasible plan can be devised, it is the height of wisdom for all people using the river water to either boil, or thoroughly filter, all water used for drinking, or that in any way comes in contact with food or utensils used in its preparation or serving.

That the people of this region are being aroused to the seriousness of the matter is indicated by the demand for bottled spring waters, two varieties of which are now available. One is shipped in from Rochester, Michigan, and is delivered for 10 cents a gallon; the other is known as "Maple Spring Water," from a bored well upon the place of J. H. Vreeland, NW. ¼ NE. ¼, sec. 12, Monguagon township. The well is 65 feet deep, entering rock some 5 feet, and flowed up to about one year ago; ceasing, the owner thinks, owing to the great amount of drainage at the Livingstone cut or Sibley quarry. The water contains some gas when first pumped, either carbon or sulphur dioxide, which is allowed to escape when it is bottled and delivered to customers for 5 cents a gallon.

WATERS FROM LACUSTRINE AND RIVER DEPOSITS.

In Chapter III of this report, there has been described a series of beaches, terraces and river deltas formed during the closing stages of the Glacial Epoch as the result of wind, wave and stream action. These consist of hillocks of sand, or gravel and sand, attaining a thickness of 25 to 30 feet, resting upon the underlying clay. At times, the deposit is of the nature of a thin sheet which serves as a veneering over the glacial clay and often covering many square miles of territory. These loose, unconsolidated deposits are very porous, 30% of their volume sometimes being pore space, and readily absorb a large percentage of the rainfall unless the ground is frozen or covered with snow or ice. With a precipitation of 32 inches and a run-off of 25% there would be an average daily absorption of 132,210 cubic feet over every square mile, or nearly 1,000,000 gallons. This sinks until stopped by the impervious clay beneath where it is either held in depressions, or slowly works its way along the slope of the clay surface.

Shallow wells. The absorption of this vast amount of water often takes place faster than it can escape and the level of the groundwater rises and often lies quite near the surface, easily reached by shallow wells, ranging from 5 or 6 feet to 20 or 25 feet, a very common depth being 10 to 15 feet. From the way in which this water is held, it is obvious that it would possess no "head." As a rule, these wells are dug, although sometimes driven, and cased with barrels, planks, brick, stone or crocks. The water is obtained usually either by suction or chain pumps, the wind mill being occasionally used. In some cases the bucket, with chain, rope or pole, is used for dipping up the water; even the old-fashioned sweep being occasionally seen. It is not ordinarily necessary to strike clay in sinking the well, unless the supply is scant, when an excavation into the clay becomes desirable. Generally the supply is reported to be sufficient for domestic purposes, and is often abundant. It, however, fluctuates with the season and after prolonged drought may entirely fail. In sinking wells it is desirable to reach the level of ground water at the time of a prolonged dry season in order to secure a permanent yield. The principle involved is shown in the accompanying figure.

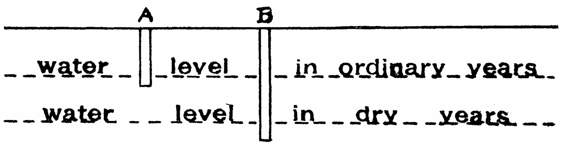

Figure 17. Diagram showing relation between depth and permanence of wells. A. Well sunk to ordinary water level, but failing in times of drought. B. Well sunk to level of water in dry years and never failing (From U. S. Geological Survey Water-Supply Paper No. 255).

In one-third of the wells from which data were procured, the owners report the water as "soft" and suitable for laundry use, no cisterns being required. This indicates that but little calcium or magnesium carbonate has been dissolved from the sand or gravel because of the absence of these materials originally, because they have been leached out or more probably, because the water has not had time to get these substances into solution. In the remaining two-thirds of the wells, the water was pronounced "hard," particularly those which approach or reach the clay. In a few instances, the water was reported to have changed from soft to hard, or vice versa. Other mineral ingredients, so commonly present in other types of well water, are either absent or only very sparingly present. The temperature of the water in these wells fluctuates more than in the deeper wells, as would be expected, being affected more by the surface temperatures of the air and soil.

This type of well is obtained with the least difficulty and expense, the work being usually done by the owner himself with what little assistance he can command. Water so obtained, however, is especially liable to contamination, unless carefully guarded, since gravel and coarse sand do not make an effective filter and because of the ease with which foreign matter may enter from above. Dupuits' experiments in France have shown that the area drained by a well is in the form of an, inverted cone, the radius of the base of which may range from 15 to 160 times the depth of the surface of the water in the well. This means that, if it is 10 feet from the surface of the ground to the level of the water in the well, that this well may receive drainage from barns and outhouses 150 to 1600 feet distant from the mouth of the well. It has also been found that a shallow well heavily pumped will drain a larger area than a deeper well subjected to moderate pumping. It thus becomes a matter of great importance to the users of the well water that it be located in the safest possible place, even if somewhat inconvenient, and it would be wise to first ascertain the probable direction of underground flow by discovering the slope of the clay surface and of the ground water. The danger of pollution is shown in the accompanying diagram. It is a mistake to suppose that the surface slope of the ground controls the direction of underground drainage, the reader being able to easily construct a diagram in which the surface slopes in one direction and the surface of the impervious clay in the other. Heaping a mound of earth about the mouth of a well to keep out surface drainage from a barnyard is a very ineffective safeguard. In comparison with the dug well, the driven well is much the safer but gives a smaller yield. The relative advantages and disadvantages of these two types of shallow wells are set forth in the following table, along with "bored" and "punched" wells. The former are made by the use of augers of various types; the latter by dropping a steel cylinder, carrying a slit upon its side for holding and lifting the material to be excavated.

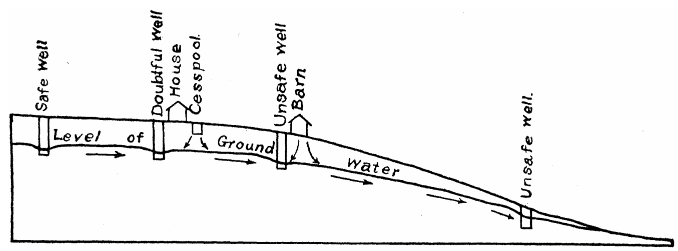

Figure 18. Diagram showing ordinary location of farm well (From U. S. Geological Survey Water-Supply Paper No. 255).

TABLE L. SUMMARY OF ADVANTAGES AND DISADVANTAGES OF DIFFERENT TYPES OF WELL.[7]

Dug wells.

Advantages.	Disadvantages.
Ease of construction; can be located, sunk, and cased by owner. Only hand power required. No outfit required. No expensive materials required for curbing.	Limitation to soft materials; liability to caving while being dug.
Cheapness in soft material.	Costliness in hard rock. Wood curbing often used affords favorable conditions for the development of bacteria. Slight depth to which it can be sunk.

Ease of entrance of water.	Ease of entrance of polluting matter through and over top of curb.
Utilization of all water strata.	Water, not being replenished, is often stagnant.
Utilization of small seeps.	Fails frequently in time of drought.
Quick response to rainfall.	Must usually be at distance from house and from barns, privies, and cesspools to insure safety.
Large storage capacity.	Necessity for frequent cleaning; danger from gas while cleaning.
Accessibility for cleaning.	Short life when curbed with wood. Ease of entrance of animals and refuse through open top.

Driven wells.

Advantages.	Disadvantages.
Ease of construction; often sunk in a few hours; only hand or horse power usually required. Outfit is inexpensive, can be quickly put up, and does not require skilled labor. Tubing is readily obtainable and inexpensive. Cheapness.	Limitation to soft materials. Utilization of a single water stratum. Usual limitation to moderate depths. Restriction to open porous water beds due to absence of storage facilities.
Safety; can be located near sources of pollution if sunk through impervious bed preventing access of contaminating matter to water bed; nothing can enter at top.	Slow response to rainfall as compared to many dug wells. Corrosion of pipes and well points. Incrustation of pipes and well points.
Permanency of supply as compared with dug wells.	Entrance of quicksand through well points. Taste of water due to solution of the iron under certain conditions.
Cleaning seldom necessary as compared to open wells.	Difficulty of cleaning in case of clogging. Short life as compared to some dug wells. Absence of information as to minor water beds or materials penetrated.

Bored wells (Arkansas type, 2 to 12 inches in diameter, tight casings).

Advantages.	Disadvantages.
Ease of construction; only hand or horse power usually required; skilled labor not essential in shallower holes.	Limitation to soft materials. Not adapted to very deep wells. Utilizes only one stratum in most places.
Cheapness for moderate depth. Deeper wells little affected by drought. Pollution shut out if properly cased. Gives good records of materials penetrated and water beds encountered.	Other disadvantages similar to those of drilled wells.

Punched wells.

Advantages.	Disadvantages.
When provided with pervious curbings the advantages are similar to those of open and Iowa type bored wells; when provided with tight casings, the advantages are similar to those of the Arkansas type bored wells.	Similar to those of open wells and the larger type of bored wells. Difficulty of operation; liability of crooked holes. Usual limitation to depths under 50 feet. Limitation to soft yet stiff materials, which are generally of local distribution.

In addition to safe guarding the well in every known way, great precautions should be taken in the disposition of garbage, kitchen and chamber-slops, manures, etc.; these being disposed of only at safe distances from the well that supplies the water for domestic use. The United States Department of Agriculture issues gratuitously a Farmer's Bulletin (No. 43) bearing upon the subject of Sewage Disposal on the Farm, and the Protection of Drinking Water. During outbreaks of typhoid, it is wise to apply to the Michigan State Board of

Health, at Lansing, for their pamphlets dealing with the subject of the control of this expensive disease. The importance of sanitation is not generally appreciated in the rural home and should be clearly and forcibly presented in all rural schools.

Seepage springs. Around the margins of the sand dunes; wherever superficial beds of sand and gravel thin out, exposing the clay; or where these deposits are cut by surface streams to or near the clay, the water "seeps" out and gives rise to one type of springs. The flow may be slight and simply moisten the surface, or it may be concentrated into a single flow of some volume. Most of the springs of this type are seen along the banks of the Rouge and Huron rivers where they have cut into the old beaches and deltas. The conditions under which they exist are shown in the accompanying diagram.

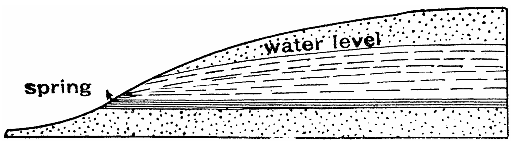

Figure 19. Spring fed from unconfined waters in porous sands (From U. S. Geological Survey Water-Supply Paper No. 255).

In Van Buren township, some of the strongest flows are being utilized by the farmers, the water being pumped into tanks by means of hydraulic rams. These waters show only small quantities of salt, gypsum and calcium carbonate, with a little iron. The largest spring noted from this class of deposits is located upon the place G. E. Barlow, sec. 29, Livonia township. It has yielded a strong flow for many years and at the time last visited was still discharging through a 2½-inch pipe with considerable force (see Pl. XXVIII, A). Field tests showed that the water is hard, containing both calcium carbonate and sulphate but gives no reaction for salt. If this spring were fully developed, along with others upon the neighboring Rouge bank, there might be found sufficient water for such a village as Wayne, from which it is 7 miles distant. The amount of fall to this village, some 14 to 15 feet, would carry the water but could not furnish sufficient pressure. This village has been unsuccessful in securing a municipal supply from deep wells and even, a one time, seriously considered extending the Detroit mains, but the expense proved prohibitive. Recently test wells have been located to the west of the village, have been found to yield a sufficient quantity and the village was permitted to reject by ballot the question of bonding for such a water supply. At the Wayne County House, Eloise, the inmates are supplied with drinking water from a large sand dune one-half mile distant, the water being collected in small reservoirs and flowing by gravity through 3-inch tiling. The water is abundant for this purpose, pure and soft, although not making a free lather with soap.

Flowing steadily from loose deposits, spring water is more liable to be free from injurious impurities than that derived from wells. Furthermore, springs are generally more favorably situated at distances from sources of pollution than are the wells. Where buildings occupy the higher ground in their vicinity pollution may occur, however, as indicated in the accompanying diagram. If the spring water is allowed to collect in a basin this should be carefully protected from stock, surface drainage and wind blown refuse.

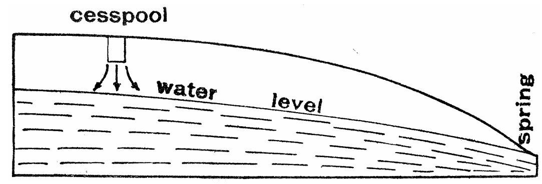

Figure 20. Diagram showing manner in which springs may be polluted by sub-surface drainage (From U. S. Geological Survey Water-Supply Paper No. 255).

WATERS FROM GLACIAL DEPOSITS.

Origin of deposits. The great Canadian ice sheets made at least three advances across this section of the state, as noted in Chapter II, from northeast to southwest, reduced much hard rock to flour and spread it over the bedrock in a sheet varying in thickness from a few feet to over 200. This deposit consists of tough, un-stratified clay, generally of a blue color, with sub-angular to rounded rock fragments, and is technically known as till. Stony portions of it have become much compacted and are popularly known as "hard pan," owing to the difficulty of penetrating it in sinking wells. While this great ice mill was at work reducing the rock to powder, streams of water beneath the ice, resulting from surface melting and rains, were assorting the deposits into gravel, sand and clay. The pebbles, rounded somewhat by mutual grinding, and the sand were arranged in layers in places favorable for deposition, and these were often subsequently covered by later till deposits. The finest sediment held in suspension by the glacial torrents was carried forward to the quiet bodies of water into which these streams drained forming the fringes of deltas, or being spread as a fine layer of clay over the lake bed. As has been described, beds of a similar nature resulted from the action of waves upon the till, the sand and pebbles during times of storm being tossed upon the beach, while the clay was carried lakeward into deeper and more quiet water. Although nearly the entire county was covered by these waters, the only extensive deposits of these glacial lake clays are found to the west and north of Detroit.

Water supply. Owing to the fineness of its pore space, lake clay and till usually contain much water but are so retentive that they act as impervious strata, yielding up little or none, but are still most valuable for confining the water bearing gravel and sand layers described. Owing to the distribution of these latter strata, the securing of a sufficient water supply is often difficult, uncertain and expensive, especially seen in the northeastern part of Van Buren, the northwestern part of Romulus and certain part of Dearborn townships. The following expressions of the farmers indicate their varying success in obtaining water from these deposits; "dry as a powder-house," "regular lake," "oceans of water," etc.

The rain water finds its way into these permeable beds of sand and gravel, often quite remote from the place at which they are tapped by the well and often at considerably higher levels. The result is that the water confined between two impervious beds of clay enters the well under head, which may bring the level to near the surface, or may even cause it to overflow. All such wells are now spoken of as "artesian" in which the water rises by hydraulic pressure, whether they flow or not. As the water generally comes from a greater distance and from a greater depth than that of wells previously discussed, its temperature is more uniform and the supply is more abundant and more constant. In general, also, the water is more highly mineralized, owing to its better opportunities for taking the minerals it encounters in solution. Of all those wells from which data were secured, 22 per cent were reported by the owners as soft and 78 per cent as hard. Where the water is drawn from just above the bedrock, it is sometimes highly charged with minerals, such as salt, sulphur, iron, etc., which characterize the waters from the rock itself, and the inference is that the rock water has mingled with that from the glacial deposits.

Non-flowing wells. The non-flowing wells generally vary in depth from 18 or 20 feet to 100 feet or more, 60 to 75 feet being a common depth. The shallower ones are dug and lined with stone or brick; the deeper ones are driven, bored, or drilled. In some instances no casing at all is used, the clay being firm enough to maintain the necessary opening to the water-bearing stratum. Owing to the considerable depth, heavy suction pumps are generally required and windmills are in common use. The deepest wells of this type are located in the northeastern part of Van Buren, northern Canton, northern Hamtramck, and southwestern Grosse Point townships, the maximum found having a depth of 182 feet. Owing to the nearness of bedrock to the surface in Monguagon and Brownstown townships, the wells of this class are necessarily shallow, many of them stopping just short of the rock in a bed of gravel. The height to which water will rise, with reference to the surface of the ground, depends on the head and the elevation of the ground at the mouth of the well, and each of these factors grows less toward the southeast. In the belts immediately surrounding the areas of flowing wells, to be next described, the water comes very near or quite to the surface and drops back from it as we pass to the east or the west. In the wells of this class from which data were secured, 80 per cent were reported hard and 20 per cent soft. When tightly cased to a level above ground, the wells are safe from contamination. If the casing is too short at the top, or if no casing at all is used, they may receive surface drainage and become a source of danger. The collecting areas of this water appear to lie in the high morainic regions to the west and north, as shown from the general diminution of head toward the south and east (see Pl. XXV). In a strip of territory extending northeastward from southern Canton and northeastern Van Buren townships, many of the deeper wells give much salt, which presumably is received from the underlying bedrock. A few data are here given concerning three of the most striking. It is likely that the Barker wells penetrated the Antrim shale without the driller knowing he had entered bedrock.

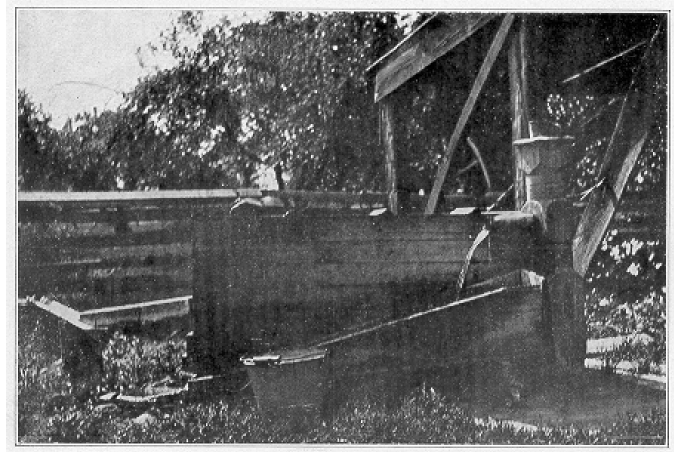

Plate XXVII. A. Flowing well from drift clay, Canton township.

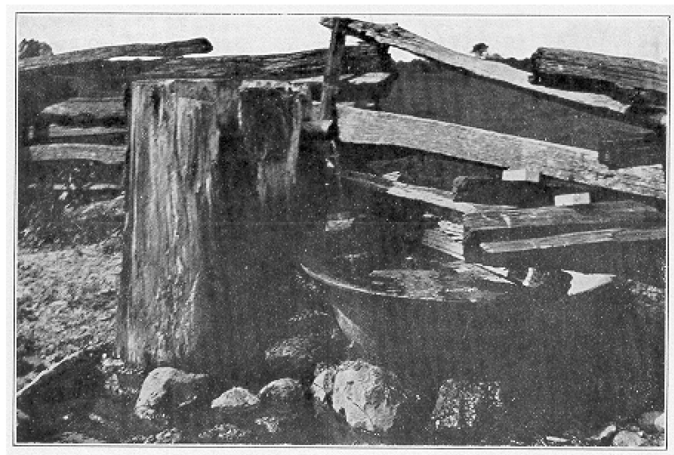

Plate XXVII. B. Primitive type of flowing well, Canton township. Flow greatly reduced by clogging or leakage.

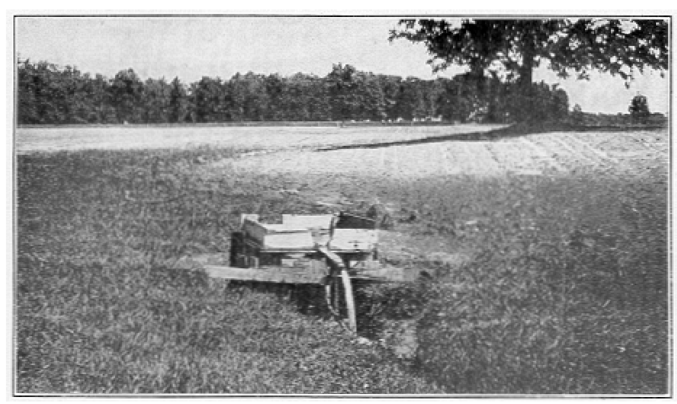

Plate XXVIII. A. Natural spring from delta of Middle Rouge.

The well of C. F. Bevernitz, NW. ¼ sec. 12, Nankin township, is 60 to 70 feet deep, the Antrim shale lying at a depth of 70 to 80 feet. The elevation of the mouth is approximately 635 feet. The supply is good, but there is too much salt in the water to permit its use; a tobacco pail full is said to have yielded, on evaporation, a pint of salt. There has been some gas in the well. The water lacks only 4 feet of reaching the surface, its actual head being about 631 feet.

Plate XXVIII. B. Spring of U. S. Fish Hatchery, Northville.

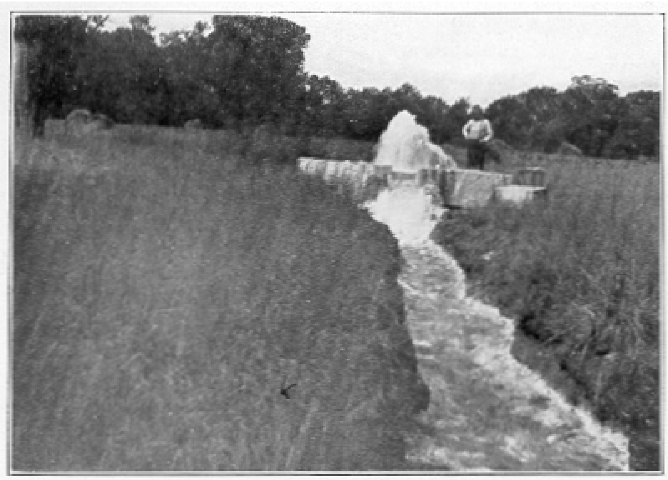

Plate XXIX. A. Swan well, Grosse Isle, in 1907.

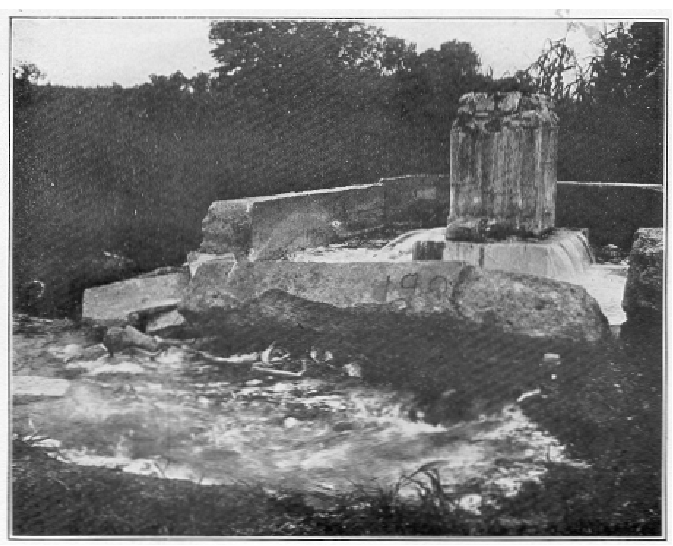

Plate XXIX. B. Swan well, Grosse Isle, after seven years of flow. Cement curbing destroyed by frost.

Edward Barker, NE. ¼ sec. 27, Canton township, has two wells, which were sunk to a depth of 108 feet in 1901. The Antrim shale is supposed to be from 100 to 110 feet from the surface. The approximate elevation of the mouth of the well is 657 feet and the head is—12 feet, giving the water level an elevation of 645 feet. Salt water was secured from near the bottom, 6 to 7 quarts yielding a teacup of salt. This water has been used for preserving pork and for killing thistles. The well was plugged below to shut off this supply and fresh water was used from a higher level in the well.

Plate XXX. A. Stratified lake clay deposit, Springwells township.

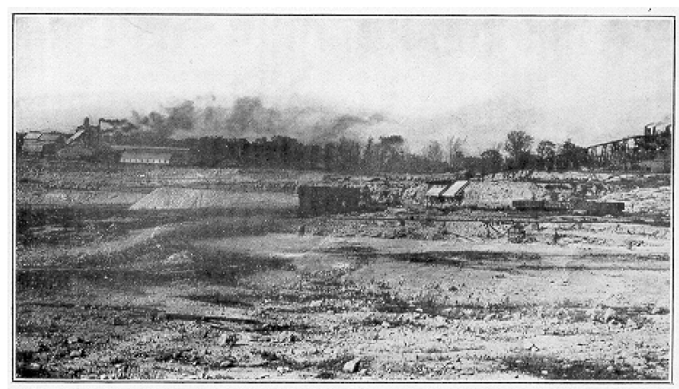

Plate XXX. B. Portion of Sibley quarry, crusher and lime kilns.

W. A. Wallace, SE. ¼ sec. 32, Canton township, has a bored well 70 feet deep. The Antrim shale lies at 80 to 90 feet. The elevation of the well mouth is 695 feet and of the water surface 687 feet. The water is secured from just over hardpan and is hard and salty, too much so to drink, but may be used for other household purposes. Cattle will drink it and require no other salt.

Some of these mineralized waters not so highly charged with salt are being put on the market for their medicinal properties and sold in Detroit by the gallon. One of these sources of supply is on the Rouge flats at Plymouth. It is owned by Dr. M. V. B. Saunders, of Detroit, and is advertised as the "Plymouth Rock Mineral Well." The depth is 74 feet, the first 25 feet of which were dug and the remainder drilled. The elevation of the mouth of the well is about 700 feet, and, as the rock surface here is believed to be from 630 to 640 feet, it is likely that the well penetrated the Coldwater shales. The water was said to have been secured from beneath an exceedingly hard 18-inch stratum. It is reported that 3,000 gallons are sold annually, and that it has been found especially efficacious in cases of rheumatism, kidney and bladder troubles. The following analysis, taken from the advertising circular, was made by Prof. John E. Clark, M. D., of the Detroit College of Medicine:

TABLE LI. ANALYSIS OF PLYMOUTH ROCK MINERAL WATER.

(*Parts per million*).

Potassium (K)	11.58
Silica (SiO_2)	8.57
Iron and alumina (Fe_2O_3: Al_2O_3)	29.76
Chlorine (Cl)	149.43
Sodium (Na)	124.01
Sulphate radical (SO_4)	4.31
Carbonate radical (CO_3)	192.95
Calcium (Ca)	24.22
Magnesium (Mg)	14.36
Organic and volatile	22.25

Carbonic-acid gas and carbonate of lithium present, but not estimated. A similar well near the above is owned by H. P. Peters and has a depth of 80 feet, possibly also reaching bedrock. The water is said to have originally flowed, and has been put on the market as "Hydrocarbon Mineral Water." Bubbles of gas, apparently carbon dioxide, are continually rising to the surface.

Flowing wells. When the head or pressure with which these waters enter the wells is sufficient, the water reaches the well mouth and overflows. Three disconnected belts of such flowing wells cross Wayne County, being the continuation of similar belts in Monroe and Washtenaw counties. One of these belts begins in the northwestern part of Van Buren township (secs. 3, 4, 5 and 6), extends northward across Canton, with a breadth of 2 to 3 miles, reaches into sec. 34 of Plymouth, and continues into the western part of Livonia township. The belt is not continuous, and all of the wells that are still flowing lie to the east of the gravel ridge formed by the waters of glacial Lake Whittlesey and known as the Whittlesey beach. This is due to the fact that the water does not have sufficient pressure to reach the level of this beach, which is about 740 feet above sea level. The artesian head in Wayne County ranges from 680 feet above sea level to about 730, but farther north in Farmington township, Oakland County, rises to 760 feet. A second belt of flowing wells, artesian head 580 to 600 feet, lies in the eastern part of the county, extending from the vicinity of Flat Rock northeastward through Brownstown, Ecorse and Taylor, into Springwells, where it is interrupted by the Detroit moraine. In the northeastern part of Grosse Point township, the belt again appears and continues along the lake shore into Macomb County. It is this belt, especially that portion of it near the Huron, that has suffered great loss of head and volume. Between these two lies the third belt entering Huron township from Exeter and Ash townships of Monroe County although most of the wells have ceased to flow during the past decade. In looking northward for the continuation of this middle belt there is some doubt as to its course. Probably the area immediately to the west and north of Wayne continuing northeastward into Bedford, across northwestern Dearborn, should be connected with those in the Willow-Waltz district, although the head is some 20 feet higher about Wayne and we should expect the belt to have a more northeasterly course.

The average temperature of the wells of the county as measured in May and June, is 52° F., or slightly less, but some show a rise of 1° to 3° in the fall, owing to the effect of the summer heat on pipes through which they slowly discharge. It is probable that if the bottom temperature were taken it would be found to be more constant, especially in the case of the deeper wells and wells with a weak flow. In these, the waters are either warmed or cooled as they approach the surface, except at times of year when the surface temperature corresponds closely with the temperature of the bottom of the well.

To the farmers, these wells are a great saving in time and expense of pumping (see Pl. XXVII, A and B) while the low summer temperature and constant flow are of great service in caring for milk in the dairy. The tanks do not ordinarily freeze over in winter and are thus available for the stock. The wells are about equally divided between hard and soft water, some of unusual softness occurring at Dentons, where they take the place of cistern water.

The two following partial analyses, furnished by M. O. Leighton, of the United States Geological Survey, show the relative composition of drift and rock waters at Dearborn:

TABLE LII. PARTIAL ANALYSES OF DRIFT AND ROCK WATERS AT DEARBORN.

(*Parts per million*).

	1.	2.
Color	32	32
Iron (Fe)	Trace	2
Chlorine (Cl)	19	15
Carbon dioxide (CO_2)	87.94	97.61
Sulphur trioxide (SO_3)	86	522

S. J. Lewis, analyst. 1. A. Wagner; depth, 28 feet. 2. A. Wagner (rock); depth, 115 feet.

These waters are said to produce only a very little scale in the tea kettle, even after several years' use. Simple tests show slight traces of salt, iron, and lime carbonate, but no lime sulphates, or but a trace. This condition of the water may be due in part to continuous leaching, the result of which would be to change flowing wells from hard to soft. The breaking in of new veins might, however, suddenly change the water from soft to hard. The water in the eastern belt is almost invariable charged with either iron or sulphur, along with the other minerals commonly present, owing to the nearness of bedrock. The pressure is generally low and sufficient only to elevate the water a few feet above ground level, but is somewhat greater in the western district. In the Penny well, sec. 3, Canton township, there is a strong flow which will rise 12 feet, thus having an elevation of about 727 feet above sea level. Most other wells in the western part of this belt indicate an artesian head of 710 to 720 feet, which, as a rule, drops to the southeast more rapidly than does the surface slope of the land, ranging from 6 to 12 feet to the mile within the belt. Most of the flowing wells in the eastern belt are from the bedrock, and thus belong to the class next to be described. The similarity in the character of the water would indicate that the western wells derive their supply and head from the same source, and hence that the eastern and western belts of flowing wells are genetically distinct, the western coming from the drift to the north and west and the eastern from bedrock. Table LIII shows the chief characteristics of this group of wells.

TABLE LIII.—FLOWING WELLS IN DRIFT, WAYNE COUNTY.

Township S.	Range E.	Section.	Quarter.	Township.	Owner.	Depth.	Quality.	Temperature.	Size of flow.	Head.		Elevation.	Remarks.
										Maximum.	Present.		
						Feet.		°F.	Inches.	Feet.	Feet.	Feet.	
1	8	34	NW.	Plymouth	S. Bennett	70	Soft	51	[illegible]		0.7	720	Small amount of salt.
2	8	3	NW.	Canton	O. F. Penny	86	Hard	51.5	[illegible]	+12	3	715	Will flow a 2-inch stream.
2	8	4	NE.	Canton	E. Everett	35	Hard	51.5	[illegible]	+5	2.5	708	Some salt.
2	8	8	NE.	Canton	G. S. Bonsteel	28	Soft	52	[illegible]	+8	3	711	Has flowed 3.5-inch stream.
2	8	8	SE.	Canton	H. O. Hanford	30-35			[illegible]	+2.5		708	Strong in iron.
2	8	9	NW.	Canton	Mrs. D. Schrader	50-60	Hard	60	[illegible]	+2	2	708	Waters 75 head of cattle.
2	8	9	NW.	Canton	J. Quartle	28	Soft		[illegible]	+9	3	711	Made in 1868; contains salt.
2	8	31	NW.	Canton	S. Goddell	70	Soft	50	[illegible]	+4	2	715	Used in dairy and laundry.
2	8	30	SE.	Canton	J. Smith Estate	50-60	Soft		[illegible]	+2		689	Free from iron.
2	8	32	SE.	Canton	J. F. Duntley		Soft	51	[illegible]		2	692	Used in dairy.
2	8	33	SE.	Canton	J. E. Betts	30	Hard	51			1	685	Not affected by drought.
2	8	33	SE.	Canton	G. Kissane		Hard	55	[illegible]		1.5	686	Running 15 years.
3	8	4	NW.	Van Buren	J. Couch	63		53	[illegible]		3	696	Used in dairy.
3	8	4	NW.	Van Buren	W. Deyo	42		51	[illegible]		2	693	Once flowed 49 gallons a minute.
3	8	4	NE.	Van Buren	A. Kruger	75	Soft	51.5	[illegible]		3	690	Used in laundry.
3	8	4	NE.	Van Buren	C. Nass	70		52	[illegible]		2	690	
3	8	4	NE.	Van Buren	A. Gunther	72		50		+4		688	Running 14 years.
3	8	5	SE.	Van Buren	W. H. Burrell	70	Soft	51	[illegible]		3	698	Used in laundry.
3	8	5	SE.	Van Buren	F. Van Tassel	48	Hard		[illegible]	+12	4	696	Has flowed 1.5-inch stream.
3	8	6	NE.	Van Buren	I. Glass	76	Soft	51	[illegible]	+2.5		705	Used in laundry.
3	8	6	NE.	Van Buren	C. Shlicht	72	Soft		[illegible]		1	706	Denton village.
1	9	18	SE.	Livonia	W. Hake	50	Medium	51			1	690	Would flow 1-inch stream.
1	9	17	SW.	Livonia	R. L. Alexander	45	Hard	50.5	[illegible]	+4	2.5	693	From gravel over bedrock.
1	9	19	NE.	Livonia	O. Melow	55	Soft		[illegible]	+12	1	680	Has flowed 2.5-inch stream.
2	11	18	SE.	Springwells	Detroit Brick Co.	80	Hard	51	1½		4	590	Flows 90 barrels a day.
2	11	20	NW.	Springwells	L. Maples	67.5	Hard	52	[illegible]		3	595	Strong in sulphur.
3	11	14	SE.	Ecorse	J. Porout	78			Trickle	+4	.5	596	Contains sulphur.
5	10	5	SE.	Ecorse	R. Smithson	28		51	1	+25		588	Iron but no sulphur.

The village of Wayne recently purchased five acres of the Kissane property, near the center of sec. 33, Canton township, and put in a test well to the depth of 120 feet, without reaching rock. A heavy vein of water was struck in a gravel stratum at a depth of 63 feet and a flowing well secured. The water is of medium hardness and shows no especial mineral substance. The pumping test conducted by Biggs and Sherman, engineers of Toledo, indicated an available daily supply from this one well of 150,000 gallons.

The following partial analysis of an unusually soft water from the parsonage well (depth 75 feet) near Denton, in the western part of the county, has been furnished by M. O. Leighton of the United Slates Geological Survey. The water tested is one of the softest in the state.

TABLE LIV. PARTIAL ANALYSIS OF WELL WATER AT DENTON.

	Parts per million.
Color	10
Iron (Fe)	Trace
Chlorine (Cl)	8.75
Carbon dioxide (CO_2)	97.61
Sulphur trioxide (SO_3)	.29 (?)
Hardness	56.1

The following partial analysis of the well water at the Commercial Hotel at Wayne is furnished by M. O. Leighton, of the United States Geological Survey.

TABLE LV. PARTIAL ANALYSIS OF WELL WATER AT COMMERCIAL HOTEL, WAYNE.

	Parts per million.
Color	19
Iron (Fe)	Trace
Chlorine (Cl)	15
Carbon dioxide (CO_2)	99.81
Sulphur trioxide (SO_3)	88

S. J. Lewis, analyst. Depth of well, 14 feet.

Boiling springs. The western half of Plymouth and nearly the whole of Northville townships are covered with ridges and knolls of till, interpersed with similar masses of stratified gravel and sand, giving a very rough aspect to the country. The features are those of a moraine formed at the ice margin during a temporary halt in its general eastward retreat. The glacial lake waters subsequently covered the lower knolls lying to the east, but elsewhere the original roughness left by the ice has been very largely retained. Securing water from these clay knolls and ridges by means of wells is as difficult and uncertain as on the clay plains to the east and at times becomes impossible. The deposits of sand and gravel, however, serve as reservoirs for water, and, owing to their extent and height to the north and west, frequently yield large quantities under pressure. Along the hill slopes and in the valleys heavy natural flows occur, giving rise to what are known as "bold" or "boiling" springs. They differ from the seepage springs in that they have "head," and a generally stronger flow, are subject to less variation, show a steadier temperature, and yield a harder water. In numerous cases, the waters are piped to dwellings and barns and yield an ideal supply, as on the Starkweather place in the southwest part of Northville township, where a spring located in the NW. ¼ sec. 8, is piped to the house, having a fall of 16 feet, delivering a 1-inch stream and keeping 5 troughs supplied with most excellent water for stock. This water contains considerable calcium carbonate, a very little salt, and gives no reaction for calcium sulphate.

Two similar springs are utilized by the United States fish hatchery at Northville (Pl. XXVIII, B). After cleaning in 1896, the flow from the large spring was somewhat more than 500 gallons a minute, but has been gradually declining since. In the fall of 1904, a second cleaning failed to increase the flow much. According to the earlier reports, the temperature was 47° F., but is now 48°, with only slight variation from season to season. This is the coldest water observed in any part of the county. It is rendered hard by considerable calcium carbonate, but gives no reaction for salt or gypsum. Immediately beneath the hatchery building is a second spring which has yielded 136 gallons a minute and has a temperature of 48°. There are two flowing wells having a depth of 106 feet, which yield 1½ and 2 gallons a minute, with a temperature of 50°, but the water contains sulphur and iron and is destructive to both eggs and fish.

The villages of Northville and Plymouth are favorably situated for utilizing similar flows from springs sufficiently elevated to give the necessary pressure without pumping. The water is cold and pure; is rendered hard by calcium carbonate; gives no reaction for gypsum, and only a slight one for salt. The supply is sufficient except during times of prolonged drought. The water is not metered and no estimates are kept of the amount used. Neither of the villages is supplied with sewers, the drainage being good in both eases. The plants are owned and operated by the villages themselves. Northville, with a population of 1665 draws its supply from two springs in Oakland County, about 4 miles distant. The springs are about 1,000 feet apart and empty into a small receiving basin, from which the water flows by gravity, with slight fall, to a reservoir overlooking the village and 100 feet above it. The village of Plymouth, with a population of 1671 has a system similar to that of Northville, its springs being in the NE. ¼ sec. 8, Northville township, in the bottom of an old drainage channel from the ice sheet. The village has here purchased an acre of land on which an excavation 50 by 60 by 6 feet has been made, lined with cobble, and surrounded by a high wire fence. From this the water flows by gravity to a reservoir, which is located 2 miles from the village and 103 feet above it. Both of these villages made the mistake of first putting in vitrified crock instead of iron piping and this had to be replaced with the latter at great expense.

WATERS FROM THE BEDROCK.

Geological formations. Beneath the mantle of clay, sand, and gravel, resulting from the joint action of wind, water and ice, there lies a series of stratified rocks, consisting of sandstone, shale, limestone and dolomite (see Pl. XXV). These have been described in detail in Chapter VI of this report and only a brief summary need be given here. Formed in the sea, in approximately horizontal layers, they were early upheaved and tilted, so that their edges have a general northeast trend in Wayne County, and the beds themselves dip to the northwest at the rate of some 25 feet to the mile. They still retain some of the minerals belonging to the concentrated brines of the primitive seas, and others deposited at the time the rocks were forming, or subsequently. These beds supply a limited part of the county with a more or less highly mineralized water, much of which flows, but some of which must be pumped. The youngest and highest of this series of beds in Wayne County cuts across the northwest corner. It consists of shales, with some sandstone, and is known in the state as the Cold-water shale (Waverly and Cuyahoga). Beneath this lies the dark Antrim shale (Genesee), generally yielding gas and faint traces of oil. Next in order come the bluish beds of shale and limestone, making up the Traverse group (Hamilton), and frequently referred to as "soapstone;" beneath which lies a solid, light-gray limestone known in the state as the Dundee (Onondaga). Below this limestone is a drab dolomite, the Monroe group ("Lower Helderberg"), which drillers do not ordinarily separate from the preceding. Embedded in it and of the same geologic age is the so-called Sylvania sandstone, a pure glass sand, cutting across the extreme southeastern part of the county; this is the oldest of the formations reached directly beneath the clay in the county. Still older and lower, however, and coming near the surface in Monroe County and bordering parts of Ohio, lie, in order, the Monroe beds below the Sylvania sandstone, the Salina, Niagara, Medina, Hudson, Utica and Trenton, the last being the oldest bed reached by borings in the county.

Flowing wells. The wells of this class comprise most of those in the eastern belt described above. They are heavily mineralized, as a rule, and frequently rendered rank by sulphur and iron. The average temperature is 51.4°, as compared with 52° for the flowing drift wells, but rises slowly as the water comes from greater depth. Theoretically the temperature should be still more constant than in the drift wells, but it must be affected in the same way and to the same extent as it rises to the surface. With reference to the level of the ground the head is generally slight, ranging from a mere rise to the surface to 15 and 25 feet above in exceptional cases. At Dentons, in a well along the railroad track, the water is reported to have reached the second story of a building, indicating its rise to about 715 feet above sea level. The Swan well on Grosse Isle is the easternmost of the flowing wells in the county and has a head of 597 feet. Measured between these two extreme wells, the average reduction in head toward the southeast is 5.6 feet to the mile. Between the Flat Rock wells and those on the lake shore, the average reduction per mile is 3.5 feet. Although the rock strata are dipping to the northwest, these facts indicate that the source of supply is to the west, as pointed out by Fuller in his report on the failure of wells along lower Huron River (p. 37). In his investigation of the wells of this region, he found the average reduction in head of the wells about the Swan Creek-Rockwood district to be about 3 feet per mile to the eastward.

Table LVI gives the principal data concerning the flowing wells from bedrock. The most wonderful of the entire set is the Swan well described by Fuller (pp. 43-44), which flows 3,000 gallons a minute, or 4,320,000 gallons a day—enough to supply several times over the entire river front from Trenton to Detroit.

The following analysis shows the composition of this water.

TABLE LVI. ANALYSIS OF WATER FROM JAMES SWAN'S WELL ON GROSSE ISLE.

(*Parts per million*).

F. K. Ovitz, Ann Arbor, analyst, Jan., 1905.

Silica (SiO_2)	188.00
Iron and alumina (Fe_2O_3, Al_2O_3)	14.00
Calcium (Ca)	5,082.96
Strontium (Sr)	317.00
Magnesium (Mg)	730.57
Sodium (Na)	216.78
Potassium (K)	79.68
Sulphate radical (SO_4)	14,245.21
Carbonate radical (CO_3)	871.35
	21,745.55

It was the original intention of the owner to market the water under the trade name "Kathairo" but this was done for but a short time. When the water is fresh, there is a pronounced flavor of sulphur which does not appear in the above analysis. In 1905 a strong flow of sulphur water (temperature 52.3°F.) was struck at Dearborn, upon the River Rouge flats (NE. ¼ NE. ¼ sec. 21), at a depth of 108 feet and penetrated 182 feet, the water rising to a height of some 30 feet above the mouth of the well in the casing, and indicating a head of 635 to 640 feet above sea level. The well is capped but the casing is leaking and indicates no loss in pressure, suggesting that the flow is truly hydrostatic and not due to gas pressure as originally supposed.

TABLE LVII.—FLOWING WELLS FROM BEDROCK, WAYNE COUNTY.

Township S.	Range E.	Section.	Quarter.	Township.	Owner.	Depth.	Geologic horizon.	Character of water.	Approximate elevation.	Diameter of discharge pipe.	Temperature.	Depth of rock.	Remarks.
						Feet.			Feet.	Inch.	°F.	Feet.	
3	8	6	NE.	Van Buren	Bandy	125	Coldwater	Soft	705			81	Village of Denton.
2	8	28	NE.	Canton	M. Carleton	140	Antrim	Salt and iron	682	(a)		70	Gas; not usable.
2	11	18	SW.	Springwells	A. Lapham	129	Traverse	Hard	588	1/4	52	100	Recently ceased flowing.
3	10	34	SW.	Taylor	J. Shetrum	86	Corniferous (b)	Sulphury	603			83	Now rises 4 feet.
2	11	4	SW.	Springwells	J. C. McDonald	250	Corniferous	Hard	605	3/4	53	125	Rank in iron and sulphur.
3	11	30	SW.	Ecorse	Beaubien	64	Corniferous	Hard	587	1/4	51	64	Strongly mineralized.
3	10	35	NE.	Ecorse	Unger		Corniferous	Hard	598	1/4	51		Minerals abundant.
4	10	13	SE.	Monguagon	Duman	30	Corniferous	Hard	580	1/2	52	2	Strongly mineralized.
4	10	25	NW.	Monguagon	E. Lathrop	12	Corniferous	Sulphury	578	3/4		10	
4	10	3	NE.	Brownstown	Clark	68	Corniferous	Hard	597	1/8	51		Mineralized.
4	10	3	NW.	Brownstown	G. McDonald	76	Corniferous	Hard	602	1/8	52	76	
4	10	4	NE.	Brownstown	J. G. Carson	65	Corniferous	Hard	603	1/8	51		Strongly mineralized.
2	10	1	SW.	Dearborn	W. Robertson	357	Monroe	Hard	611	1/4	52	100	Rank in sulphur.
2	11			Ecorse	Detroit Salt Co.	1,096	Monroe	Sulphur	582			95	Sulphur water at 223 feet.
2	11			Ecorse	Brownlee & Co.	1,200	Monroe	Sulphur	578			82	Strong sulphur vein at 168 feet.
2	10	21	NE.	Dearborn	Dr. T. V. Law	290	Monroe	Sulphur	605	8		108	Head 635 to 640 ft.
5	10	8	NE.	Brownstown	B. Hall, Sr.		Monroe	Hard	587	1/2	51		Iron and sulphur; little salt.
5	10	9	NW.	Brownstown	E. T. Wood	22	Monroe	Hard	587	1/2	55	22	Iron and sulphur; little salt.
5	11			Grosse Isle	J. Swan	2,375	Trenton	See analysis	575	13	52	17	Flows 50 gallons a second; head 597 feet.

(a) Trickle. (b) Corniferous (Dundee.)

The deep wells about the mouth of the Rouge will flow if permitted to do so, giving a type of water strongly mineralized and rank in sulphur. Two samples of such water from the Oakwood salt shaft have been analyzed in the laboratory of the Bureau of Mines, Department of the Interior, Washington. The first is of the cold water as it comes from the rock, before it has had an opportunity to become heated by mingling with the steam. The second analysis is of the hot water as it flows from the pipe at the mouth of the shaft. The depth of the first sample is not given, probably between 480 and 533 feet, the latter depth being the greatest at which water now enters.

TABLE LVIII. ANALYSIS OF WATER FROM OAKWOOD SALT SHAFT.

Analyst A. C. Fieldner, Bureau of Mines.

(Parts per million).

	Cold.	Hot.
Total solids at 105°C.	4785	9520
Loss on ignition	389	933
Silica (SiO_2)	16	14
Alumina (Al)	5	9
Iron (Fe)	3	9
Calcium (Ca)	727	927
Magnesium (Mg)	217	310
Sodium (Na, as alkali)	502	1848
Sulphate radical (SO_4)	1990	1937
Chlorine (Cl)	1117	3880
Hydrogen sulphide (H_2S)	249	43

The head of the combined flows here was found to equal 20 feet above the surface, or about 595 feet above sea level. By the time 420 feet of depth was secured, the total flow into the shaft was estimated by the engineer, Mr. Eugene Bradt, as 2,000,000 gallons a minute, or about 1-47 of that of Detroit River. A more detailed description of the various veins encountered in this remarkable undertaking will be found in the chapter following. Compared with the water of the Swan well, the salt shaft water is seen to be less heavily mineralized. This may be due to the partial leaching of the neighboring strata in consequence of the excessive flow from them during the past five years. The first heavy flow in the Swan well was encountered at 420 feet and a still heavier one at 450, corresponding very closely to that of the salt shaft. The head of the water in the two cases is so nearly the same (595 and 597) that a close connection between the veins may be inferred. In passing northwestward towards Dearborn, the head rises to 635 or 640 feet, a gain of 40 to 45 feet, or somewhat less than 8 feet to the mile, the water being encountered some 160 feet higher in the rock series. Whether we assume that these two flows are connected, or not, we must look to the northwestward for their source, the most probable collecting area being the high morainic strip of country passing NE.-SW. across Washtenaw and Oakland counties. The rock surface here rises from 700 to 800 feet, above sea level, and reaches 900 feet in western Washtenaw and Livingston counties.[8] The water may be assumed to find its way through the drift cover to bedrock, entering through joints and fissures, and working its way to lower levels across the strata, dissolving minerals en route, is ready to escape under great hydraulic pressure whenever an artificial opening is afforded. Not being confined to a single, pervious rock stratum, as is generally the case, makes the obtaining of such artesian flows at any given point a decidedly uncertain matter.

At the plant of the Murphy Power and Ice Co., corner Wayne and Congress streets, Detroit, four wells have recently been put in to a depth of 275 to 300 feet. Rock was struck at about 100 to 110 feet (about 490 feet above sea level), from which a flow of sulphur water was obtained. A much heavier vein was reached at a depth in the limerock (dolomite) of 170 to 200 feet, rising to within about 15 feet of the surface, where the elevation is about 595 feet above sea level, thus showing 580 feet as its head. Tests relative to the amount of flow from the wells indicated a possible 1000 to 1200 gallons per minute. The temperature of the water is 52 °F., especially adapting it to use in the condensers.

Springs. In the Brownstown region of flowing wells, there are numerous natural flows charged with iron, sulphur, calcium sulphate, calcium carbonate, and sometimes considerable salt. These are most numerous along Huron River, from Flat Rock to Lake Erie and northward to Gibraltar. The water is generally too rank for use and is believed to come from bedrock, having made for itself a natural channel through the clay. Such springs are found in Brownstown as follows:

T. 4 S., R, 10 E.; NE. ¼ sec. 28, SW. ¼ sec. 30, SE. ¼ sec. 31, NE. ¼ sec. 36.

T. 5 S., R. 10 E.; SW. ¼ sec. 5, NE. ¼ sec. 9, SE. ¼ sec. 13, NW. ¼ sec. 1, eastern and; southern portions of sec. 24.

An analysis of the "Wyandotte White Sulphur Springs," the location of which is unknown to the writer, is given by Peale[9] and is quoted by Lane.[10]

Non-flowing wells. The principal facts relating to the non-flowing wells from rock have been grouped together in table LIX from which the character of the water from the various geologic horizons may be seen at a glance. The water is generally hard and highly mineralized, in a few cases only being reported to be soft. Time did not permit the securing of records of the temperatures of the water of these wells, but owing to the fact that it stands more quietly in the pipes, frequently not far from the surface, it is undoubtedly more variable than in the artesian wells. The head of these rock waters also drops as we pass eastward. The following analysis of the water from an 850-foot well at the Wayne County Infirmary at Eloise shows how heavily charged with minerals these waters may become. The well was drilled for gas by C. C. Nims. The Traverse group was struck at 130 feet (the elevation of the well mouth being about 625 feet) and yielded a flow of fresh water. The well passed through this formation and the underlying Dundee (Corniferous) and entered the Monroe group, from which a strong brine was secured, with some suggestions of oil. The analysis was made by Dr. S. P. Duffield, of Detroit, April 18, 1888.

TABLE LIX.—NON-FLOWING WELLS IN BEDROCK, WAYNE COUNTY.

Township S.	Range E.	Section.	Quarter.	Township.	Owner.	Depth.	Geologic horizon.	Character of water.	Approximate elevation.	Head.	Depth to rock.	Remarks.
						Feet.			Feet.	Feet.	Feet.	
2	8	27	NE	Canton	B. Barker	132	St. Clair	Very salty	677	−12	100	"Water will support an egg."
1	9	35	NW	Livonia	C. Kinney	80	St. Clair	Fresh	636	−8	70	Considerable gas.
1	9	24	SW	Livonia	F. Schroeder	160	St. Clair	Medium	635	−25	65	Water abundant.
2	9	15	SW	Nankin	C. Schultz	97	St. Clair	Rather soft	652	−2	77	Some gas at first.
2	9	10	NE	Nankin	W. Dickinson	110	St. Clair		639	−4	50	Some little gas.
1	10	22	SE	Redford	J. F. Chavey	82	St. Clair	Hard	628	−17	73	Flowed at first; some gas.
1	10	25	NW	Redford	A. David	116	St. Clair	Salt and sulphur	630	−10	72	Heavy gas flow at 114 feet.
1	10	23	NE	Redford	J. F. Stahelin	93	St. Clair	Hard	633	−6	80	Still yields gas.
1	10	13	NW	Redford	G. Miller	107	St. Clair	Medium	647	−30	80	Considerable gas.
1	11	1	SW	Greenfield	C. and E. Roberts	127	St. Clair	Very soft	632	−14	124	Iron and gas; good supply.
1	11	11	SW	Greenfield	Log Cabin dairy	126	St. Clair	Salt and magnesia	643	−26	90 (?)	Five wells about the same.
1	11	13	SW	Greenfield	Stevens estate	156	St. Clair	Hard	640	−12		Heavy flow of gas at first.
1	12	8	NE	Hamtramck	W. S. Thomas	163	St. Clair	Hard	628	−19	146 (?)	Salty; gas at 100 feet and 158 feet.
1	12	15	NE	Hamtramck	Store	137	St. Clair		623	−20	130	Used in greenhouse; little gas.
1	12	9	SW	Hamtramck	E. A. Norris	170	St. Clair	Salt	627	−25	160+	Some gas.
1	12	16	NW	Hamtramck	H. Arbeter	162	St. Clair	Salty	627		140	Little gas.
1	12	12	SW	Hamtramck	G. Brinckman	147	St. Clair	Soft	615	−8	130	"Good as cistern water."
1	12	15	SE	Grossepoint	J. Brinckman	143	St. Clair	Sulphury	615	−12	138	Neither salt nor gas.
1	12	15	SE	Hamtramck	Pelky	141	St. Clair	Soft	615	−8	140	"Regular river of water."
1	12	23	NW	Grossepoint	J. S. Sullivan	260	St. Clair	No water	600		160	Some oil and gas.
1	13			Grossepoint	A. K. Kiefer	133	St. Clair	Hard	586	−7	110	On lake shore; some salt.
1	13			Grossepoint	Claire View farm	162	St. Clair	Salty	587	−12	112	Abundant; near lake shore.
3	8	11	NW	Van Buren	Wm. Stirling	160	Traverse	Soft, milky	680	−17		Sulphur and iron; stock only.
3	8	21	SE	Van Buren	S. Campbell	183	Traverse	Magnesia	678	−18	99	Belleville; good flow at 99 feet.
3	8	24	SW	Van Buren	Sanitary works	250	Traverse	Salty	660		175	Well abandoned.
2	10			Dearborn	Arna Mills	140	Traverse	Sulphury	620	−30	140	Not usable in dyeing.
1	8	26	SW	Plymouth	Plymouth well	280	Traverse	Salt	730	−2	100	One vein rose 2 feet above surface.
1	10	5	NW	Redford	Rodgers	336	Dundee (Corniferous.)		640	−3	90	Flows at 94, 150 and 200 feet.
2	9	28	SW	Nankin	Wayne	305	Dundee	Sulphury	638	−60	157 (?)	Water at 220 feet; some gas.
2	12			City	Detroit	268	Dundee	No water	600		127	Old test well in 1829.
2	12			City	Sanitarium	307	Dundee	Sulphury	595		120	Strong mineral water.
3	8	17	NE	Van Buren	D. L. Quirk	383	Monroe		703		100	Water only at bottom.
2	9	26	SW	Nankin	County House	850	Monroe	Salt	625	−9	130	Fresh water over rock.
1	12	5	NW	Hamtramck	C. Krause	996	Monroe		635		180	Gas reached at 100 feet.
3	9	12	NW	Romulus	E. Twark	1,820	Niagara	Salt	632	−18	95	Fresh vein at 125 feet; sulphur at 220 feet.

TABLE LX. ANALYSIS OF WATER FROM SALT WELL, WAYNE COUNTY INFIRMARY, ELOISE.[11]

	Parts per million.
Calcium (Ca)	9,714.65
Carbonate radical (CO_3)	3,970.25
Magnesium (Mg)	150.17
Sulphate radical (SO_4)	12,354.88
Chlorine (Cl)	40,214.11
Sodium (Na)	25,354.54
Total solids	91,758.60
Hydrogen sulphide	405.00

These highly charged mineral waters are used for bathing purposes at two places in Detroit—the Clark Riverside Bath House and the Detroit Mineral Bath Co. Along Detroit River from Delray to Trenton, artificial brines are made by forcing water to the salt beds of the Salina series, where they dissolve the solid rock salt and flow to the surface. The salt is then secured by evaporation or used in the manufacture of soda, soda ash, and bleaching powder. The most promising horizon for securing a supply of fresh water is the Sylvania sandstone, a porous bed of pure sand-rock holding an abundance of water. Although fresh, it is liable to contain sulphur and iron, carried up from, the dolomites of the underlying Monroe group. In the northern part of Monroe County and the southern part of Brownstown township, this bed lies immediately beneath the clay and furnishes an abundance of good water. In the 7 miles to Trenton it drops to 280 feet below the surface, or at the rate of about 40 feet to the mile. Toward Wyandotte the bed thickens, with practically no dip, and in the Eureka well it was reached at 230 feet, while in a well of the Michigan Rock Salt Company, at Ecorse, it was reached at 220 feet. Beyond Ecorse, it drops rather rapidly again, having an average thickness of 99 feet in ten wells of the Solvay Company at Delray.

WATER DECLINE IN LOWER HURON REGION.

Facts relative to decline. During the past twenty years, or more, a marked decline in the volume and head of the well water of the lower Huron region has been in progress, causing great annoyance and much expense to the farmers of the localities involved. This is in striking contrast with the belt of flowing wells in the western part of Wayne County where the only reduction observed may be reasonably ascribed to accumulation of sand and defective casing; difficulties that are rather easily remedied. In the lower Huron region, however, from the vicinity of New Boston to Lake Erie, the wells appear to have been flowing too near the level of their head and. over a strip 5 to 6 miles broad, upon either side of the river, have virtually ceased to flow. The loss of head during the past ten years averages from 5 to 10 feet and, in regions where flowing wells could be counted by hundreds, scarcely a one remains (see Pl. XXV). To the south of the Huron in Monroe County a careful survey of the flowing well districts, made during the summer of 1911, revealed the fact that not a single well now reaches the general surface and but five still remain flowing upon flats from 3 to 5 feet below the general level. North of the river, very exceptionally a genuine flowing well may still be found, but giving only a greatly reduced flow under low head. The wooden casing projecting above ground with its succession of holes tells the pathetic story. Although the decline has been continuous over a long period it does not appear to have been gradual. A very marked reduction occurred in 1904 and led to an investigation of the probable causes by Myron L. Fuller, of the U. S. States Geological Survey.[12]

Fuller's investigation. The data gathered for this report were obtained in the main from Monroe County, adjacent to the Huron, the region north of the river, between Rockwood and Detroit River, then showing comparatively little shortage. Since then, however, every well in this section upon the general level has ceased to flow, some of them as late as August, 1911. Evidently the causes are still operative and before discussing what these appear to the writer to be, it will be of interest to the reader to learn the conclusions of Fuller as presented in his report.

"The general decline which has been going on for many years is probably due to a gradual and far-reaching change of conditions, such as deforesting of the land, improvement in surface drainage, etc., but the rapid decline of the last two seasons is doubtless due to local causes acting with special force in the region in question."

Grosse Isle well.—"That the Grosse Isle well (see Pl. XXIX, A and B) is the cause of the special decline in 1903 and 1904 may at first thought seem well sustained by the behavior of certain wells, as J. E. Brown's of the Swan Creek and Charles Bancroft's of the Rockwood district, which went dry when the big flow of the Grosse Isle well first began in 1903, but returned soon after the insertion of the casing, only to cease again after its withdrawal in May, 1904. This interpretation, however, seems opposed by the fact that numerous other wells much nearer Grosse Isle maintained nearly their usual flow, those nearest, even those on Grosse Isle itself, showing no decrease whatever. The conditions of underground drainage would need to be very exceptional, which would leave a nearby district unharmed while seriously affecting more remote districts, and belief in them would need be supported by indisputable evidence in the altered slope of the water table. In order to obtain light on this point the height to which water will rise was platted for each well in the Swan Creek-Rockwood region. It was found that this height showed an increase westward which averaged about 3 feet to the mile, indicating a source from that direction. The increase of head to the west or decrease to the east was found to be quite regular, with no local lowering or reversed slope that could be referred to a strong intake at a particular place. It was also found that the water level of the Grosse Isle gusher is higher than that of the shallow wells around it, and even higher than that of the wells of the Rockwood and eastern portion of the Swan Creek area, being 25 feet above the lake, or 597 feet above the sea, while the normal level in many of the wells which have been thought to feed it is several feet lower, in some of them being less than 590 feet. It would appear, therefore, that if any connection exists between the Grosse Isle well and the shallow wells in the Rockwood and Swan Creek areas the water would be forced up in the shallow wells rather than drawn away from them. The failure of such wells as the Brown and the Bancroft flows in 1903 was probably a mere coincidence. The precise point where the main water-bearing bed of the Grosse Isle well outcrops and takes in its main supply can not be stated. On the basis of the dip of the rock formations from southeast to northwest, at the rate of about 20 feet a mile, it would seem probable that the bed struck at 450 feet in this well will come to the surface somewhere west of Leamington in Canada. The supply seems, therefore, more likely to come from the Canadian than the Michigan side of Detroit River.

Newport quarry.—The underdrainage caused by the quarry at Newport was, next to the Grosse Isle well, most commonly advanced as a cause of the shortage along Swan Creek. A visit was accordingly paid to the locality and the conditions were investigated. It was found that a few of the wells near at hand have been affected, but the decrease in water supply is not universal even within a few hundred feet of the quarry. A quarter of a mile back no effect has been noted. From this it appears that the quarry can not be considered a factor in the shortage along Swan Creek or in the Rockwood region.

Low stage of streams.—The level of streams generally determines that of the ground water in their vicinity, the latter subsiding as the streams fall. During 1904 both Huron River and Swan Creek were unusually low, and thus drew unusual quantities from the surrounding water table, which was thereby naturally lowered. Huron River, being a longer stream, and one having its source in a region of greater rainfall, was not so low as Swan Creek, the entire course of which is within an area of low rainfall. Moreover, the latter, flowing over clay nearly destitute of water, receives in considerable portions of its course only slight additions by percolation. It is probably for these reasons that the shortage is most marked along its course rather than in any other part of the region.

Early winter of 1903.—This appears to have been an important factor in bringing on the present acute shortage. According to the official records, the permanent freezing of the ground took place on November 17, which was before heavy snows and heavy winter rains had fallen. There was, therefore, little chance for the rainfall to soak into the ground during the winter and early spring months. This was made manifest by the low water in many of the wells during the winter, the result being that when spring opened the ground water was at an unusually low stage.

CONCLUSIONS.

The low rainfall, which in the spring of 1904 varied from one-eighth to somewhat more than one-half of the usual amount at the stations in, the tables, was, on the whole, even less in the lower Huron River region itself. The deficiency of rainfall, following as it did an autumn and winter during which little water was absorbed owing to the frozen condition of the ground, together with the preceding dry season of 1903, seems ample to explain much if not all of the observed shortage.

Although considerable rain fell in July, and even more than the normal in August, it came largely as short heavy showers, and the water, instead of soaking into the ground, as in more gentle rains, formed streams and ran off rapidly. The part that soaked into the ground was entirely insufficient to compensate for the many dry months which had preceded, especially as the relatively wet months of August and September were followed by several months when almost no rain fell. In this connection it may be remarked that, while the shortage was felt in the region under discussion sooner than elsewhere, the drought became severe enough later in the summer to be felt through all the states bordering the Ohio and eastward to New England, causing much shortage in wells.

If, as seems probable, the failure of the well is due largely to the severe drought of 1903-4, the return to the normal rainfall should result in an increase in the water supply, although, because of the excessive dryness of the ground, the increase in the available water may not be immediately noted. The full supply may not return until a wet year, or perhaps a succession of wet years, occurs.

In some cases the return of the water may not bring restoration to the wells, for water passages in clayey material when dried out may, to a certain extent, crumble and become more or less clogged, so that their capacity for carrying water is lessened or destroyed even when the ground again becomes soaked. The return in any case will probably not be complete, as the thorough ditching which the region has undergone will result in a permanent lessening of the water supply of the region.

The wells in the lower Huron River region obtain their supplies largely in the upper few feet of the rock. The water, judging from its head, is derived from glacial deposits overlying the rock in the region northwest of the area under discussion. It probably traverses the upper more open and jointed portion of the rock, because there is less resistance to its flow through the crevices and openings in the rock than through the compact clayey deposits which; so generally overlie the rock formations of the region. The rock formations appear, therefore, to take in the water from the overlying glacial deposits, and, as shown above, a deepening of the wells into the rock has generally met with at least partial success. The great majority of wells now are exceptionally shallow compared with those of large areas in Michigan, where depths of 100 to 150 feet or more are common. It seems probable that wells of such depths in the region under discussion would yield permanent and abundant supplies."

Present conditions. The exceptional climatic conditions of 1903-4 held responsible for the decline of the water in the above region have passed away but without furnishing any relief in the situation. So far as we may judge from the Detroit records, the amount of precipitation in this section of the state has about held its own during the last decade. Deforestation, better drainage, cultivation of the soil over the collecting areas for this underground water, along with cycles of climatic change, may be expected to have operated equally upon the western belt of flowing wells and upon the northeastern extension of this same eastern belt. Not having done so, leads one to infer that some exceptional causes are operative in the lower Huron area. There is little doubt that the large number of flowing wells and springs opened in the district, with no attempt whatever to reduce their flow, would sooner or later, bring about a marked reduction in head. The effect should show itself first in the higher, western tract and gradually work its way toward the lake, near which we should expect to find some wells still flowing. That these have also ceased indicates, either that the collecting area has failed to receive the amount of water adequate to maintain the regular flow, or that the water is being drawn off at a lower level. In view of the facts stated above the former of these hypotheses may be eliminated from the discussion and we may consider any facts relative to the latter in our search for the probable cause of the water failure in this region. Our attention is thus directed to the quarries of the region, the Livingstone cut, the Grosse Isle flowing well and the Oakwood salt shaft, all of which are instrumental in abstracting the water from the deeper strata and delivering it at the surface.

Mr. Fuller has given good theoretic reasons for believing that the Grosse Isle well of James Swan could not be held responsible for the sharp decline which called forth his investigation. The farmers of the district were thoroughly convinced, however, from the behavior of their wells, that it was the immediate cause and made up a purse in 1904, which was used in bringing about a conference between Judge Swan and the supervisors of the townships interested. As a result of this conference, the farmers were asked to raise a fund of $500 for the purpose of reducing the flow of the well to a 4-inch stream, when, if it should appear that the well was really responsible for the loss of head upon the mainland, a gross sum or annuity, to be decided upon later, should be paid Mr. Swan. The proposition was not accepted by the farmers and the well is still discharging into Detroit River some 4,320,000 gallons daily, with no attempt at utilization. As to the possible connection between this well and the sudden decline in the wells at Flat Rock, Mr. Curtis L. Mettler, flour and lumber merchant, writes: "In the summer of 1903, Mr. Swan was boring a well on his farm, supposedly for oil; and at about 400 feet below the surface, struck a vein of water. So strong was the flow, that he was obliged to case it in order to proceed drilling. During the time between the striking of the vein and getting the casing in place, many of the small flowing wells stopped running. When the casing was placed in the well, it cut off the flow of water, and all, or nearly all of the wells commenced flowing again. He continued drilling until the well was about 2200 feet deep, and gave it up, (in the summer of 1904) and drew the casing out, which allowed the water to run again. The wells on all the farms again ceased flowing, and are still dry" (Dated Nov. 15, 1911). The heavy flows of water referred to were struck at depths of 420 feet and 450 feet, consisting of fresh water, the sulphur being introduced from smaller flows at a greater depth. The casing was in position from August, 1903, to May, 1904. It might be urged that the response of the wells upon the mainland was too prompt, but with subterranean passages in the dolomitic strata perhaps this can not be urged against the explanation given.

From the Livingstone cut in the strata of the Detroit River bed, opposite Stony Island (see Pls. V, A and XXIV), there has been a very heavy pumpage, estimated by Supt. G. P. Locker at 12,000,000 gallons daily. Since the first steam shovel was started Oct. 27, 1908, the flow from strata has gradually increased and although some of this comes directly from the river, the presence of much sulphur and iron indicates that the bulk of it is directly from the rock, to a depth of 24 feet below the river level, or an actual elevation of 550 feet above sea level. Mr. George H. Cohoon, a well driller of Trenton, of many years' experience, is convinced that we have here the cause of the recent failure of wells in northern Brownstown and Monguagon townships. Before this report finds its way into print, the water will have been allowed to fill this cut and former conditions to some extent restored by water pressure. Mr. Fuller considered the possibility of the quarry at Newport being responsible for the shortage in that vicinity, but finding that the drainage into this amounted to but about 43,200 gallons daily and that some wells near at hand seemed to be unaffected, decided that this might be neglected. When, however, all of the quarries of the Detroit River region and the Oakwood salt shaft are considered together there seems much more probability that we may have here one of the efficient factors. An effort was made to collect as definite data as possible from those in charge of these industries relative to the average daily pumpage. In combination with the loss of water from other sources, we have the following table which shows that the rock strata during the past three years have been losing *daily* between 17 and 18 millions of gallons, equal to the entire flow of Detroit River for *11 seconds*. Or to look at the matter differently, this quantity of water represents the probable absorption over 17 to 18 square miles of the collecting area. With these data before us there is little cause of surprise that the wells of the adjacent region should have lost a few feet of head.

TABLE LXI. ESTIMATED AVERAGE DAILY PUMPAGE.

Livingstone Channel cut	12,000,000 gallons.
Grosse Isle well	4,320,000 gallons.
Oakwood salt shaft	568,800 gallons.
Sibley quarry	350,000 gallons.
Anderdon quarry	150,000 gallons.
Gibraltar quarry (now filling)	144,000 gallons.
Rockwood sand pit (no estimate available).	
Newport quarry (now filled)	43,200 gallons.
Total	17,576,000 gallons.

Remedies. As to remedies there is something to be said although there may be little of practical value to be done. The Livingstone cut is now filled, the Patrick quarry upon Grosse Isle, the Gibraltar and Newport quarries have been abandoned and now stand full of water, the pressure of which will prevent loss from the strata. The shaft of the Oakwood salt shaft will be eventually completely jacketed with cement which will take care of the loss there. So long as there is no attempt made to utilize the flow from the Grosse Isle well, this should be securely confined. In this way, the loss will be reduced to 600,000 gallons daily, a very small percentage of what it has been during the past three years. In closing his report, as published in the Michigan Geological Report for 1904, Fuller calls attention to the desirability of legislation looking towards the control and conservation of this very important resource, the necessity for such legislation becoming more and more urgent each year (page 29).

"Ground water is properly a commodity belonging to the public at large, and is an asset of recognized value. The amount is not unlimited at any point, and any decrease in its volume means a reduction of assets and a permanent loss to the community. It is difficult to prove damages to surrounding wells caused by free flows, but when it is remembered that the underground supply is limited in amount, and that the available supply is being constantly decreased by such flow, it is readily seen that the loss is none the less real. A freely flowing well is in itself a proof of such loss, and should be forbidden, except where reasonable use is made of it.

(1) An enactment should be passed making it unlawful to permit water to escape where no use is made of it regardless of the size of pipe or volume of flow, and a penalty should be fixed for its infraction.

(2) An enactment should be passed making it obligatory in case of abandoning a well over two inches in diameter to securely plug it above and below each water horizon, or to fill the hole with cement or other impervious material, with a penalty fixed for its infraction as before.

(3) An enactment should be passed requiring that wells, when not in use, shall be closed down until not more than an inch stream[13] is flowing, a penalty to be attached for its infraction as before.

(4) Provision should be made for restraint of flows by injunction on application of parties presenting evidence of waste.

(5) The power of entering private property for the purpose of determining questions relating to waste should be given to proper officials."

1. Water-Supply and Irrigation Paper No. 30, 1899, p. 45.

2. Statistics relative to the various village and city water supplies of Wayne County, as well as the water powers, were collected by the writer and published in Water-Supply and Irrigation Paper No. 182, 1906, which the reader may obtain by application to the United States Geological Survey, Washington, D. C.

3. Twenty-first Annual Report of the Michigan Board of Health, 1902, p. 63. (Recomputed to ionic form by the United States Geological Survey.)

4. Twenty-eighth Annual Report of the Board of Health of the City of Detroit, 1909, p. 97. For other analyses see Lane, Lower Michigan Mineral Waters: Water-Supply and Irrigation Paper No. 31, 1899, pp. 18 and 19.

5. Detailed data relative to the Detroit Water Works will be found in the annual reports of the Detroit Water Board. An interesting article appeared in the Engineering Record, vol. 47, No. 25, 1903, p. 650, by Clarence W. Hubbell. See also Water-Supply and Irrigation Paper, No. 182, 1906, p. 53.

6. Williams, Typhoid Fever and the Water Supply of Detroit: Proceedings of the Sanitary Convention, Detroit, 1897, p. 90.

7. Fuller, Underground Waters for Farm Use: Water-Supply Paper No. 255, United States Geological Survey, 1910, p. 36.

8. Geological Survey of Michigan, Report for 1907, plate VI. Also Water-Supply Paper 183, plate II, U. S. Geological Survey.

9. Peale, A. C., Lists and analyses of the mineral springs of the United States: Bull. U. S. Geol. Survey, No. 32, 1886, p. 150.

10. Lane, A. C., Lower Michigan mineral waters: Water Supply and Irrigation Paper, No. 31, U. S. Geol. Survey, 1899, p. 72.

11. Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

12. See Water Supplies of the Lower Huron River Region. Flowing Wells and Municipal Water Supplies in the Southern Portion of the Southern Peninsula of Michigan, 1906, p. 33. Water-supply and Irrigation Paper No. 182, U. S. Geological Survey, Washington, D. C. Also Geological Survey of Michigan, Annual Report for 1904, p. 7.

13. The writer would make this a quarter-inch stream instead, or perhaps prescribe a certain measured flow per minute.

CHAPTER VIII. ECONOMIC RESOURCES.[1]

MATERIALS USED IN CONSTRUCTION.

Clays. Although the bedrock of the county is covered with a heavy burden of glacial clay, the occurrence of pebbles more or less abundantly throughout the formation renders it unfit for the usual forms of manufacture. In certain sections, the percentage is relatively low and, by running the raw clay through a crusher, they may be reduced to powder, the rock fragments too coarse for the crusher being removed by hand. Another method for utilizing such clay is to place it in tanks where it may be disintegrated by water and the water, carrying the clay in suspension, allowed to flow into settling vats from which it may be recovered. The inconvenience and expense necessitated by either of these methods prevent their use until the purer grades of sedimentary clays have been exhausted in this region. As pointed out in Chapter III, these clays have already been subjected to this washing process in Nature's great laundry, resulting in the removal of the sand, gravel and boulders and the deposition of the clay along the river courses and over the beds of the extinct lakes. The most important of these deposits have been described in Chapter III of this report and their characteristics presented.

When subjected to the burning process, as in the manufacture of brick and tile, the clay loses its original color and assumes a pink, or pale red. The deeper red, commonly desired, is obtained in the case of the brick by dusting over them, before burning, pulverized iron oxide and in the case of the roofing tile a clay wash rich in iron. The paleness of the burned clay is not due to an insufficiency of iron in the clay itself but to its neutralization by the alkalies present, and is a positive advantage in the case of the roofing tile since this color serves as a better background for the ordinary glazes than a deep red would do. The shrinkage of the clay is ordinarily low and may be still further reduced by adding sand in small quantity, too much giving a porous product. Data relative to the air and fire shrinkage have been obtained by W. G. Worcester, formerly superintendent of the Detroit Roofing Tile Company, as follows:

TABLE LXII. SHRINKAGE UPON SIMPLE DRYING OF SPRINGWELLS CLAY.

Percentage of water loss.	Percentage of shrinkage.
2.0%	1.0%
4.0	4.5
12.3	5.0
17.0	5.0

This table indicates that although the loss of water beyond 12.3% continues, the shrinkage ceases at 5%. The fire shrinkage is indicated in the following table:

TABLE LXIII. SHRINKAGE UPON FIRING OF SPRINGWELLS CLAY.

Cone	.010	.08	.06	.04	.02	1	2	3	4	5
% Shrinkage ..	0	0	0	.50	.50	2.50	3.75	5.50	6.00	Melting.

These experiments were conducted in a small kiln, "under commercial conditions," and indicate a fusing point of approximately 2246° F. (1230°C.) for the clay. With long continued firing, as in the actual kiln, Mr. Worcester thinks that the clay would fuse at about cone 3, or 2174°F. (1190°C.). The following table shows the composition of ordinary brick clays, giving the range met with and the average percentage of each ingredient.

TABLE LXIV. CHEMICAL COMPOSITION OF COMMON BRICK CLAYS. (RIES.)

Constituent.	Range.	Average.
Silica (SiO_2)	34.350-90.877%	49.270%
Alumina (Al_2O_3)	22.140-44.000	22.774
Ferric oxide (Fe_2O_3)	0.126-33.120	5.311
Calcium oxide (CaO)	0.024-15.380	1.513
Magnesium oxide (MgO)	0.020- 7.290	1.052
Alkalies (K_2O, Na_2O, NH_3)	0.170-15.320	2.768
Water (H_2O) chemically combined...	0.050-13.600	5.749
Moisture mechanically combined	0.170- 9.640	2.502

These lake clays are utilized mainly in the manufacture of the common variety of building brick, some two dozen plants being so employed, one of them making also drain tile. In general, only the "soft mud" process is employed, the brick being moulded by hand or machinery and ordinarily "burned" in the familiar type of "score kiln." These kilns are loosely constructed each time of thoroughly dried brick to be burned, are of rough, rectangular form, crossed at the base with a series of parallel arches in which the fuel is consumed and the heat generated. The top of the mass is covered with a more tightly fitting layer of brick ("platting") while the sides and ends are daubed with mud to exclude the cold air while the burning takes place. Wood, coal and coke have been used as fuel but are now almost entirely replaced by crude oil. The burning requires from 5 to 7 days, depending upon the nature and condition of the clay and the atmospheric conditions prevailing at the time. At a few of the yards, especially where the drying is done artificially in steam-heated rooms, the burning is done in kilns more permanently constructed and provided with the "down-draft" system, thus securing a more uniform distribution of the heat. At the Clippert plant dryers are used with a capacity of 64,000 brick into which they are introduced at a temperature of 160°F. and pushed along to where the temperature is about 212°F. The air is heated by the fan system, drawn in over hot coils and about 48 hours are required for the drying. Many millions of brick have been burned here for years, the shallower deposits of clay nearer the city being gradually used up and the works shifted westward along Michigan Avenue. The markets have been mainly local, the product delivered by teams, but some have also been shipped by rail to various parts of southern Michigan and northern Ohio. Most of the yards are operated 5½ to 6 months of the year, closing down with the advent of freezing weather in the fall. Two or three of the larger plants, however, are so equipped that they can operate the year round, the clay being handled with steam shovels and small cable-drawn carts.

The manufacture of pressed brick was attempted for a short time by the Detroit Red Pressed Brick Co. but soon given up, the clay not being well adapted to this style of brick. According to the observations and experiments of Mr. W. G. Worcester, the clay has a strong tendency to laminate, thus unfitting it for pressed brick, as well as those made by stiff-mud processes. These clays were found to possess very high cross breaking strength while in dry condition, permitting their use for thin section ware. A small plant is in operation at Fifty-Ninth St., just south of Michigan Avenue, for the manufacture of flower-pots.

Drain tile are manufactured at the plant of J. C. McDonald and Son, Warren Ave. (SW. ¼ sec. 4, Springwells), in addition to the common brick. The local markets only are supplied, this being the only tile plant within the limits of the county at present. The southern part of the county, however, is supplied with drain tile from the John Strong plant at South Rockwood, just south of the Huron. The chief demand is for 3 and 4-in. sizes but 2½, 6 and a few 8-inch sizes are also manufactured. Only the circular style is made, which burn to a pale red in down-draft kilns in about 3½ to 5 days. The "stiff mud" process is employed in moulding the tile and about a week's time is required for drying. The Detroit Roofing Tile Co., one of but 13 now in this country, has been in operation since 1905, located alongside the Michigan Central Ry., halfway between West End and Woodmere. Here they have 12 feet of clay well suited to their purpose, overlain by 3 feet of sandy loam stripping. After being thoroughly worked in the pug mill, the raw clay is allowed to “age" for 3 to 4 days by which process it is considerably toughened. The soft mud process is employed and many styles and varieties of interlocking roofing tile are turned out, most of which are shipped to the Atlantic coast and south as far as New Orleans. The local demand for this product is growing and seems destined to greatly increase because of its durability and artistic qualities.

Some 40 to 50 years ago, the city of Detroit was supplied with brick mainly from the vicinity of Leesville, Gratiot Ave., where some 6 feet of a yellow clay were available. The plants were located from a half mile south to a mile north of the village and some were in operation as late as 1900. Although the clay suitable for brick was not entirely exhausted, the business has been shifted to Michigan Avenue. Brick are also manufactured at Dearborn, in the southeastern part of the village, by Anthony Wagner and shipped to neighboring cities. The clay is of a brownish yellow variety, about 7 feet deep and said to extend over about 28 acres, about one-half of which has been used. It burns to a good shade of red in about 8 days, the plant running from 6 to 7 months each year. Both brick and tile were manufactured in the SE. ¼ NE. ¼ sec. 26, Bedford township, up to about 1892, supplying the local demand only. There is said to occur here some 40 acres of suitable clay, from 6 to 10 feet thick. Brick and tile have been manufactured for many years by Milton E. Carlton, SE. ¼ NE. ¼ sec. 28, Canton township, the clay being obtained from the Rouge flats, brown in color and about 4 feet thick. Below this clay is a sandy type of clay, utilizable for brick but not tile. Two down-draft kilns are used for burning the product. Brick were made some 35 to 40 years ago at the NW. ¼ NW. ¼ sec. 5, Dearborn, to supply the demand for use in chimneys when the old fashioned stick and mud chimneys passed out of date. Some drain tile were also made here, only surface clays being available. For a time, some brick were also burned in sec. 33 of Bedford (NE. ¼ NE. ¼). Farther north in sec. 10 (SW. 14 NW. ¼), S. K. Burgess began making brick and a few tile in 1871,—at the time of visit, the plant being operated by L. J. Burns. The clay is stratified, 4 to 5 feet thick and overlain by 4 to 8 inches of surface soil, containing enough sand so that none needs to be added. Below the clay is two feet of quick sand and then blue clay ("till"). The stiff clay process was the one employed. In the village of Northville, along the Rouge (NE. ¼ NE. ¼ sec. 9), a small brick establishment was operated for a time by Walter Randall, the bricks made being perforated at either end with a ⅝-inch hole (stiff clay process). The clay deposit was 4 to 5 feet thick and contained some pebbles; burning very unsatisfactorily, to a yellow, then red and sometimes a dark purple.

That the clays of Wayne County have not been utilized in the manufacture of Portland cement is due probably to the absence of any very extensive beds of marl, or "bog lime." An entirely suitable rock can be obtained from the Sibley and Macon quarries, but is in great demand for the purification of beet sugar and the manufacture of soda-ash.

Sand, gravel and boulders. Along the broad belts described and mapped as the Wayne, Grassmere and Elkton beaches, almost unlimited quantities of a more or less pure yellow sand are available. Although heaped up by wind action, and with little sign of stratification, a small percentage of clay is generally present. Many such ridges and mounds are entirely free from pebbles. The most accessible deposits are those near Sand Hill and Romulus, but less extensive ones can be reached along any of the steam and electric roads leading out from Detroit. The Maumee, Whittlesey and Warren beaches contain poorly assorted patches of a sharper, gray sand, interstratified with gravel strata. The kame hills in the northwestern corner of the county, although largely gravel, contain also some sand which locally became separated from the pebbles. The gravel in the kames is generally pretty well assorted but differs considerably in different ones, as might be expected. The pebbles are rounded to subangular and consist of 40 to 50% of limestone and dolomite, with 12 to 20% each of chert, quartzite and igneous fragments. The sandstone and argillites were largely eliminated from the deposits, perhaps by stream action. In the case of one kame from which 200 pebbles were collected at random

(NW. ¼ SE. ¼ sec. 11, Northville) and then classified, the limestones and dolomites numbered but 9 (4½%), with a corresponding increase in the number of the harder fragments. If the sample studied fairly represents the entire kame such gravel would have much higher value for road construction; since the limestones and dolomites are more readily ground to powder and blown away. The composition of the beach pebbles does not differ greatly from those of the kames, being slightly lower in the limestones and dolomites and somewhat higher in the quartzites and igneous varieties. The location of these beaches, especially rich in gravel, as the younger ones are in sand, is shown upon Pl. X. Nearly the entire upper two-thirds of Northville township is dotted with gravel deposits; especially sections 2 to 11, inclusive. Many of these could be made very accessible by building short spurs from the Pere Marquette Ry. and the electric lines. Much of this gravel has been already utilized in road building in Northville and Plymouth townships, but comparatively little has been shipped outside.

The gravel for the system of concrete roads now being built has been obtained from the neighborhood of Chilson, Livingston County, where the deposit is more accessible to the railway. The firm supplying the same is known as the Michigan and Ohio Sand and Gravel Company. In geological reports, it has been customary to urge the importance of good roads, but this would be a waste of effort so far as Wayne is concerned. The people of this county are thoroughly awake as to their importance and have set a splendid example for other counties to follow, who may well send their officials here to investigate the working of the plan. With some 57 miles of good roads already constructed outside of the limits of Detroit and Wyandotte, the county voted upon Nov. 8, 1910, to bond itself for $2,000,000 by which it is proposed to build 200 additional miles of concrete road within the next five years. This splendid work has already begun with most gratifying results, the farmers estimating that fully 60% of the expense of marketing their produce is thereby saved. This saving is in horse flesh, wagon and harness repairs, and in time; besides which are to be considered the advantage of marketing produce at the convenience of the farmer, or when the market is just right, instead of when the roads happen to permit. The roads now under construction are built of concrete, 6½ to 7 inches thick and 10 feet to 18 feet in width, and will form a net work over the county.

The field stone, or "hard heads," were quarried by the old ice sheets in Canadian territory and transported for many miles to Wayne County, being dropped as the ice melted from beneath them. They mantle the moraines already described and are arranged in three rather distinct belts across the county, from north to south (see Pl. X). They have been extensively gathered and used as supports for sills, horse blocks, foundation walls for barns, houses and other buildings, for chimneys; in some cases entire buildings being constructed of them. Where especially abundant, ridges formed of these boulders and cobbles serve as fences. They are often utilized to prevent a stream from eroding its bank, or to check the velocity of a temporary torrent in a side hill gully. An examination showed that these stone consist largely of igneous rocks (62%) and quartzite (29%) rocks; the softer limestones and argillites being comparatively rare (3%). When crushed, they form a much more durable material for road macadam, than gravel, limestone or dolomite. Owing, however, to their relative scarcity, the expense of collecting them and the abundance of other road metal in the county, they are not thus utilized. Occasionally one is found capable of receiving a good polish, in which case it may be used for a monument, corner stone, key stone, etc. Within the last few years, several car loads of such cobbles have been shipped from Michigan, as far west as Iowa, to be used in the grinding of portland cement.

Limestone and dolomite. The artificial exposures of these rocks in the vicinity of the lower Detroit River region furnish three types of material that may be classified under the head of construction; viz.: building stone, macadam and lime. The various localities in which such materials are available have been described in some detail in Chapter VI of this report. Solid blocks of bluish-gray limestone, of almost any desired size, may be obtained from the lower strata of the Sibley quarry, just north of Trenton (Pl. XXX, B). The drab dolomitic strata of Monroe age are not so heavily bedded and still some massive blocks were obtained for the retaining wall at the northern end of the Livingstone cut. Buildings constructed of this dolomite in Monroe show that the rocks remain intact but in the course of 36 to 50 years a mealy coating 1-10 of an inch thick has formed over the surface. In the case of Trinity Church, built in 1868, the sandstone sills still retain some of the tool marks, but the dolomitic blocks give considerable evidence of surface decay.

The limestone appears to be more resistant to the atmospheric influences. The above church contains a water-table of Sandusky limestone, of the same general nature and geological age as that of the Sibley quarry, which shows much less evidence of decay than does the Monroe dolomite. The present popularity of cement for bridges, culverts, side-walks and curbing has greatly reduced the demand for building stone of the type here available.

When run through heavy crushers, both the limestone and dolomite are converted into road metal, for macadamizing purposes, for which there has been considerable demand. Much of this has also been used in providing a dustless and weedless ballast for the steam and electric railways. The demand for such material seems to have slackened, since the Patrick and Gibraltar quarries have been temporally abandoned and the two great dump heaps of the Livingstone cut (Pl. V, A) are to remain unutilized. The Sibley quarry converts its rock, unsuited to other purposes, into macadam (Pl. XXXI, A).

When subjected to heat, the high grade limestone of the Sibley quarry loses its carbon dioxide gas and is converted into calcium oxide, or quick-lime ($CaCO_3$—CO_2=CaO). This has the well-known property of uniting with water ("slaking"), forming calcium hydrate, with the evolution of much heat ($CaO+H_2O=Ca\ (OH)_2$). In this form, it is sparingly soluble in water forming "limewater," useful as a mild form of alkali in medicines and various industries. When a slush of calcium hydrate is mixed with sand, to prevent shrinkage and to render it more porous, and exposed to the air, the carbon dioxide of the atmosphere unites with the hydrate forming lime carbonate over again and water ($Ca\ (OH)_2+CO_2=CaCO_3+H_2O$). The excess of water originally present, as well as that newly formed, is evaporated and the mortar, or plaster, is slowly hardened, adapting it to the familiar building uses. An excellent quality of lime is made at the Sibley quarry in iron kilns of the "continuous" type, which are fed periodically with suitable stone at the top and from which there is periodically removed the fresh lime at the bottom. These are a great improvement over the side-hill stone kilns in vogue a few years past. The dolomites yield a different type of lime, which slakes more slowly, develops less heat, capable of binding less sand and requiring more time for setting. The chemical action taking place is shown by the following equation, showing that magnesium oxide ($CaO.\ MgOH\text{-}H_2O=Oa(OH)_2.\ MgO$) is combined with the calcium hydrate. When once thoroughly set, however, the product is often harder than that obtained from the limestones, partaking sometimes of the character of hydraulic cement. Owing to their inaccessibility, these dolomitic strata were not much used in Wayne County in an early day, the supply of this type of lime coming from Monroe County. Some 25 years ago, small quantities of lime were burned at Flat Rock by James and William Breeland, father and son, the rock being obtained from the bed of the Huron.

The impression has been held by different individuals that the Monroe dolomites, upon being properly handled, should yield hydraulic cement which differs from ordinary plaster and mortar in that it will harden out of contact with air, as under water, thus adapting it to many new uses. The rock employed which may be either a limestone or dolomite, should contain some 15 to 35% of clay and a little potash or soda. The presence of sand in the form of grit is objectionable. The analyses of the Monroe County strata and the few experiments that have been made upon them have not held out much prospect of success along this line.[2] An artificial mixture of calcium carbonate (72 to 77%) with a silicious, but not gritty clay (23 to 28%), containing potash or soda, may be heated to a high temperature (2900°F.) and reduced to powder, forming Portland cement. During the so-called "burning" there are formed tricalcium ortho-silicate ($3CaO$, SiO_2) and tricalcium aluminate ($3CaO$, Al_2O_3)),[3] which, upon becoming wet, are converted into crystalline insoluble hydrates of calcium and aluminum. Certain beds of the Sibley quarry could be selected, which with the lake clays of the West Detroit area would give the right combination for the manufacture of this much utilized product.

Sand-lime brick. Wayne County possesses two plants for the manufacture of this type of building material, in which Michigan leads all other states. The industry is but 12 years old in this country, having been introduced from Germany, and consists in the moulding of brick from a mixture of lime (CaO) and quartz sand (SiO_2). As carried out by the Sibley Brick Company, operating since 1904, thoroughly hydrated lime of their own manufacture is ground to powder and mixed with sand, sucked from the bed of Lake Erie, near Gibraltar. Any type of silicious sand may be used which is reasonably free from clay and not too coarse, but those sands are preferred in which there is considerable variation in the size of grain. The granules should be sharp and angular to secure the best results, so that the Sylvania with its rounded, evenly assorted granules is not ideally adapted to this use. The lime used should be as free as possible from any content of magnesia. Five shovels-full of moist sand are thoroughly mixed with one of the powdered lime hydrate, producing a mixture in which about 95% is silica and 5% lime. The bricks are moulded under a pressure of 8,000 lbs. to the square inch, placed in a boiler and subjected to a steam pressure of 125 lbs. to the square inch for 10 hours, giving rise to a chemical union of the calcium and silica, to form calcium silicate ($CaSiO_3$). The bricks are then allowed to stand for about three months before being placed upon the market, during which an absorption of carbon dioxide gas from the atmosphere occurs. The bricks thus produced are a very light gray, perfectly formed, with sharp edges and smooth surfaces and have undergone practically no shrinkage or warping. They may be colored to almost any desired shade. Subjected to pressure tests it has been found that they show greater regularity than common brick and a crushing strength equal to that demanded for brick of good quality. The average of 255 tests gave an average of 2190 lbs. pressure per square inch. The loss of strength through the absorption of water averaged 14%. The amount of water absorbed amounted to 14.9% weight and 26.3% volume, less than for ordinary clay brick, while the test with heat and sudden dash of water shows that they stand up as well as the clay. Mortar is found to adhere slightly better to the sand-lime brick than to those made of clay and because of their more nearly uniform, size and shape they can be more rapidly laid. In localities where clay is absent or scarce and sand and lime abundant, this type of brick is bound to come into favor. In addition to the plant at Sibleys, they are also manufactured in Detroit by the Michigan Pressed Brick Co., corner of Lawton Avenue and the Michigan Central Railway, this present company having operated since 1908. The lime is obtained from, the Sibley Quarry Co. and the sand from near Rochester, Michigan.

CHEMICAL MATERIALS FOR DIRECT USE OR MANUFACTURE.

Calcium carbonate. High grade calcium carbonate with very little or no magnesia, and small percentages of silica and iron, is in great demand for the manufacture of soda-ash (Na_2CO_3) and the purification of beet sugar, in both of which industries Michigan holds a leading rank. The rock should contain from 95 to 99% of the calcium carbonate and can be obtained from the "9-foot; bed" of the Sibley quarry, which averages 98% pure. The Anderdon bed has been reached in the deeper excavations of the quarry and will probably be found to carry a uniformly high percentage of this carbonate, as at the Anderdon quarry upon the eastern side of Detroit River. One of the first steps in the manufacture of the so-called soda-ash is to secure a quantity of ammonium hydrogen carbonate (NH_4HCO_3) and this is done by saturating water with ammonia gas and passing through it a current of carbon dioxide gas, obtained by heating calcium carbonate as in the manufacture of quick lime previously described. The reaction that takes place is indicated by the following equation:

$$(1)\quad NH_3+H_2O+CO_2=NH_4HCO_3.$$

This product is converted into sodium carbonate, through the agency of salt in a way to be mentioned later.

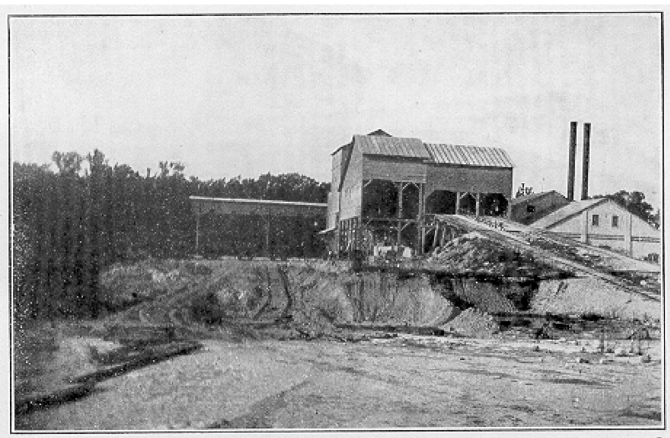

Plate XXXI. A. Near view of Sibley crushing plant.

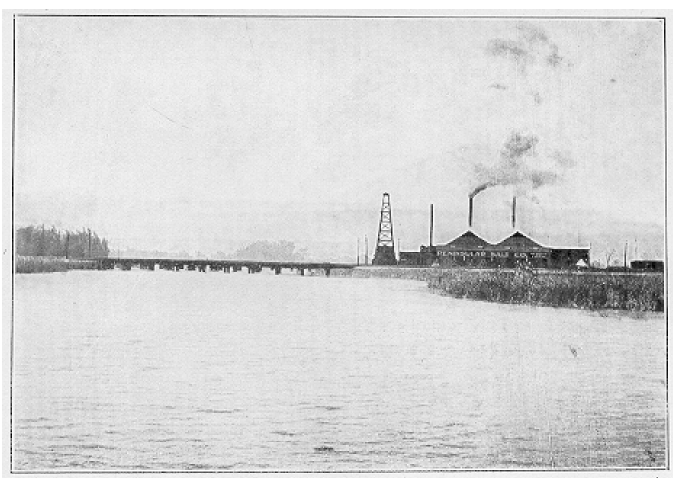

Plate XXXI. B. Plant of Peninsula Salt Company and River Rouge.

In the manufacture of beet sugar, a high grade limestone is also required, a plant using 300 tons of beets daily needing from 35 to 40 tons of limerock. Both the quick lime and carbon dioxide gas obtained by heating the calcium carbonate are utilized, the two being again united. Too much silica, silicates and alumina cause trouble in the burning, while magnesia and gypsum interfere with the filtering and evaporation of the juice. The lime in the form of powder, or in solution as "milk of lime," is added to the beet juice and unites mechanically and chemically with the impurities present. The addition then of the carbon dioxide brings about a union between it and the calcium hydrate, according to the equation previously given:

$$Ca(OH)_2+CO_2=CaCO_3+H_2O.$$

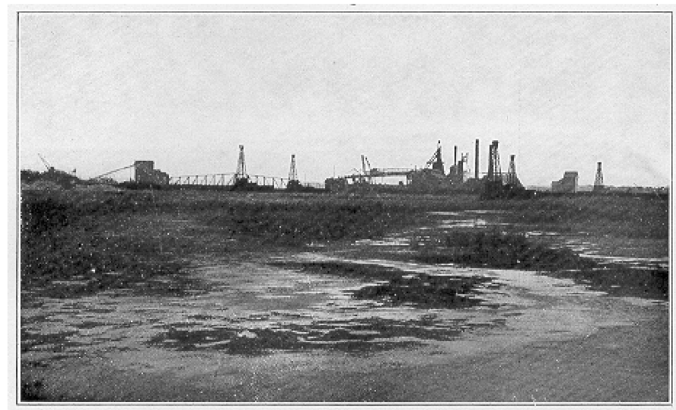

Plate XXXII. A. Plant of Solvey Process Company, Delray, for the manufacture of soda ash.

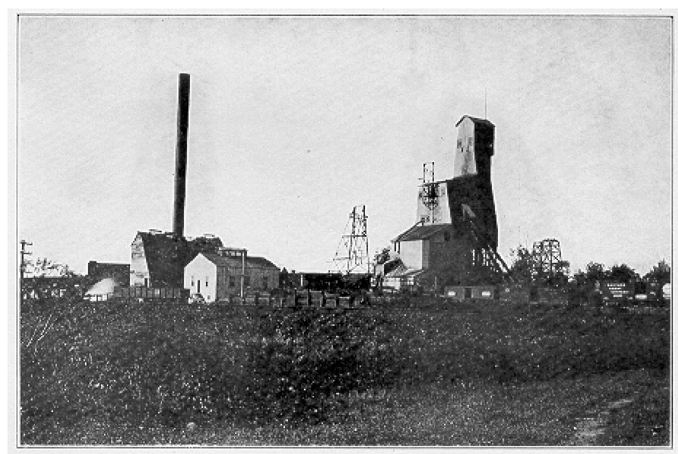

Plate XXXII. B. Surface plant of Oakwood salt shaft, Michigan’s only salt mine.

The calcium carbonate appears as a flaky precipitate and settles to the bottom carrying its load of impurities, being then readily separated from, the juice by filtering. At present this material is carted away as waste and used as a land fertilizer by the farmers. If some practical scheme for purifying it could be devised the calcium carbonate could be recovered, with some necessary waste, and utilized, over and over again. The exhaustion of the supply of suitable limestone may eventually make this necessary. Lime is still further used in recovering from the "molasses" its final content of sugar, forming with it tricalcium saccharate, $C_{12}H_{19}O_{11}.\ (CaOH)_3$. From this saccharate, both the sugar and the calcium hydrate may be recovered. Were it not for the heavy covering of drift the section of country between Sibley and Dundee would supply a high grade carbonate for many years to come.

Deposits of marl occur only in limited amounts in the county and usually in too impure condition to be used for the production of soda-ash or beet sugar, but entirely suitable for cement manufacture, for quicklime and as a fertilizer. This form of calcium carbonate is produced in ponds and swamps through the action of plant and animal organisms in secreting from the water the calcium carbonate there held in solution. The mollusca extract this substance for use in the production of their shells and, upon their death, the animal substances decay and these shells may accumulate in quantity, before undergoing complete solution again. The amount of calcium carbonate (actually in the form of the bicarbonate $CaH_2(CO_3)_2$ held in solution is dependent upon the presence of the carbon dioxide gas in the water, and when this gas is abstracted by green plants, for their use in securing carbon, the calcium carbonate is deposited often over their stems and leaves in the form of minute crystals forming an incrustation. One very common plant of this character forms thick mats over the bottoms of our ponds and is known as *Chara*. It secretes and deposits so much of the calcium carbonate as to render its slender leaves and branches quite brittle, suggesting that this material may be deposited as the result of some physiological action on the part of the plant. Upon the decay of these and related plants quantities of the slightly soluble calcium carbonate collect upon the bottom and give rise to a chalky deposit known as marl. It is evident that shells may also be present in greater or less quantity and more or less mineral impurity in the form of sand and clay.[4] Under favorable conditions deposits many feet in thickness have been formed since the withdrawal of the ice sheet from Michigan. In Wayne County, however, owing to its long submergence by the glacial lakes and the almost complete absence of subsequent ponds and minor lakes no very extensive deposits were formed. Although favorable conditions for marl formation and deposition occur about the present margins of Lake St. Clair, Detroit River and Lake Erie, the time that these present conditions have existed seems of too short duration. In the vicinity of the swamps, those still existent mid those which have been drained, often in association with peat, shallow deposits of marl are found; as in secs. 5, 8, NE. ¼ sec. 28, of Brownstown; secs. 9, 10, 15 and 16 of Sumpter; NE. ¼ sec. 18 of Canton. This latter deposit is estimated to cover some 10 acres, to be 2 to 3 feet thick and is overlain by 10 to 16 inches of muck. These marl beds could all be utilized as. a land fertilizer and when mixed with thoroughly dried and disintegrated peat would add very greatly to the fertility of the soil.

Glass sand. The Sylvania sandrock formation, described as of probable æolian origin, has all the qualities needed for high grade glass manufacture. It is finely and uniformly grained, rung very high in silica and is so incoherent that it is readily disintegrated by water and pumped from the pit. Mixed with the fusible bases it melts readily and yields a glass free from color. This sand has been mined and marketed for a number of years in Monroe County, where there was a natural outcrop. The bed strikes northeastward, with an outcrop of two to three miles beneath the drift cover, and crosses the southern point of Brownstown township, as shown upon Pl. XXV. Just east of Rockwood, upon the land of Dr. Dayton Parker (NW. ¼ SE. ¼ sec. 15) a pit has been opened under 15 to 18 feet of a hard glacial till and is operated by the American Silica Co. The deposit here is said to be 75 feet thick, but all of this will probably not yield to the hydraulic treatment now employed. A sample of this washed sand was analyzed by Dr. John E. Clark, Detroit, and gave 99.70% silica (SiO_2); .08% calcium carbonate ($CaCO_3$); .22% magnesium carbonate ($Mg\ CO_3$). The Rockwood Silica Sand Co. acquired 82 acres of land just east of the Grand Trunk Ry. (SE.¼ SW.¼ sec.10), and three years ago sunk a well to the depth of 122 feet, through 15 feet of clay. An additional 15 feet of limestone (dolomite) was penetrated when the glass sand was entered to a depth of 92 feet, without reaching the base. A 6-inch casing was used to the rock and below a 4-inch, through which steam under 60 lbs. pressure is forced, bringing out water and sand. The sand is dried and screened to the amount of about a carload a day, being shipped to Ohio and Pennsylvania. The water from the well contains sulphur and when allowed to do so rises to within 3 feet of the surface. In the Oakwood salt shaft, the bed was reached at a depth of 420 feet, has a thickness of 113 feet and much of it could be removed if it was desired to do so, using the same hoisting machinery as that employed for the salt.

Mineral waters. Although all natural water may be regarded as a mineral resource. Chapter VII has been devoted to its discussion and there has been reserved for this section only a brief discussion of those waters which are economically valuable because of their mineral content. The waters which permeate the beds of the Dundee and Monroe formations become heavily charged with a great variety of minerals; chief of which are sulphur, salt, calcium and magnesium sulphate and carbonate. When heated and properly administered, such waters have undoubted medicinal value for certain diseases and are in demand. By penetrating the proper horizon, almost unlimited quantities may be obtained over the entire county. Two plants are in operation in Detroit,

Riverside Bath House, Clarke Ave. and Fort.

Detroit Mineral Bath Co., Cor. 21st St. and Fort.

The various industries utilizing the salt deposits along Detroit River (Pls. XXXI, B and XXXII, A) from Delray to Trenton, prepare an artificial brine by forcing the water of the river to the salt strata, where it becomes saturated and flows to the surface. The salt is then recovered by the evaporation of the water and marketed as such, or utilized in the manufacture of soda-ash and caustic soda. As explained in an earlier part of this chapter the first step in the manufacture of the former product (Na_2CO_3) is the production of ammonium hydrogen carbonate (NH_4HCO_3) by the use of ammonia and carbon dioxide. When this solution receives a strong solution of salt (NaCl), two new substances are formed: sodium hydrogen carbonate ($NaHCO_3$), or bicarbonate of soda, and ammonium chloride (NH_4C1), as shown in the following equation:

$$(2)\ NaCl+NH_4HCO_3=NaHCO_3+NH_4Cl.$$

The sodium hydrogen carbonate is but sparingly soluble and is precipitated and recovered. This is the common baking soda which is manufactured extensively at Ford City and formerly at Trenton. Upon being heated in a retort, this compound breaks up into its three components, according to the following equation:

$$(3)\ 2NaHCO_3=Na_2CO_3+H_2O+CO_2.$$

Upon being treated with lime, the ammonium chloride of equation 2, is converted into calcium chloride ($CaCl_2$), with the liberation of ammonia and water.

$$(4)\ 2NH_4Cl+CaO=CaCl_2+2NH_3+H_2O.$$

It is thus seen from equations 3 and 4 that all of the ammonia and half of the carbon dioxide gas are recovered and may be used in the further production of ammonium hydrogen carbonate, according to equation 1. The calcium chloride containing the calcium of the lime and the chlorine of the salt, form the by-product, great quantities of which may be seen about the plants of the soda-ash manufactories at Delray and Wyandotte. When heated, this becomes a valuable drying agent because of its strong attraction for water. The soda-ash sought contains the sodium of the salt and the carbonate radical (CO_3) of the limestone, which has been exchanged for the chlorine. This is known in the market as *sal soda*, is used extensively for softening water, in the manufacture of glass and numerous other chemicals. When dissolved and treated with calcium hydrate ($Ca(OH)_2$), a recombination occurs,

$$(5)\ Na_2CO_3+Ca(OH)_2=CaCO_3+2NaOH,$$

resulting in the formation of lime carbonate and sodium hydroxide, commonly known as *caustic soda*, or "alkali." This is extensively manufactured by the Michigan Alkali Co., at Ford City and used largely in the production of soap.

Rock salt. In a swamp bordering Detroit River, south of the River Ecorse, the first unsuccessful attempt was made in 1902 to sink a shaft for the mining of rock salt. The failure, however, was a success in that it presented the first serious problem, and suggested its solution. A square hole, 24 feet x 24 feet, was first dug to a depth of about 14 feet, passing through 4 feet of fresh muck, 2 feet of mucky clay and 4 to 6 feet of a mottled (yellow, brown and blue) lake, or river clay, carrying shells, but no pebbles. Then followed about 70 feet of soft, bluish-drab till, with some few pebbles, cobbles and boulders, the only break being at 80 feet where a 6 to 8-inch stratum of gravel, or gravelly clay, was encountered. A drop casing of brick, cylindrical in form, 15 feet in diameter and one foot thick was constructed and provided with a steel shoe. This was allowed to settle as the excavation proceeded and was added to at the top. At a depth of about 55 feet a great amount of "creep" was experienced, 48 hours' progress amounting to but 1½ feet, instead of about 14 feet. When within a short distance of the rock, at a depth of some 80 feet, the casing showed signs of weakening under the strain caused by the *creep* of the clay and, although an effort was made to strengthen it, the entire structure collapsed and the hole filled with water.

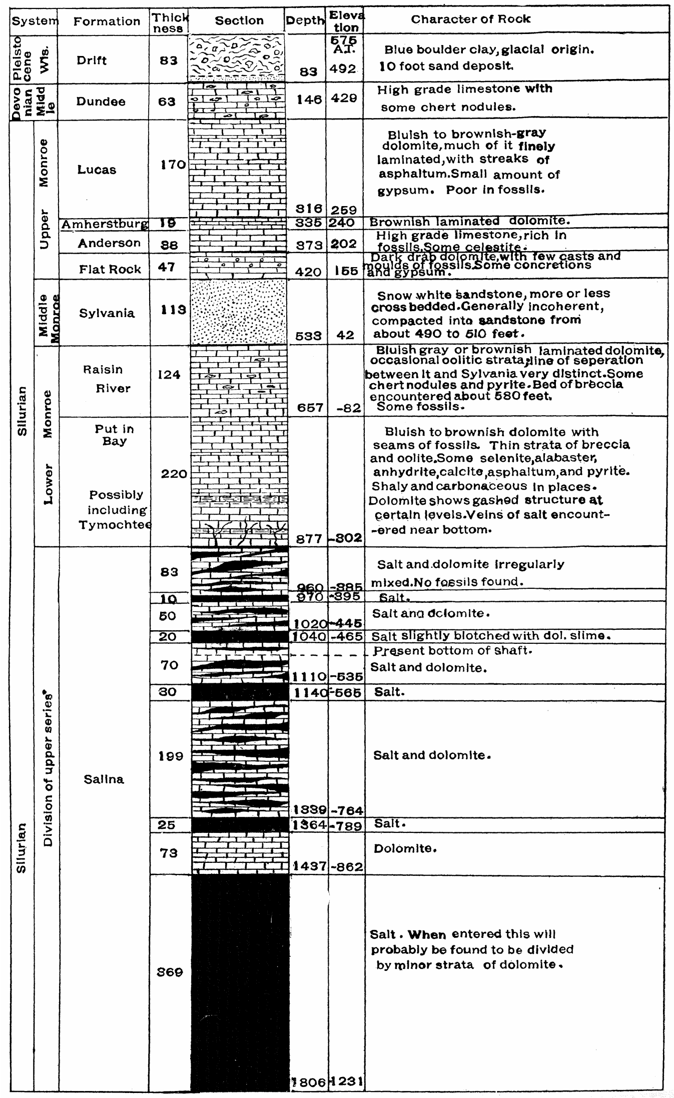

Figure 21. Section of Oakwood salt shaft.

The second attempt to get at the solid salt has proven successful but only by the most determined effort and highest engineering skill. Reaching the solid rock, its removal proved comparatively simple, but the suffocating gases and floods of water encountered would have literally swamped and discouraged most companies. That the enterprise was brought to successful completion is due to the rare skill and judgment of the engineer in charge, Eugene P. Bradt and his corps of efficient helpers. The work was begun Dec. 12, 1904, by the "Detroit Salt Mining and Manufacturing Co.," capitalized at $500,000, and was intended to include later the Detroit Salt Co. and the River Rouge Salt Co. The site of the shaft, is in Oakwood, a small Detroit suburb, just south of the Rouge about ½ mile and two miles from Detroit River. The elevation of the mouth of the shaft, as determined by W. C. Cooper, is 575.2 ft., above sea level. A drop shaft of timber was constructed, 6 ft. x 16 ft. in the clear (8 ft. x 18 ft. outside) with a cutting edge, protected by a sheet of steel. As the digging was carried on below the casing was allowed to settle and was built on above, passing through 73 feet of soft, blue clay (Wisconsin till) and 10 feet of sand and clay mixed, reaching bedrock (Dundee limestone) at 88 feet, or an actual elevation above sea level of 492 feet. This limestone was entered 17 feet, early in July, 1905, but was so strong in hydrogen sulphide gas (H_2S) that work was suspended until the 20th of November. The eyes of the men were painfully affected and some of the workmen were overcome. At one stage of the work, firemen's helmets were used, supplied with fresh air through rubber hose, but were found cumbersome and were then discarded. The almost imperceptible structural break between the Dundee and the Monroe came at about 146 feet and then followed the succession of strata making up the various divisions of the Monroe formation, as indicated in the section given on Fig. 21. Below 100 feet the casing was reduced to 5 ft. 4 in. x 15 ft. 4 in., inside measurements, the shaft being cased with 2 in. planking and 12 in. framing timbers.[5] The last week of June, 1909, the work extending over a period of 4½ years, an 8-foot stratum of salt was reached at a depth of 878 feet. With no water or gas now to cause trouble, it was simply a matter of time to reach the heavier deposits of purer salt, and, by the close of the year, a depth of 1042 feet had been reached, entering a 20-foot vein of salt which is the one now being worked by means of "drifts," (1040 to 1060 feet). The average monthly progress made was 17⅔ feet, the greatest record being made in the dolomite, April, 1909 (672 to 765 feet), amounting to 93 feet. This was accomplished by offering the men a bonus for all that was accomplished beyond a certain amount.

Six noteworthy water horizons were encountered as the work progressed as follows:

1. Depth 83 ft.; elevation 493 ft. Just over rock with a temperature of 52.2°F. (Cooper).

2. Depth 86 to 88 ft.; elevation 489 to 487 ft. Dundee limestone, quite heavy flow and rank in hydrogen sulphide gas.

3. Depth 135 ft.; elevation 440 ft. Dundee limestone, small flow.

4. Depth 155 to 168 ft.; elevation 420 to 407 ft. Lucas dolomite, porous. Flow continuing down to 181 ft., or elevation 394 ft. Sulphurous. Temperature at 180 ft. was 49.5° F. (Cooper).

5. Depth 191 ft.; elevation 384 ft. Remarkably heavy flow from a horizontal opening extending across the shaft. Lucas dolomite. Water strong in sulphur and under a pressure of 90 lbs. per square inch, causing the shaft to fill in 3 to 4 hours.

6. Depth 420 ft. to 533 ft.; elevation 155 ft. to 42 ft. above sea level. Seepage flow of sulphur water throughout Sylvania sandstone, except for a 27-foot stratum of dry, silicious dolomite (Sylvania dolomite).

Mr. Bradt estimated the total flow above the base of the Sylvania as 2,000,000 gallons a minute, this being reduced to not over 500 gallons by the use of Portland cement forced into the fissures of the rock under a pressure of 1200 lbs. to the square inch. The vein at the depth of 191 feet required several carloads of cement before the flow could be controlled, and the services of a diver to insert the pipe at the proper point. Preparatory to blasting, holes were drilled obliquely about the margin of the shaft, one foot apart, and into these were forced all the cement slush that they would receive. In the case of the Sylvania, a concrete lining, 24 to 30 inches thick was required to restrain the flow. Below the Sylvania, the flow was greatly reduced and finally completely disappeared. The shaft was ventilated during the progress of the work by a canvas flue, in 50-foot lengths, and 4½ feet in diameter, through which air was forced to the workmen.

The shaft is to be divided into three compartments, separated by board linings, two for the operation of the 2½-ton skips and the third provided with a set of ladders for emergency purposes. A series of 10-inch holes is being drilled alongside the shaft to receive the steam and water pipes, electric wiring, etc. The surface equipment consists of a boiler house, hoisting plant, and a coal crushing, steel head frame 125 feet in height (see Pl. XXXII, B). Six grades of salt are secured by crushing and screening; as follows:

Lumps. Coarse fragments for salting stock.

No. 2. Passes through ⅜ inch mesh and caught on ¼ inch mesh screen.

No. 1. Passes ¼ inch mesh and caught up on 3-16 inch mesh.

"C.C." Coarse chemical. Passes 3-16 inch mesh and caught upon ⅛ inch mesh.

"F.C." Fine chemical. Passes ⅛ inch mesh and caught upon 1-16 inch mesh.

"Dust." Everything passing through 1-16 inch mesh.

The plant is located alongside a branch of the Michigan Central Ry. and the company has constructed a line—"The Detroit and Western Ry." From its shaft house to the Wabash, slightly over a half mile to the west. The markets for the salt thus far are mainly Chicago and St. Louis, the salt being used mainly in curing fish, meat and hides, manufacture of ice cream and general refrigeration. Henceforth, the mining of rock salt is to be reckoned as one of Michigan's important industries, the only other states producing this material being New York, Kansas, Louisiana, Utah, Idaho and California.

Pigments. Deposits of red and yellow ochre, of sufficient size to be of economic importance, occur in Sumpter township. These represent swamp deposits of iron oxide, transported through the "agency of plants and finally precipitated along with impurities of sand and alumina. Iron bearing minerals contained in the soil furnished the original supply, the decay of which led to the formation of iron oxide, which in the presence of the carbon dioxide gas, resulting from plant decay, was converted into the very soluble iron sulphate ($FeSO_4$) or the iron carbonate ($FeCO_3$), which is somewhat soluble, especially in water containing the carbon dioxide gas. In these forms, the iron may be transported to the swamp, where upon standing the carbonate or sulphate is decomposed and a compound of iron, oxygen and water formed, known as hydrous ferric oxide, or limonite ($2Fe_2O_3+3H_2O$). These changes are expressed by the following equations readily intelligible to those having studied chemistry.

$$4FeCO_3+7H_2O+2O=(2Fe_2O_3+3H_2O)+4H_2CO_3$$

$$4FeSO_4+7H_2O+2O=(2Fe_2O_3+3H_2O)+4H_2SO_4$$

When the deposit is sufficiently pure, irregular, brownish-yellow lumps are formed which are known as "bog ore," local deposits of which occur in numerous parts of the township and in an early day were of economic importance. When the deposit goes down in earthy condition, with more or less impurity, it is known as "yellow ochre" and when ground and mixed with oil has value as paint. Upon standing under certain conditions, this form of the oxide is changed to the ferric oxide, hematite (Fe_2O_3), which contains no water chemically united with it, although often mechanically mixed therewith. This has a cherry red color and when earthy is known as "red ochre," valuable also as a pigment. An extensive deposit, mostly of the yellow but with some of the red, occurs a mile west of Martinsville in Sumpter township (secs. 9, 10, 15 and 16), reputed to be a mile square and an average thickness of 6 to 10 feet. It is said to rest upon marl which indicates that it is a younger and true swamp deposit. Other deposits are reported from secs. 6, 18, 20 and 22. Some 7 or 8 years ago a company ("Huron Valley Consolidated Oil and Paint Co."; Thomas W. Boatwright, President, Ypsilanti, Mich.) was organized to put this material upon the market. Land was purchased and some farms leased and the intention was to erect a factory at Belleville, but there the matter still rests.

MATERIALS AS ABRASIVES.

When examined under the microscope, much of the Sylvania sand is seen to have been secondarily enlarged, crystal faces having formed over the well rounded granules, giving highly perfect edges and points. Such sand is peculiarly well adapted to serve as an abrasive, wherever loose sand can be utilized; as in scouring, sanded surfaces, sand blasting, etc. Along Raisin River, in the neighborhood of the outcrop in Monroe County, the farmer's wives have long known of its superiority over the common sand of the region for scouring kitchen utensils. Owing to its purity, whiteness and sparkle, it has proven popular with the match manufacturers to supply the rough surface placed upon each box. It should make a very superior soap of the *sapolio* type, when supplied in the proper proportions. For use in aquaria and in schools where sand moulding is carried on, the Sylvania has no superior. An exceedingly fine grayish sand obtained from the Huron valley has been placed upon the market and sold locally by Frank Miller, of Belleville. It was advertised as "Deep down Polish" and recommended for iron, tin, brass, copper and silverware. The individual grains can just be detected with the naked eye when spread thinly over a dark surface and when rubbed between the fingers; under the microscope appearing as sharply angular mass of grains, chiefly quartz. The sand probably represents a delta deposit of the Huron during one of the ancient lake stages.

MATERIALS FOR FUELS.

Peat. The waters of the glacial lakes lingered so long over the more poorly drained portions of Wayne County that no extensive beds of peat were able to form. The production of this type of material requires shallow water, or swamp conditions, for the favorable growth of the mosses and sedges (*Sphagnum* and *Carex* principally), and for their subsequent preservation. The sites of the more extensive swamp areas, previously located (see Pl. X), furnish deposits of peat, but are probably of no great thickness, and, at present, of little commercial value. The utilization of peat as a fuel is seriously retarded by the expense of drying, this being done by the sun in many countries where peat is extensively used as a fuel. For commercial purposes, this seems so far to be impracticable. The production of gas from peat is now possible by placing the partially dried product in an especially designed retort, with a certain amount of air and superheated steam. The by-product is ammonium sulphate ($(NH_4)_2SO_4$), which has high value as a land fertilizer. The use of fibrous peat as litter in bedding stock is also to be strongly recommended. When used as an absorbent for the liquids about the barn yard that are wasted the peat becomes even more valuable than the leached manure itself. A discussion of the occurrence, origin, composition and properties of peat will be found in the Ann Arbor Folio.[6]

Oil and gas. Much money has already been expended in searching for oil arid gas in southeastern Michigan, but with practically nothing in the way of direct returns. As a result of these enterprises, however, we have learned much concerning the geological substructure of this portion of the state, of its water-bearing horizons and through the log of the deep well at Wyandotte in 1887 (Eureka Iron and Steel Works) the presence of rock salt was made known. This discovery has meant more for the industrial development of Wayne County than any reasonable amount of oil and gas could have done. It has also shown that there is no justification for further heavy expenditures in the search for oil and gas, since the rock strata are dipping to the northwestward and these desired products appear to have shifted to the Canadian fields about Leamington. The heavy flows of pocket gas, often encountered when the Antrim shales are penetrated will continue to arouse false hopes and stimulate unwise expenditures in the future as in the past. This gas at times shows pressures of a hundred pounds, or more, to the square inch and if confined properly could be utilized by the farmers for cooking, heating and lighting their homes and in caring for stock. Just over the Base Line in Oakland County, W. J. Purdy has a 110-foot well (NE. ¼ NW. ¼ sec. 25, Southfield township) which has supplied his home with fuel for 16 years, the original pressure being 37 lbs. to the square inch. Under the terms of a lease to outside parties 5 other holes have been drilled, all but one yielding gas. The supply from each well will be exhausted, sooner or later, which may be replenished by sinking a new well.

Since fragments of this shale will often burn with flame when placed in the fire, it has been mistaken for coal and efforts made to start mining, as reported from near Belleville. As a bed, it contains great quantities of gas, oil and other combustibles, which might be secured by distillation, but which will not become commercially valuable until our present fuel supply is more nearly exhausted. Upon the estate of W. H. Stevens, NW. ¼ NE.¼ sec. 13, Greenfield township, the experiment was tried for a few years of manufacturing lampblack through the incomplete combustion of this natural gas, causing the carbon to be deposited. The experiment was not especially successful and was given up about 12 years ago.

1. When the original data relative to the economic resources of Wayne County were collected in 1902-3, detailed statistics were obtained concerning the various industries. Since these are now out of date and the State Geological Survey has recently been assigned the duty of gathering such statistical data, the reader is referred to the Survey for such information.

2. See Geological Report on Monroe County, 1900, p. 180. Geological Survey of Michigan, vol. VII, pt, 1.

3. Along with tricalcium aluminoferrite, $3CaO_2(AlFe)_2O_3$.

4. For a discussion of the origin of marl, its occurrence and uses see report in the Geological Survey of Michigan, vol. VIII, pt. III, 1903.

5. A detailed description of the shaft from an engineering standpoint will be found in the Engineering and Mining Journal, March 18, 1911, p. 565. "Shaft of the Detroit Salt Company" by Albert H. Fay.

6. C. A. Davis, U. S. Geological Survey, No. 155, p. 8. See also Report of the State Board of Geological Survey of Michigan for 1906, p. 92 and 1908, p. 205.

CHAPTER IX. SUMMARIES BY CIVIL DIVISIONS.

To furnish residents of the county with condensed information relating to their own or neighboring localities and to point out the near at hand illustrations of the various features discussed in the body of this report, it is proposed to devote this chapter to a set of summaries by townships. The classification adopted is genetic, and hence natural, and groups together townships which are related in topography, soils, agricultural products, problems of drainage, water-supply, roads, etc. Most of the townships fall readily into some one of the main divisions, some of them overlap the natural areas so that they combine characteristics of the two and have been placed in the division that appears dominant.

MORAINIC AREAS, UNDULATING SURFACE AND CLAY SOILS.

Northville township. T. 1 S., R. VIII E., (northern part). Named from village when it was detached from Plymouth township in 1897. Township lines were originally surveyed by Alexander Holmes in 1815 and subdivided the same year by Joseph Wampler. Area 18,270 square miles; population 2274. Surface rough with knolls, ridges and depressions strewn with surface boulders; soil mainly stiff clay of glacial origin; many of the hills composed of gravel and sand of the type known as kames. The highest elevation in the township (the county as well) lies in the NW. ¼ sec. 6 and equals about 980 feet above sea level; the lowest is at the SE. corner (sec. 13) and is about 715 feet. A broad glacial drainage channel extends sonthwestward from Northville village, across secs. 3, 4, 9, 8, 17 and 18, floored with gravel and sand, once carrying the drainage of the ice sheets to the southwestward, while the ice was forming the Defiance moraine, lying just to the eastward. This moraine covers conspicuously the eastern half of the township excepting sec. 13 and is drained into the Middle and Upper Rouge. The drainage of the old glacial channel noted is now reversed being to the northeastward. West of this channel lies the Northville moraine, involving secs. 4, 5, 6, 7 and 18, many of these hills being kames. The northwestern half of sec. 6 was coated with more or less sand and gravel by the glacial outwash when the ice was forming this Northville moraine. The Upper Maumee beach cut southwestward from the NE. cor. sec. 12 to the SW. cor. sec. 14, lying just above the 800-foot contour, showing also in the depression that crosses secs. 1 and 2. The Middle Manmee beach enters the township in the SE. ¼ NE.¼ sec. 12, showing excellent development in sec. 7, Livonia, and passes southwestward just above the 680-foot contour. The Lower Maumee beach enters in the NE. ¼ SE. ¼ sec. 12, lying above and parallel with the 660-foot contour. All three beaches mark the successive shore lines of the old glacial Lake Maumee, consist of disconnected ridges of gravel and sand, approximately parallel and with a NE. to SW. trend. The best place to identify and study them is along the N-S road at the eastern margin of sec. 12. The lowest of the series is the least well defined, which is believed to indicate that it was formed before the middle one and was then washed over while the middle was forming. The outlet of the first of the series of lakes was at Ft. Wayne, Indiana, into the Wabash and later by this and another at Imlay City into Grand River to the site of Chicago. Eastward of these beaches, the land was submerged for a, time, including the SE. ¼ of secs. 12 and 14 and all of 13, by which the morainic knolls were lowered some and smoothed and the hollows between partially filled. The diagonal road through the SE. corner of sec. 13 is carried upon a still better defined gravel beach, known as the "Belmore" or "Whittlesey beach," the shore line of Lake Whittlesey, which drained across the "thumb" at Ubly, into the Grand Northville township is well supplied with springs of pure cold water, from its gravel and sand deposits; but getting water from. the clay hills is uncertain, the supply being meager in amount and often obtained at considerable depth (8 to 125 feet), invariably hard, but free from, sulphur or gas. The bedrock is buried by 90 to 250 feet of clay, sand and gravel ("drift") and consists of light colored shales, sandstone and some limestone, yielding fresh water under sufficient "head" to nearly reach the surface in the depressions. The township was originally forested with a heavy growth of black walnut, beech, maple, oak and hickory, with some birch and bass.

Plymouth township. T. 1 S, R. VIII E., (southern part). Probably named from locality in Massachusetts; established in 1827; included Canton until 1834 and Northville until 1897. Township lines surveyed by Alexander Holmes in 1815 and subdivisions made the same year by Joseph Wampler. Area 19.140 square miles; population 2248. The western half of the township is rough, rolling morainic topography, rendered so by short, slightly curved and irregularly placed clay ridges of the Defiance moraine, with much less gravel than is found in Northville. Field boulders and cobbles strew the surface as they were dropped from the ice sheet. The outwash glacial drainage channel, located in Northville township, extends across sec. 19 giving some sand and gravel; slack drainage and swampy. A somewhat flat ground morainic area extends NE. to SW. across secs. 29, 30 and 31. The Upper Maumee beach, in the form of a disconnected gravel ridge, pursues an irregular, wavy course across secs. 22, 28, 33 and 32 into sec. 5 of Canton, just above the 800-foot contour as it follows along the dissected eastern flank of the Defiance moraine, marking the highest stage of the glacial waters in this region. The Middle and Lower Maumee beaches roughly parallel the Upper, at a distance of ¼ to ½ mile to the eastward, but are disconnected and rather difficult to follow. Their lakeward slopes determine the location and general direction of the 680 and 660-foot contours passing through secs. 22, 27, 28, 33 and 32. A good location in which to see all three is along the N-S highway between secs. 32 and 33, the Upper being seen just where this road is crossed by the diagonal road leading towards Plymouth, while the Lower crosses the town-line at the SE. corner of sec. 32. Along the line of the Pere Marquette By., leading west from Plymouth, a good section of he Lower Maumee may be seen ½ mile west of the station (SE. ¼ SE. ¼ sec. 22), and of the Upper about ¾ mile further west, with the middle less well defined and lying between. The Belmore or Whittlesey beach, marking the margin of glacial Lake Whittlesey, is a splendidly defined gravel ridge, carrying the diagonal road which passes SW. across sec. 24 to where it is intersected by the diagonal road from the NW. Here the beach leaves the road, curves to westward entering sec. 26 near the NE. corner and pursues a very direct course SW. across secs. 27, 34 and 33. In the village of Plymouth, it has determined the direction of the main residence street and the beautifully graded sites for the homes, at an elevation of approximately 736 feet above sea level. Eastward of the Whittlesey beach, the topography is relatively flat, the soil a gravelly, sandy loam as a result of the delta deposits of the Middle Rouge during the glacial lake stages, involving all of secs. 25, 35 and 36, the greater portions of secs. 24, 26 and 34 and the SE. corners of secs. 27 and 33. Over this delta deposit there ccur in secs. 26 and 36 a few low gravel or sand ridges, having a course N. NE. to S. SW., representing bars in the old lake, or washed over beaches of Lake Arkona stage, which were supposed to have been formed before the Whittlesey, an advance of the ice dam then forcing the water to the Lake Whittlesey level. The highest elevations are found at the NW. corner of sec. 20 and the adjacent NW. corner of sec. 21, along the crest of the Defiance moraine, rising to 880 feet above sea level. Outside the bed of the Rouge, the lowest elevation is at the SE. corner of sec. 36 where it is close to 690, giving an extreme relief in the township of 190 feet. The drainage of the NE. and NW. corners of the township is into the Middle Rouge, the remainder into the Lower Rouge. The bedrock consists of the "Coldwater shales," which are light colored and interstratified with seams of sandstone and some limestone. They are covered by from 90 to 250 feet of clay, sand and gravel, the depth to rock at Plymouth being 100 feet and having an elevation-above sea level of about 635 feet.[1] The elevations of the rock surface probably do not differ greatly, apparently rising some to westward, the great differences in the thickness of the rock cover being due mainly to the morainic features noted. So far as known, the water from bedrock is not highly mineralized and contains no notable amounts of gas or sulphur unless the underlying black-shales are reached. At Plymouth, the head of this water is about 725 to 735 feet. Over the morainic area, springs occur but not as abundantly as in Northville township, since the gravel hills are not so numerous, and the problem of getting well' water is somewhat uncertain. The wells range in depth, from 14 to 80 feet and yield a hard water; often abundant but sometimes all too meager. East of the Whittlesey beach the wells are shallow as a rule, 9 to 18 feet, the delta deposit reposing upon the clay and attaining a thickness of some 18 to 30 feet. On the beach itself the gravel is 20 to 25 feet in thickness, yielding, a limited supply of hard water, liable to contamination. In section 34, within ¾ of a mile of the. Whittlesey beach there occurs a cluster of flowing wells from 50 to 70 feet in depth, rising some two to three feet, containing iron but little other mineral besides and having a temperature of 51° to 52°. The natural forest growth over the morainic, clay areas. was walnut, hard maple, beech, whitewood, oak, white ash, rock elm and basswood. Over the sandy gravelly loam areas; elm, black ash, whitewood and hard maple.

Monguagon township. T. 4 S., R. X to XI E., (in part). Passing from the western part of the county to the extreme eastern we have a strip of territory that has much in common with it. This township was named from the old Potowatamic chieftain; was originally surveyed by Joseph Fletcher in 1816 and 1817; established in 1827; has an area of 23.355 square miles and a population of 3367. It includes Grosse Isle and some of the smaller adjacent islands. Except for a narrow, sandy strip running southward through secs. 11, 14, 23 and 26, marking the level of the First, or Upper Lake Rouge beach (elevation about 594 feet), the soil of the township is stiff, glacial clay, sparingly strewn with boulders and cobbles and having a gently undulating surface. These undulations are very different in appearance from the ridges and knolls of Plymouth and Northville townships, consisting of approximately parallel, N-S. corrugations in the clay, varying in height from 1 ft. to 12 or 15 ft. These are highest in the vicinity of Trenton where they rise some 28 feet above the river level (elevation 602 feet) and upon the western half of Grosse Isle, gradually becoming lower toward the westward and dying out on the flat till plain just over the township line in Brownstown. In Amherstburg, opposite in Ontario, the same type of ridging is seen, also fading out to the eastward. These ridges were formed at the front of the ice sheet, in some 225 feet of water, the oscillations of the ice wall gouging into the clay of the ground moraine and pushing it up into these regular ridges, dropping on top of them whatever stones were brought to the margin of the ice. These features constitute the Grosse Isle moraine and while they were forming, the shore line of the glacial lake (Maumee) was in the vicinity of Plymouth and Ypsilanti, with its drainage through the Imlay channel into Grand River and Lake Chicago. Some of the depressions between these glacial ridges were occupied by streams of water (the "distributaries" of Taylor) when the level of Lake Rouge fell from its higher to its lower stage (elevation about 590 to 580 above sea level). The current was probably not great and the cutting and deposition were correspondingly small. One of the most conspicuous and typical of these distributary channels leaves the Trenton channel of Detroit River, just north of the Church and Co. abandoned plant, curves to the southwestward, about ½ mile west of Trenton, branches in the SE. ¼ sec. 24, gives off a number of minor branches to the southeastward in sec. 25 and itself joins Brownstown Creek. The "thoroughfare" on Grosse Isle is of the same nature, crossing diagonally to the southwestward and sending off a branch opposite Slocum's Island. Even where not of the nature of distributaries, the ridges control the present drainage, forcing it into the depressions which slope to the southward; good illustrations of very young, consequent streams. The highest land in the township is over the crest of the moraine, along the road between secs. 6 and 7, reaching approximately 605 feet above sea level, or about 31 feet above ordinary river level. Along the eastern flank of this elevation, at Wyandotte Heights, the First Rouge beach shows somewhat poorly, extending southward through the western part of sec. 5, and southwestward across sec. 7. Just opposite upon Grosse Isle, the same poorly defined, gravel ridge curves about the head of the island. Monguagon township was submerged during the second and third stages of Lake Maumee and during the lives of the entire series of glacial lakes to the first stage of Lake Rouge, when the crests of the higher morainic ridges had emerged from the glacial waters. In spite of this long submergence, conditions were not favorable for the deposition of lake sediments in the form of clay; the glacial clays, cobbles and boulders showing upon the surface. The bedrock consists of Dundee limestone over the northern portion of the township and Upper Monroe dolomite over the southern portion of the mainland and Grosse Isle. Natural outcrops occurred at Sibley, Stony Island and the southern part of Grosse Isle. At the two latter places quarries into the dolomite have been opened and abandoned, while the limestone quarry at Sibley (sec. 7) is in very successful operation. The drift cover increases most rapidly to the northward attaining a thickness of 70 to 80 feet on the town line between Monguagon and Ecorse, and at the head of Grosse Isle. Water is ordinarily obtained from layers of gravel or sand in this drift at variable depths. Springs are not abundant owing to the scarcity of surface gravel and sand deposits. Northward through secs. 25, 24, 13, 12 and 1 there have been strong flows of artesian water, with some sulphur, but practically all have ceased flowing, for reasons not yet positively known. The native forest growth is white and black ash, hickory, walnut, beech, hard and soft maple, elm, basswood, yellow and white oak, whitewood, cottonwood and sycamore.

City of Detroit (City of the "strait") T. 1 and 2 S., R. 11 and 12 E., (in part). Founded in 1701; incorporated as a town in 1802; as a city 1806; charter repealed in 1809 and regranted in 1815. Area approximately 42 square miles; population 465,766. Although in the vicinity of the suburbs, there occurs considerable sand and the type of ridging that accompanies this soil, the city is built upon a broad clay ridge, the Detroit moraine, which appears in the vicinity of Birmingham, passes southeastward, crosses the river to Windsor and continues southeastward across Essex County. The highest elevation in the city is in the vicinity of Voigt Park, out Woodward Avenue near the city limits, where the sand covered morainic surface rises from 636 to 638 feet above sea level, or some 62 feet above river level. The slope is rather gradual to the southeastward, across Woodward Avenue, in the direction of Elmwood Cemetery, becoming steeper as the ridge narrows and curves slightly to the west of the cemetery. From the city limits, along the crest of the ridge to Gratiot Avenue, the average slope is but 3 feet to the mile, while, beyond to the river, the average slope is about 34 feet to the mile. From the crest of the ridge, the slope is gentle and rather regular to the southeast and southwest. This moraine is believed by Taylor to have been formed *sub-glacially*, (as an "interlobate") along the line of junction of the Huron and Erie lobes of ice during the final stage of the Late Wisconsin, thus accounting for its smoothness and generally subdued character, its breadth, direction, location and freedom from boulders. For a distance of two miles back from the river, across the crest of this moraine and upon its eastern and western flanks, there occurs a series of corrugations similar to those just described in Monguagon township and believed to have been formed in the same way and at the same time. They may be seen typically by passing out Gratiot Avenue to the vicinity of Joseph Campau Avenue and for a distance of two miles from the City Hall out Michigan Avenue by glancing along the side streets. They are believed by the writer to represent the ridges of ,a water-laid moraine, pushed up by the rythmic movements of the ice-front, extending across the previously formed Detroit moraine, in some 150 to 200 feet of water. Those to the eastward of the crest of the ridge would be arbitrarily assigned to the Huron lobe of ice and those to the westward to the Erie lobe, and hence to be part of the Grosse Isle moraine which passes from the head of that island to Detroit upon the Canadian side of the river. Those ridges for which the Huron lobe was responsible may be connected with the Mt. Clemens moraine, which comes in from the north, but the writer believes that they are directly connected by additional and similar ridges with the Emmet moraine which passes along the eastern shore of Grosse Point township to Milk River Point, there entering Lake St. Clair.

Belle Isle and Isle aux Peches, in the upper Detroit River, probably owe their existence to this same moraine, these islands representing ridges which have been emphasized by stream action, exactly as have those in the lower Detroit region where the correlative moraine crosses the river. The lake chart shows a submerged ridge between Belle Isle and Detroit lying mainly to the north of the bridge and parallel with the others. In the vicinity of the river, some of these ridges have been emphasized by stream action, two of the depressions having furnished the beds of “distributary channels," similar to those described as occurring near Trenton. The Detroit moraine is conceived of as a dam when the waters of the First St. Clair stage were dropping to the next lower stage and through these depressions the currents coursed, carrying much sand and gravel and depositing it in the vicinity of Ft. Wayne and Clark Park in the western part of the city, obscuring life glacial clay. Congress Street, eastward of Woodward, marks the axis of one of these distributary channels and the depression along Labrosse and Baker, to the west of Grand Circus Park, seems to have served as another. Others probably existed in what is now the channel of the river. These ridges subsequently controlled tine surface drainage of the region, to a large extent, until deflected by sewers.

The present site of Detroit remained submerged during the entire series of glacial lakes from Maumee to Lundy, 2nd stage. During the 1st stage of this latter lake, the main shore line was just north of the present city limits, in Highland Park, but disconnected sand bars and beaches were being formed in the northern and northeastern portions of the city at elevations of 630 to 636 feet above sea level, showing that the present site was just awash. One of these sand ridges crosses Woodward at right angles between Schiller and Shakespeare streets, on the west and Boston and Chicago upon the east, extending towards Kenwood Station, turning SE. on Oakland and then to the south from Mott as far as Koch, one block east of Woodward. A similar, but not so sharply defined sand belt, has a southerly course, about ½ mile west of the Milwaukee Station and a second roughly parallel and just east of Harper Avenue. To the second stage of Lake Lundy, the water dropped about 25 feet uncovering much of the present city's site, and depositing considerable sand to the north and east of Elmwood Cemetery, between the contours of 610 and 620 feet, along, but mainly to the east of Gratiot. In the opposite part of the city, this shore line (Elkton) is indicated by a sand ridge, having a general easterly course through Beech Hearst, north of Warren Avenue, crossing Warren in the vicinity of 27th Street and continuing as far as 17th, where it dies out, having followed closely the 610-foot contour. In passing around the nose of the Detroit moraine, just west of Elmwood Cemetery, there seems to have been more current action, since we find a cut bluff instead of a sand ridge, well shown between Monroe and Macomb streets, in the vicinity of Joseph Campau Avenue, but continuing eastward and westward for many blocks. Standing at Grand Circus Park and looking out Woodward the cut bluff shows plainly, between Columbia and High streets, although grading has interfered some with its distinctness. Lake Lundy during both stages drained through Mohawk River eastward while the ice front is believed to have stood in the vicinity of Alpena. Between the contours of 590 and 595 feet, and following Jefferson Avenue quite closely throughout nearly its entire length, another cut bluff marks the water level of the First Lake St. Clair, a little sand having been deposited to the northwest of the Waterworks. In the vicinity of Wayne Street, this water line crosses Jefferson to the westward, intersecting Larned, Congress and Fort streets and roughly following Lafayette as far as the Boulevard. Somewhere along its course this beach line changes to that of the First, or Early Lake Rouge, the waters of which took the sand deposited by the distributaries noted above and heaped it into beach and bar ridges between Clark Park and Woodmere Cemetery, Ft. Wayne and West Detroit. The lower beach of lakes St. Clair and Rouge, just above the 580-foot contour, may be seen in the vicinity of the Waterworks and of Ft. Wayne, but between has been largely obliterated by grading and water front construction.[2] During the existence of the early lakes Rouge and St. Clair, the drainage of Lake Algonquin, their correlative to the north, shifted considerably, being at one time at Trent, Ontario, at Chicago and through these two lakes into Lake Erie. The ice had retreated far to northward, finally withdrawing into the Mattawa and Ottawa valleys. The lower stage of lakes Rouge and St.

Clair is correlated with the Lakes Nipissing, the disappearance of the ice in the Georgian Bay region, allowing drainage by North Bay, Ontario. The thickness of the drift ranges from 90 to 160 feet, overlying the bedrock, consisting almost entirely of Wisconsin till, only sparingly charged with rock fragments and so soft that it can be easily cut with a spade. Lenticular masses of quicksand and occasional strata of gravel occur, charged with fresh water. The clay is largely leached of its lime carbonate to a depth of 12 to 15 inches and oxydized often to a depth of several feet. The occurrence of quicksand in the till may make the taller buildings very insecure upon their foundations, requiring the use of piles, or the placing of the supporting masonry upon bedrock. Only a full series of borings should be relied upon to prove the absence of such quicksand deposits at each locality. The bedrock underlying the city is largely limestone of Traverse (Hamilton) and Dundee ("Corniferous") age, the elevation of the surface of which ranges from about 440 to 500 feet over the greater part of the city. In the preliminary borings for the tunnel, "sandstone" is reported in a number of cases, but in view of the full development of Dundee at Oakwood. in Windsor, and at the Ford building, and the fact that no sandrock is to be expected at this geological horizon, the identification may be seriously questioned. The rock surface drops slowly to the eastward being about 457 feet above sea level at the head of Belle Isle, culminating in local depressions in Gratiot and Hamtramck townships. Were it not for the drift, the present site of Detroit would be covered by an average of about 85 to 90 feet of water. In the early days, the settlers obtained their water directly from the river but an increase of population rendered this inconvenient and a system of public and private wells was made use of, these being dug to the water-bearing strata in the sand and walled up with stone. In the summer of 1829 a deep well was sunken by The Hydraulic Company on the south side of Fort Street, between Shelby and Wayne, to a depth of 268 feet and 4 inches in diameter, bedrock ("geodiferous limerock") being reached at a depth of 127 feet. Water in sufficient quantity was not obtained and recourse was again had to the river. A crude pumping plant was begun in 1825 to use the river water, the mains being made of hollowed tamarack logs and the pump was driven by horse power. Water from the bedrock is highly mineralized and contains sulphur. The head in the western part of the city reaches 595 feel, rises to the north and west and drops slowly to the eastward, being about 580 at the Murphy Power Plant, corner Wayne and Congress streets. The temperature of this water may range from 49.5° to 52.5°F., so far as may be judged from the half dozen records available. The original forest growth was white and red oak, ash, whitewood, cottonwood, walnut, butternut, beech, birch, hickory, elm, maple, basswood, cedar, etc.

Grosse Point township. T. 1 to 2 S., R. XIII E., (in part). Named from the large point of land constituting the northeastward corner of Wayne County. Separated from Hamtramck town-ship in 1848, contributed to Gratiot in 1903. Approximate area 11.310 square miles; population 3,579. Surface rendered undulating by the Emmet moraine which follows the shore line, the crest of which rises to 620 feet, near the center of the township, or about 45 feet above the lake level. Drainage is to the southwest-ward by Fox Creek and to the northeastward by Milk River, lying to the westward and being deflected by the morainic ridges. The divide between the two streams is poorly defined, in the western part of the township, opposite Vernier. The entire township was subdivided into "French claims," running back from the water front, the direction of which determined the course of the roadways and private lanes, with a NW. SE. trend, as well as those which crossed the claims at approximately right angles. The exact location of these latter was determined very largely by the NE.-SW. sand ridges of the first stage of Lake St. Clair. Soil mainly a glacial clay, with some surface dressing of sand and a little gravel, but with few cobbles and boulders distributed over the surface. In the northeastern part of the township the moraine lies nearer the lake shore, has been cut into by wave action and there has been a concentration of boulders and cobbles which have partially protected the bank from further encroachment (Pl. XI, B). In addition to this protection, trees, brush, logs, piles, planking and breakwaters have been used to prevent cutting. Since French occupancy, it is estimated that 1000 feet have disappeared to the east of Jefferson Avenue at one place, carrying away a cemetery and orchard; some 130 feet having disappeared during the last 30 years in the vicinity of Vernier Road. Farther north a settler's house had to be moved back twice to keep it from falling into the lake. A fragment of a till ridge, about a mile lakeward from the main ridge of the moraine, lies just eastward of Windmill Point and enters the lake forming a bluff 12 to 14 feet above lake level. Between this point and Fairview Village considerable marshy land and muck borders the lake. In the depression occupied by Fox Creek and Milk River, there is some marsh, mucky soil and more or less lake clay deposited. During the first stage of Lake St. Clair, the township was under water except for an Elliptical island, about two miles long by one mile broad, extending from Claireview to Grosse Point Farms, rising about 20 to 25 feet above the water. The narrower portion of this crest existed as a bar during the Elkton stage of Lake Lundy, the main shore line lying some 3 to 4 miles to the west. Upon both the eastern and western slope of this island, sand and gravel ridges were deposited during the life of the two preceding stages of Lake St. Clair, the eastern lying near the present shore line and parallel with it, the western having the same NE.-SW. trend and about a mile to westward, rising to the height of 620 feet. From Grosse Point Farms, two ridges of sand unite from opposite sides of the island and extend W.-SW. as a single ridge, attaining a height of 620 feet, and giving an irregular and more or less disconnected belt of sand to the north of Jefferson Avenue and curving around to St. Clair Heights. The second stage of the lake formed a sand ridge between 580 and 585 feet, which is followed closely by Jefferson Avenue, especially well shown at

Cottage Grove, where the ridge has deflected the course of Fox Creek to the westward and lengthened the stream by some two miles. From Grosse Point Farms, to the northeastward, this beach lies mainly on the lake-ward side of Jefferson and has been largely destroyed by wave action of the present lake. A second sand ridge was thrown up by the waves about 1½ miles to the westward, parallel with the present shore to an elevation of 484 to 488 feet above sea level; determining the location of Mack Avenue for its last four miles in Wayne County. This sand is 5 to 6 feet thick, rests upon blue clay, and yields a poor supply of moderately soft water. Obtaining water from the glacial clay is uncertain, requiring depths of 35 to 80 feet; water hard. Rock records are meager in the township the depth to which ranges from 90 to 160 feet, the extreme southern portion of the township being apparently underlain by limestone and bluish shale (Traverse) and the remainder by the black shale (Antrim). The latter generally gives gas, with some sulphur; the former formation generally yields water more or less charged with salt. The head is insufficient to bring the water to the surface except on the old Woodbridge estate (claim No. 183), just south of the Vernier Road upon Jefferson Avenue, where rock was struck at 95 feet and entered .5 foot, the water rising a foot above lake level, marking the beginning of a belt of lowing wells which become numerous along the lake front in Macomb County. The native timber was elm, oak, basswood, black ash, hickory, sycamore, with some beech, maple and whitewood.

Gratiot township. T. 1 S., R. XII to XIII E., (in part). Named from Col. Charles Gratiot Established, in 1003 from portions of Hamtramck and Grosse Point; area 10.425 square miles; population 1900. Rectangular survey by Joseph Fletcher in 1816; eastern and southern parts of township made up of "French claims" from Lake St. Clair, Detroit River and Conners Creek, causing much irregularity in the direction of highways, both as to their direction and spacing. The soil is very largely a glacial clay, but with relatively few boulders and cobbles strewing the surface and flat, smooth topography, with slopes changing from east, through south around to southwest, directing the drainage to Milk River, Fox Creek and Conners Creek. The township contains the southern extension of the Mt. Clemens moraine, much better defined to the northward, but here a broad, poorly defined swell of glacial clay with no perceptible ridging. It was deposited under water, at a depth of 1G5 to 175 feet, the ice margin having here none of the gouging, pushing effect that marked the formation of the Emmet and Grosse Isle moraines. Just northward in Warren and Erin townships, boulders and cobbles are much more in evidence. The main slope of the township is slightly south of east and averages but about 8 feet to the mile, dropping from 629, at the extreme NW. corner (sec. 2), to about 588 along the eastern border. The even topography and clay soil are interrupted in secs. 2 and 11 by an irregular set of sand ridges, some 10 to 12 feet above the general level, representing shore deposits in the early stage of Lake Lundy and more or less modified by subsequent wind action. When the waters of this glacial lake fell to the Elkton stage (about 635 to 610 feet, above sea level), the shore lay to the east of Gratiot Avenue, where on the shallow and gently sloping strand, small, disconnected ridges of sand were formed over an area, ½ to 1 mile broad, reaching from the Base Line to Conners Creek. The wave action does not seem to have been heavy, in part accounted for by the presence of the morainic ridge and island in Grosse Point township. When the water level fell to the First Lake St. Clair stage, wave action continued slight, apparently because the force of the waves was broken to eastward, and a small notch, 12 to 18 inches deep, was cut in the clay, with practically nothing in the way of deposit. This starts just where the Vernier Road joins the Base Line, passes across the claims, veering slightly to the west and curving around to where Mack Avenue crosses-Conner Creek. In this vicinity, passing from behind the island above noted, the wave action appears to have been greater and a sandy ridge was formed. The course of this shore feature was mapped before the topographic map was made and was found to be almost exactly parallel with the 600-foot contour, and at an elevation of about 595 feet. Medium hard to soft water is obtained from the sand areas at shallow depths. Over the clay portions of the township hard water is obtained only at variable depths and in varying quantities, depending upon how successfully the water bearing horizons are reached. These wells range from 9 or 10 feet to bedrock, which varies from about 110 feet in the eastern part of the township to 135 in the western, increasing to some 160 or 170 feet at the south. The elevation of the rock surface ranges from 420 to 500 feet above sea level, dropping to about 420, where the depth is greatest to the south of Conners Creek. This rock is mostly black shale (Antrim) and yields gas in small quantities. Ground water nowhere reaches the surface, falling short by some 5 to 20 feet, the head ranging from 600 to 612 feet. The original forest growth of this region was white and black ash, basswood, white oak, beech, hard maple, butternut and some walnut.

TILL PLAIN AREAS, FLAT SURFACE AND CLAY SOILS.

Canton township. T. 2 S., R. VIII E. Named from city of China. Derived from Plymouth township, established in 1834. Township lines surveyed in 1815 by Alexander Holmes; subdivided in 1819 by Joseph Wampler. Area 35.935 square miles; population 1113. Soil largely a stiff glacial clay; only restricted sand and gravel areas. Although submerged by the glacial lakes Maumee, Whittlesey and Arkona, there are no recognizable lake deposits from their waters. All but about 4½ square miles of the township is remarkably level and flat, left smooth by the Late Wisconsin ice sheet as it retreated from west to east. Two square miles at the northwestern corner (sec. 6 and portions of 5 and 7) are rough and rolling because of the Defiance moraine, formed at the front of the ice sheet during a stage of halt. This crosses from Plymouth, southwestward into Superior township, much of it above the 800-foot level, reaching 850 feet at the extreme NW. corner. This small area has all the characteristics given for Plymouth and Northville townships, of which it is geologically and physiographically a part. The eastern flank of this moraine held back the waters of Lake Maumee during its three stages and more or less continuous ridges of sandy gravel were built along the slope from materials washed out of the clay. The morainic knolls were thus subdued and the slopes rendered more regular as is indicated by the course of the 800, 780 and 760-foot contours. The three beaches cross secs. 5, 6 and 7, roughly parallel, from NE. to SW. and from ½ to ¾ of a mile apart. The first, or upper, is the less well defined and most difficult to follow as it was made when the lake was narrow and wave action relatively slight. It crosses the NW. corners of secs. 5 and 7 and the SE. portion of sec. 6. The third, or lowest, beach is the most direct and continuous, cutting diagonally through secs. 5 and 7, while the middle, lies about half way between these two. The most advantageous point from which to examine the series is at the SE. corner of sec. 6. From a half to a mile SE. of the Lower Maumee, and roughly parallel with it, lies the much more conspicuous and better known "ridge," known as the Belmore, or Whittlesey beach, standing some 10 to 15 feet above the general level, and having an elevation of 735 to 740 feet. Except for short distances at two points, this beach has furnished the site for the diagonal road in secs. 18 and 19 of Canton and sec. 25 of Superior (Washtenaw County), enters sec. 8 at the SW. corner, crossing the section to the west of the center, then crossing the SE. ¼ sec. 5 and the NW. ¼ sec. 4. Being so typical throughout its course, it may be observed to advantage at any point. It contains some 20 to 25 feet of gravel and sand and furnishes a desirable site for farm buildings, a number of houses in Cherry Hill being so placed. The slope from this beach to the southeastward is regular and relatively rapid to the 720-foot contour and then so gentle as to be barely perceptible to the eye, dropping to about 667 feet at the SE. corner. The drainage is thus deflected eastward into Tonquish Creek, a Tributary of the Middle Rouge, and southeastward into the Lower Rouge. From the second stage of glacial Lake Maumee, with drainage at Ft. Wayne, Indiana, into the Wabash and at Imlay City, into the Grand River Valley, the waters are believed to have dropped to the Arkona stage, during which drainage was around the "thumb" directly into the Grand. The level of the lake waters fluctuated and built up ridges from about 695 to 710 feet above sea level, when an advance of the ice covered the tip of the "thumb" again, raised the level of the water to the Whittlesey stage and forced the drainage across at Ubly into the Grand River Valley. The Arkona beaches were thus submerged and to some extent obliterated so that they may be traced often only with difficulty. They pass northward from Dentons through secs. 32, 31, 30, 29, 28, 20, 21, 15, 16, 17, 8, 9, 10, 4, 3, 2 and 1. A good development is seen at the NE. corner sec. 30 and .in the NW. ¼ NW. ¼ sec. 1. The Warren, or Forest beach, passes northward through the village of Canton as a moderately well defined gravel ridge, just above the 680-foot contour, crossing through the middle of secs. 34, 27 and 22. Riding out for a couple of miles and reappearing in 11, 2, 12 and 1. Some sand was blown, or washed westward from the Wayne beach in Nankin township and forms a thin veneer over the eastern row of sections from north to south. The NE. and SW. corners of Canton township extend into the gravelly sand deltas of the Middle Rouge and Huron rivers, representing deposits formed during the Arkona stage of the glacial lakes. Considered as a whole Canton township is at present the best watered of any in the county, containing the largest number of flowing wells and the best quality of water. These wells lie to the east of the Whittlesey beach, distributed over a belt three miles broad, crossing the township from northeast to southwest. The water ranges from soft to hard, generally contains iron and occasionally some salt and gas derived from bedrock, is obtained from the drift at depths ranging from 25 to 100 feet; 65 to 75 feet being a common depth. The head ranges from 690 to 720 feet, falling off to the eastward about as rapidly as the surface slope, so that the water rises generally from 2 to 4 feet above the level, and has an average temperature of 51 to 53°F. Shallow wells, requiring pumping, are obtained from the sand and gravel deposits and occasional springs appear. Bedrock records are very meager because of the ease with which water may be obtained from the drift, rendering our knowledge of the nature of the bedrock and its depth incomplete. The NE.-SW. diagonal of the township seems to roughly separate the black (Antrim) shale to the southeast from the Coldwater series of sandstone, shale and limestone to the northwest. The depth ranges from 80 to 100 feet over an E.-W. central strip of the township, deepening to 130, or 140 feet, toward the SE. and NW. The actual elevation of the rock surface over this central strip is about 620 feet above sea level, dipping to 575 feet in sec. 4 and about 535 in sec. 36. The original forest growth was hard maple, beech, oak, whitewood, walnut and butternut over the morainic regions at the NW. corner of the township; over the flatter areas black ash, elm, whitewood, swamp oak, soft maple with some beech, basswood and wild cherry.

Springwells township. T. 2 S., R. XI E., (in part). Name alludes to the abundance of flowing wells. Original survey of boundary lines in 1816, and subdivisions in 1817, by Joseph Fletcher. Line between public lands and private claims run by same surveyor in 1822. Established 1827; contributed heavily to Greenfield township and Detroit, having but 9.830 square miles left; population 1835. Southern portion of the township taken up with French claims from the Rouge, determining the direction of most of the highways. The topography is unusually flat and even, sloping very gradually from an elevation of 610 feet, along the north boundary line, SE. to the level of the stagnant portion of the Rouge, about 574 feet. The drainage to the Rouge is sluggish and the streams largely intermittent. The soil is almost exclusively clay, of glacial origin over the western half of the township, but with few cobbles and boulders. The eastern half of the township has received a deposit of stratified clay which was deposited as a sediment in the waters of the series of glacial lakes. This sediment was derived, in large part, from the underlying till, separated from the sand and gravel by wave action, carried lakeward and deposited in the depression that lay to the westward of the Detroit moraine. The heaviest of this deposit, so extensively utilized in the manufacture of brick and tile, lies between Michigan Avenue and the Michigan Central Ry. and eastward of the Pere Marquette Ry. From this as a center, it wedges out in all directions and mingles with the glacial clay. When quite wet and worked up by the wheels of vehicles, this type of clay gave almost impassable roads. Boulders are exceedingly rare in the deposit and to be explained as having been drifted in on icebergs floating in the glacial waters. The small "clay dogs," are of the nature of concretions and were formed where found, probably while the clay sediment was accumulating. The township was completely submerged by the glacial waters until the Elkton stage of Lake Lundy, when the extreme NE. corner began to emerge and a sand ridge was formed by the waves and given an E.-W. trend, just south of Holden Avenue and extending for a half mile upon either side of the Detroit, Lansing and Northern Ry. (elevation about 610 feet). During the first stage of Lake Rouge, with the water level at about 595 feet above sea level, a slight notch was cut in the clay, behind the Detroit moraine, very similar to that formed upon the opposite side by the correlative Lake St. Clair. This curves from West Detroit, around to Edward, just south of Michigan Avenue, lakes a course slightly south of west across the township, curving southward across the SE. tip of Dearborn township into Ecorse. During this stage of the lake waters a little sand was spread over the clay in the immediate vicinity of Campbell Creek. Water, very rarely anything but hard, is obtained from two horizons and is generally abundant. The upper water stratum is reached at 12 to 30 feet; 15 to 18 feet, being a common depth. The deeper stratum ranges from 75 to 130 feet, approaching bedrock, furnishes a water with iron and sulphur and strong in chlorine, calcium and sulphates, temperature 51° to 53°F., under hydraulic pressure that brings it near, or above the surface, the maximum height reported being 20 feet. In a few instances, considerable salt is present, rendering the water unfit for use, and indicating its derivation from bedrock. The central portion of the township appears to be underlain by the limestone and blue shales ("soapstone") of the Traverse formation; the southern by the greyish limestone of the Dundee (Onondaga) and the northern by the black Antrim shales. The depth ranges from about 90 feet along the northern and southern margins to about 120 to 130 feet across the central portion of the township, indicating that there exists a shallow trough, entering from Dearborn and extending into Detroit. The rock surface in the northern part of the township has an elevation of 510 to 520 feet, dropping to 470 to 480 feet, and then rising along the Rouge to about 500 feet. The original forest growth over the higher land was beech, hard maple, oak, whitewood, basswood and walnut; over the lower areas elm, black ash, soft maple and poplar.

Ecorse township. T. 2 to 3 S., R. X to XI E., (in part). Named from the Ecorse River, meaning *bark* in French. Made up largely of French claims. Established 1827; contributed to Taylor in 1847. Area 35.410 square miles; population (including Wyandotte) 9398. Although there is a margin of sand along the northern and eastern borders, the large part of the township is a flat, poorly drained till plain, with a stiff glacial clay soil, having only a small deposit of sedimentary clay from the series of glacial lakes that covered the region down to the birth of Lake Rouge. Surface boulders and cobbles are conspicuous only in the SE. corner, where the margin of the Grosse Isle moraine grazes the township. The western town line is remarkably level ranging in 6 miles only from 000 to 604 feet, above sea level, and the slope is gradual to the eastward, down to the river (574 feet), about 4 feet per mile, upon an average. The township is drained mainly by the three sluggish branches of Ecorse River and by short, intermittent tributaries of the Rouge. Both of these streams, as well as Monguagon Creek and the Huron River, show the phenomenon of "drowning," by which is meant that they have marshy banks and unexpectedly deep channels near their mouths, which were cut when Detroit River was practically out of commission and these streams had greater velocity because of their flow to a lower level. This cutting is believed to have occurred during the life of Lake Algonquin when the drainage was either by Chicago, or the Trent Valley in Ontario. The return to the St. Clair—Detroit outlet restored the former level and submerged the lower courses of these rivers. The original banks are still under water about their mouths and so little time has elapsed that they have not yet silted up their channels. Schools in the vicinity of these drowned areas should instruct their pupils as to these conditions since children in wading along the streams occasionally step off the submerged bank and are drowned. Ecorse township did not appear above the waters of the glacial lakes which followed the retreat of the ice from this region, until the level dropped from the Elkton stage of Lake Lundy to the first stage of Lake Rouge, when a poorly defined notch was cut in the glacial clay at an elevation of about 593 to 594 feet. This shore line enters sec. 31, SE. ¼, from Monguagon, curving to the northward through the eastern half of secs. 25 and 24, across the claims for a couple of miles and then veering slightly to westward and curving around in the NW. corner of the township and across the SE. corner of Dearborn into Springwells township. Very little sand is deposited along its course and only a careful inspection of the flat country will enable one to detect the shore line, which must have made with little wave action. In dropping from the first to the-second stage, the distributary channels in the vicinity of Detroit and Windsor brought down considerable sand and this was worked into a rather well defined beach ridge along the eastern margin of the township, closely following the 580-foot contour.

Upon Brady Island, along its eastern margin, there is a pretty well defined gravel ridge at the right level for this beach. The gravel itself was probably deposited by the distributaries and subsequently modified by wave action. This gravel and sand ridge has obstructed the natural drainage, gives water at shallow depths and is indirectly responsible for much of the malaria and typhoid of the past. Good drainage for the country districts, sewers for Wyandotte and the villages and a closely guarded water supply are imperatively demanded. As is generally the case, getting water from the glacial clay is more or less uncertain, depths of 60 to 80 feet being common. A belt of flowing wells extends along the western margin of the township, the continuation of those from Monguagon, and although all have suffered loss of head and volume a number are still in commission. The water is generally charged with hydrogen sulphide gas (H_2S), often so much so as to be unfit for use. The depth to rock ranges from 70 to 90 feet over the township and so far as known it consists largely of the Dundee (Onondaga) limestone, seen in the Sibley quarry. At the northern end of the township (Oakwood) the elevation of the rock surface is 492 feet above sea level and at the southern margin some 510 to 520 feet, with no marked variation in range between.

Brownstown township. T. 4 to 5 S., R. X E., (in part). Named from Adam Brown, an early settler. Original survey by Joseph Fletcher in 1816 and 1817; established 1827. Reduced in 1842 to add to Monguagon. Area 40.005 square miles; population 2045. Entire township covered with the rectangular survey and only slightly interfered with by the French claims, ordinarily adopted along the main water courses. The highest elevation is in the NW. section (620 + feet), dropping to the SE. very gradually and deflecting the drainage to the Lake Erie level, 573 feet. The streams are of the young, consequent type, intermittent in their upper courses, straight, low banks, marshy, slightly branched. Smith Creek is peculiar in that it parallels the Huron for nearly its entire length and lies so near throughout. Those portions of the streams below the 580-foot contour owe their position and direction of flow to the distributary channels and the depressions between the ridges of the Grosse Isle moraine. The general topography is flat and the soil is a stiff, glacial clay, as left by the Late Wisconsin ice sheet. For a distance of two miles west of Gibraltar and southward as far as the Huron gentle, parallel undulations of the Grosse Isle moraine are impressed upon the clay and the surface carries boulders and cobbles. These features constitute a waterlaid moraine, formed by an oscillating ice front, as it stood in some 200 feet of water of glacial Lake Maumee. The undulations are most conspicuous in secs. 27, 34 and 35 and grow fainter towards the Huron, giving out completely south of the river and seemingly continuing as a boulder belt. In the NW. corner of the township, some eight square miles of land, were covered with sand during the Elkton stage of Lake Lundy, rather pronounced ridging occurring in secs. 9, 16 and 29, as the result of wave and subsequent wind action. The flat topography and clay subsoil have given rise to an extensive swamp in the north half of sec. 8, the southern half of 5 and NW. ¼ sec. 9. A swamp and marl deposit occurs in NE. ¼ sec. 28, the amount of marl not being ascertained. From Flat Rock to the mouth of the Huron there is more or less sand deposited along the northern side, or left bank. Some rather pronounced ridging occurs along the railroad (Detroit, Toledo and Ironton) and also just east of the Detroit and Toledo Shore Line at Rockwood, between 590 and 600 feet elevation. This sand was probably deposited by the Huron when the level of Lake Erie corresponded with that of the first stage of Lake Rouge, and was then modified by wave and wind action. A narrow belt of sand at the same approximate level crosses secs. 11 and 14 (Monguagon) just east of the center, diagonally across sec. 23 and continues southward through the western portions of secs. 26 and 35, then following the contour, jumps three miles westward to Flat Rock. There is very little indication along the lake and river shore of the stage of water corresponding to the second stage of lakes Rouge and St. Clair. Small patches of sand, or loamy soil do occur, however, in the neighborhood of the 580-foot contour (secs. 13, 23 and 24; T. 5 S.), and one mile west of Gibraltar (NW. ¼ NW. ¼ sec. 1) there occurs a short stretch of gravel beach, at the right level. The SE. point of Brownstown, largely submerged at this stage, received a veneering of black, mucky soil and is still largely swamp. Water has ordinarily been obtained with great ease over the greater portion of the township and flowing wells could be numbered by the hundred. However, a steady decline has been in progress and scarcely a one remains that reaches the actual level of the region in which it is located. A few still occur between Flat Rock and Rockwood that rise to the level of flats 3 to 5 feet below the general level, greatly reduced in quantity and head. The water was obtained in close proximity to the rock surface, either just on the rock, just above and a few feet within. The presence of iron and sulphur, along with chlorine, calcium and the sulphates, suggest that it has always come from bedrock. Over the southern half of the township some very heavy flows of similar spring water were common in an early day, but the flow from these has also been greatly reduced. Owing to the nearness of bedrock to the surface in the southern portion of the township (10 to 30 feet, as a rule) the wells are commonly shallow and some of them were reputed to be able to rise 10 to 20 feet above the surface. In the northern part of the township the bedrock lies from 70 to 80 feet below the surface and the wells generally go to this depth. The temperature of the water is very uniform, generally 51° to 52°F., but ranging from 50° to 55°. Over the sand covered regions limited quantities of fresh water are obtained at shallow depths, by reaching the clay. The loss of the flowing water is a serious one to many of the farmers, entailing considerable annual expense and it is hoped that this resource may still be properly conserved. The elevation of the surface of the bedrock ranges from 520 to 530 feet in the northern portion of the township to about 580 feet in sec. 35 (SW. ¼ SE. ¼) and about Flat Rock, dropping again some 15 to 20 feet toward the Huron. From the latitude of Rockwood southward, the glacial clay is underlain by the pure white Sylvania sandstone, extending nearly or quite to the mouth of the Huron. The distance down is but 12 to 18 feet, as a rule, and the sandrock is so incoherent that it often causes trouble in the wells. The middle third of the township is underlain by the dolomitic limestones making up the Upper Monroe formation and the high grade Anderdon limestone. The northern 3 tiers of sections must rest upon the Dundee limestone, exposed at Sibley and upon the Ma con in Monroe County. The dolomites have been quarried for some years at the quarry W. NW. from Gibraltar (SW. ¼ SE. ¼ sec. 35) and reduced to road metal, but this plant was closed down and dismantled, Sept., 1911. ; It is noteworthy that the flowing wells come from each of the three formations represented, rather than any one, the strongest sulphur and iron waters being derived from the Upper Monroe. This suggests that the water is conducted through joints and fissures into the neighboring strata/and permits the hypothesis that the collecting area lies to the northwest, although this is the direction of dip for the rock strata. The native forest growth consisted, in the main, of white and black ash, hard and soft maple, yellow and white oak, hickory, elm, basswood, walnut, beech, whitewood, cottonwood and sycamore.

DELTA AREAS, FLAT SURFACES; SOIL GRAVELLY, SANDY LOAM.

Van Buren township. T. 3 S., R. VIII E. Named from President Martin Van Buren. Township lines surveyed in 1815 by Alexander Holmes; subdivisions by Joseph Wampler in 1819. Township established in 1835, derived from Huron; area 36.690 square miles; population 1700. Practically all except the NE. quarter of the township was strewn with delta deposits of gravel, sand and silt during the three stages of Lake Arkona, giving a smooth, flat topography, except for the occasional beach ridges. In the western part of the township the thickness of this deposit runs to 15 or 20 feet and where subsequently cut through by the Huron furnishes the conditions requisite for seepage springs along its banks. The gravel becomes finer and finer to the eastward and passes into sand, practically free from pebbles. Two-thirds of the deposits lie. to the south of the Huron and appear to have deflected the river some five miles eastward before allowing it to take its natural southeast course to the lake. A small patch of glacial clay occurs just north of Belleville and secs. 2, 3, 10 and 11 have a similar soil, receiving but little of this delta dressing. The general surface slope is southeastward, average rate 7½, feet per mile, dropping from 720 feet to about 656. The Huron has deeply incised the country, the banks at Rawsonville being 55 to 60 feet high and diminishing slowly eastward. The township lies outside of the morainic areas but has a belt of boulders and cobbles, one to two miles broad, passing southward along the central meridian as far as Belleville, where it appears to turn westward to Rawsonville, entering Washtenaw County. This belt may be traced northward across the county and is believed by the writer to mark a temporary halt of the ice sheet, previous to the formation of the delta and incident to the final retreat from the region of the Late Wisconsin ice sheet. The three water levels of Lake Arkona are indicated by disconnected and often poorly defined gravelly-sand ridges, ranging in elevation from about 707 to 694 feet above sea level, having a generally southerly course and swinging to the southwest. The upper Arkona ridge cuts across the southern, half of sec. 18 to the eastern side and follows the section road north to Denton, passing through the western part of the village and furnishing a site for the cemetery. The middle ridge shows itself in the western part of sec. 30, was destroyed by the Huron, crosses sec. 17 and follows northward about a mile east of the highest Arkona as a faint feature, turns westward and crosses the Michigan Central Ky. near the center of sec. 5. The lowest ridge crosses the south half of sec. 31 and passes northward in secs. 32 .and 29 until it encounters the old bank of the Huron that marks the Lake Warren stage. North of the river, it has faint expression across sec. 16, until it reaches the NE. ¼ when it deposited a little gravel upon the lakeward side of a prominent off-shore bar of the Middle Arkona stage, which curves northeastward across the NW. corner sec. 15 into sec. 10, passing northward through the western part and enters sec. 4 at its SE. corner, curving westward. These ridges, although generally of slight expression, are responsible for slack drainage and swampy soil in secs. 7, 8, 17 and 18. The advance of the ice front from a position some 25 miles NE. of Bad Axe to the vicinity of Port Huron caused the water level to rise to the Whittlesey beach in Washtenaw County and to flood the entire township, as it had been flooded by Lake Maumee during pre-Arkona times. No extensive delta formed at this stage, otherwise the Arkona beaches would have been buried and obliterated and when the water subsided to the Lake Wayne stage (elevation about 650 feet), the fall must have been rather rapid, otherwise the Arkona ridges would have been leveled. The Warren, or Forest beach (elevation 682) appears in the southern half of sec. 33, passes northward through the western part of sec. 28, reappears on the opposite side of the Huron in the northern portion of 22, is poorly represented in secs. 14 and 11, entering sec. 3 at its SE. corner and leaving from the NE. ¼ NW. ¼. Where the beach is not well shown cobbly areas occur as though the waves had removed some soil, leading to a concentration of these rock fragments. During the Warren stage the ice dam is believed to have been in the vicinity of Alpena, the drainage around the "thumb" into Grand River Valley, and thence into Lake Chicago, the advance of ice forcing the water to this level from that of Lake Wayne as previously noted in the Arkona-Whittlesey episode. The glacial water history for this region may thus be summarized: Lowest stage Lake Maumee (760 feet); Middle stage Lake Maumee (780 feet); three stages Lake Arkona, (705, 698, 692 feet); Lake Whittlesey (730 feet); Lake Wayne (650 feet); Lake Warren (680 feet). The key to this peculiar behavior is furnished by the manner of ice retreat which seems to have consisted of a relatively long retreat each time followed by a short advance. During the Lake Warren stage, the Huron formed the terrace upon which the village of Belleville is situated the southern bank of the river, 10 to 12 feet high, cutting diagonally across sec. 30, southern half of 29, SW. ¼ sec. 29 and curving southward through the eastern half of sec. 33. The delta and beach deposits furnish a liberal supply of water at shallow depths, 7 to 30 feet, and numerous seepage springs, as noted, occur along the banks of the Huron and its tributaries. The water is generally hard, but sometimes medium and soft. In the clay areas, NE. ¼ of the township, it is necessary to go 50 to 125 feet, or even more, to get a supply; generally abundant, but sometimes meager. A splendid supply of flowing water (temperatures 51° to 52°F.) singularly soft, is obtained from the drift at Denton and two miles eastward by going from 70 to 80 feet in general, but occasionally from only 40 to 50 feet. According to George W. Lyons, driller, just over the rock lies a bed of "hard-pan," from one to ten feet thick, itself overlain by more or less gravel. The head of this water closely approaches 700 feet, dropping to eastward, indicating a source from the upland to the westward. The depth to bedrock varies from 80 to 90 feet at the NW. and SE. corners to about 120 feet at the center of the township, dropping then rapidly to the east and northeast. A very decided trough extends N. and S. through the eastern double strip of sections, some 170 to 180 feet deep, reaching its greatest depth at the SW. comer of sec. 1, where the rock elevation is about 495 feet, or 78 feet below the ordinary level of Lake Erie. The trough may have been gouged from the soft black shales by the action of the ice sheets, although its axis extends *across*, instead of *with* the direction of the main ice movements. The axis of the trough extends through secs. 12, 13 and 24, with elevation of 495 to 500 feet, rapidly rising some 40 to 50 feet. In the vicinity of Belleville, the shale rock ("slate") is reached at a depth of 99 to 118 feet, giving an elevation of the rock surface of some 560 to 580 feet above sea level, approximating Erie level. In passing to Denton it rises to about 620 feet, while toward the southeastward it remains approximately horizontal. A belt of black (Antrim) shale (sometimes mistaken for *coal*) underlies most of the township, passing from NE. to SW., and giving more or less gas. The Coldwater formation, consisting of light colored shale and sandstone, appears to cross the NW. corner, while the Traverse (limestone and "soapstone") crosses the SE. corner. The original forest growth was hard and soft maple, white ash, beech, elm, white oak, whitewood, basswood, sycamore, hickory; with some red and swamp oak, black ash, butternut and walnut.

Livonia township. T. 1 S., R. IX E. Supposedly named from the province in Russia in an effort to find names not duplicated elsewhere. South and east township lines surveyed in 1816 by Joseph Fletcher; north and west lines in 1815 by Alexander Holmes; north line corrected, in 181.9 by Fletcher; township subdivided in 1816 by Fletcher; Established in 1835, derived from Nankin. Area 35.960 square miles; population 1365. This township shows the greatest variation of any in its physical features and soils and is crossed by the greatest number of the glacial lake-beaches. The prevalence of considerable delta material, derived largely from the Middle Rouge during the Lake Arkona stages, as well as that brought down during this and other lake stages by minor streams, places Livonia in a class with Van Buren just described. The soil is very largely a gravelly, sandy loam, except for some ridges; sloping quite gradually from the Whittlesey beach (elevation 736 to 739), which cuts diagonally through secs. 5 and 7, southeastward to 634 (SW. cor. sec. 36), giving an average slope in this distance of some 16 feet to the mile. Westward of this well defined gravelly beach ridge the soil Is a loamy clay, with some minor ridges of the Defiance moraine showing in secs. 5, 6 and 7 which were not obliterated by the waters of the glacial Lake Maumee. The drainage is mainly eastward by Bell Branch of the Upper Rouge, the southern portion of the township draining into the Lower Rouge. Bell Branch seems to be deflected eastward by the Rouge delta deposits to the southward, just as noted for the Huron in Van Buren, its southern branches being turned *northward* by the ridges of sand and gravel in sec. 21. Two boulder belts cross the township which probably mark the temporary positions of halt of the front of the Late Wisconsin Ice in its retreat from west to east. The most westerly of these belts enters from the eastern part of Plymouth township, crossing secs. 18, 7, 8 and 5, heading towards Farmington. The second passes from N. to S. just east of the central meridian of the township, not especially well defined, and giving an indication of morainic topography in sec. 15. The bulk of the delta deposit was laid down in the SW. ¼ of the township, extending from eastern Plymouth, and reaches 12 to 15 feet in thickness, consisting of gravel and pebbly sand; resting upon glacial clay, furnishing water to shallow wells and favorable conditions for seepage springs wherever the porous deposit is cut by the streams. A splendid flow of this nature is found near the SW. corner of sec. 29; others in sec. 16 and vicinity. The gravelly sand and loam in the NW. ¼ and the northern half of the NE. ¼ is partly delta and partly shore material, from which shallow water is obtained with less certainty, often necessitating the sinking of wells to depths of 45 to 85 feet. Crossing the township in a general NE. to SW. direction there are 10, more or less distinct, beach ridges of either sand or gravel, or a mixture of the two. This series comprises all but the three youngest of the entire series of Huron-Erie beaches. The Upper Maumee cuts across the extreme NW. corner of sec. 7, entering from sec, 12 of Northville, and gives a sandy belt just above the 800-foot contour, upon both sides of the clay ridge crossing sec. 6. The Middle Maumee (3rd in age) lies ¼ mile to the eastward in sec. 7, where it shows fine development, approaches the higher in sec. 6 and lies just above the 780-foot contour. The Lowest Maumee enters sec. 7 (NW. 1/ SW. ¼) from the SW., just above the 760-foot contour, giving it a somewhat straight course to northeastward, except where destroyed by stream action, entering Oakland County very near the NE. corner sec. 6. In subsiding from the Middle Maumee stage, the waters fell to the Arkona stages, before returning to the Whittlesey beach already noted in secs. 5 and 7. The Upper Arkona is the best defined of the three in this region, lying just westward of the 700-foot contour. It enters the NW. ¼ sec. 30, passes northward through sec. 19 (being pushed, east-ward by the delta deposits) and then follows a very direct NE. course through secs. 18, 8, 5 and 4, parallel with the Whittlesey and about ¾ mile SE. of it. It is especially well developed In the northern half of sec. 4. Fragments of the Middle and Lowest Arkona are to be seen from ½ to ¾ mile to the eastward, separated rather poorly from, one another and the next lower Warren beach; owing to the relatively rapid surface slope on the delta. The latter enters the SE. ¼ SE. ¼ sec. 31, curves northward through Nankin village, between secs. 29 and 30, gives some irregular ridging in sec. 20, crosses 17 diagonally, curves through the southern half of sec. 9, showing fine expression, crosses the NW. ¼ sec. 10 and leaves the county at the NE. ¼ NE. ¼ sec. 3. Quite a well defined, gravel ridge appears in the NW. ¼ NE. ¼ sec. 32, at an elevation of about 670, crosses the eastern half of sec. 29, the western half of secs. 21 and 16, deflecting the drainage of the tributaries of Bell Branch. This ridge Is too low for the Warren beach and too high for the Wayne, and may represent a bar in the former, or a hitherto unrecognized stage of the glacial waters, which left its record just here because of the abundance of pebbles. Traces of the same stage are seen in sec. 10 (NW. ¼ SW. ¼ and NE. ¼ NE. ¼), and. at the NW. ¼ NW. ¼ sec. 2. The Wayne beach is well defined in secs. 28 and 21, leading to the village of Livonia, but at an elevation, some 7 to 8 feet too high (662 to 605 feet). Being a sand ridge this extra height may be accounted for as due to wind action. The ridge drops somewhat in sec. 15, but remaining about the 660-foot contour and flattens out to the northeastward. The Grassmere beach, representing the first stage of Lake Lundy, is indicated by some disconnected sand ridges in the SE. ¼ of the township, ranging in elevation from about 635 to 645 feet. The best defined and most continuous ridge begins in the NE. ¼ of sec. 27, curving into sec. 22, giving a branch to the northward and curving sharply to eastward across the southern half of secs. 23 and 24. Scraps of the same beach ridge occur northward on the town line in secs. 13 and 12, extending over from Redford. A limited area of flowing wells, with low head, occurs in the eastern part of sec. 18 and adjacent portion of 17; depth 45 to 55 feet; temperature 51° to 52°, somewhat soft. A "deer lick" is said to have been located on the flats at the NE. corner of sec. 7. In the SE. quarter of the township, where the delta deposit is thinner or entirely absent, it is necessary to enter the clay for water to depths of 60 to 100 feet or more, securing water reported as both hard and soft. The rock varies from 60 to 100 feet over most of the township, being more deeply buried in the NW. corner (110 to 120 feet) because of the rise in the surface levels. The elevation of much of the rock surface ranges from 550 to 580 feet above sea level, rising possibly 100 feet towards the NW. The NE.-SW. diagonal of the township approximately marks the line of separation between the Coldwater formation, of light colored shale and sandstone, and the black (Antrim) shale, carrying more or less gas. Penetrating this shale and entering the underlying Traverse, gives salt water and going still deeper into the Dundee limestone gave small quantities of a very thick black oil, serviceable as a lubricant (NE. ¼ NW. ¼ sec. 34 and SW. ¼ NW. ¼ sec. 36). The original forest growth was mainly elm, white and black ash, hard and soft maple, beech, oak and white wood.

Dearborn township. T. 2 S., R. X E., (in part). Named from General Henry Dearborn. Township lines and rectangular subdivisions surveyed in 1816 by Joseph Fletcher; established 1833. The rectangular survey is rendered irregular by the military reservation about the village of Dearborn and the French claims along the Rouge and its northern branch. Area 34.410 square miles; population 2761. Except where dissected by the three branches of the Rouge, the township is mainly level and flat, lying mostly between the contours of 600 and 630 feet. The NW. corner, however, rises to 639 feet and the SE. drops to 589, giving an extreme relief, aside from the river bottom, of 50 feet and a general southeasterly slope. The soil and subsoil are mainly a stiff glacial clay, relatively free from boulders and cobbles, which was formed beneath the Late Wisconsin ice, without any pronounced halt. Over the center of the township and towards the south and southeastward, the clay received a veneering of sand during the Elkton stage of Lake Lundy, some prominent ridges being formed as the result of wave and subsequent wind action. These dune ridges, some of them rising to 620 feet, have furnished sites for the irregular, diagonal roads leading from the village of Dearborn. This sand was brought to the lake very probably by the Rouge and originally deposited as delta sand, afterwards being worked shoreward by the waves. From secs. 4 and 5 southward to 32 and 33 there occurs a veneering of sand up to 8, 10 and 12 feet in thickness, with only very minor ridging, lying between the contours of 615 to 625 feet, which probably represents, in part, a delta deposit of the earlier stage of Lake Lundy, somewhat modified by wind. The three branches of the Rouge: Upper, Middle and Lower, enter the township with banks varying in height from 20 to 30 feet, and with average fall of 8 feet per mile, measured from the Whittlesey beach along their respective valleys. Within the limits of the township the banks become lower and the fall becomes much less, for the main Rouge amounting to less than 6 inches per mile. With these three streams converging and flowing so much below the general level, the surface drainage is good. Over the sandy portions of the township, water is obtained from shallow wells (10 to 25 feet) by entering the clay far enough to obtain a suitable reservoir. The water thus obtained is not usually very abundant, is generally hard, but occasionally soft. In the clay districts obtaining water is uncertain both as to amount and depth. In the eastern part of the township the water rises to near the surface, under artesian pressure, but does not flow. A heavy flow of sulphur water was struck in the village of Dearborn, depth 290 feet, showing a head of 635 to 640 feet. This water probably comes from a channel in the Monroe formation, instead of from a single water bearing stratum, and even neighboring wells might yield no such flow. The depth to rock ranges from 60 to 80 feet in the northern tier of sections, deepens from 120 to 140 feet across the central strip, and rises southward from 80 to 100 feet again in the vicinity of sec. 34. The village of Dearborn lies over the axis of a shallow trough in the rock surface, which enters from southern Nankin and extends across Springwells, spreading out beneath Detroit. The elevation of the bottom of the trough seems to range from 500 to 470 feet above sea level as it crosses the township from west to east. Toward the north, the rock surface rises from 550 to 560 feet and southward from 525 to 535 feet. The bedrock is probably very largely the Traverse formation, consisting of alternating layers of limestone and bluish shale ("soapstone"). The records of gas found in the wells along the northern border of the township along with the adjacent region suggest that this portion is underlain by the black (Antrim) shale. Upon the sand areas the main forest .growth was originally black and white oak, black and white ash, elm, basswood, butternut, and chestnut, with some hard and soft maple and beech. The clay supported in the main a growth of elm, black ash, oak, beech, hard and soft maple, basswood and hickory with some walnut.

BEACH AND DUNE AREAS; HEAVY RIDGING AND SANDY SOILS.

Sumpter township. T. 4 S., R. VITI E. Earned from Gen. Thomas Sumter. Township lines surveyed by Alexander Holmes in 1815; subdivisions in 1819 by Joseph Francis; reserve by James B. Mullett in 1843. Township established in 1840, derived from Huron and for a time called "West Huron." Area 37.285 square miles; population 1228. The northern half of this township extends into the delta formation of the Huron, during the Arkona stage, and geologically belongs with the preceding main division of townships, being covered with a pebbly sandy loam. This deposit is highest and presumably thickest towards the NW. comer of the township (elevation 692 feet), thinning towards the east, southeast and south; the pebbles becoming finer and finer and passing into sand. The general slope is southeastward, dropping to 626 feet at the SE. comer, or at the average rate (neglecting the sand ridges) of about 8 feet to the mile. The NE. and SW. comers of the township are almost exactly the same level, if we neglect the valley of the Huron, which there grazes sec. 1. The drainage is either into Swan Greek direct, or into its tributary Disbrow Ditch. The westernmost portion reaches Stony Greek and the extreme northern strip is drained into the Huron, the upper courses of the streams being largely intermittent. The township is crossed from NE. to SW. by the beaches of three of the series of glacial lakes, the lower two of which (the Wayne and Grassmere) show considerable wave and subsequent wind action, the ridges formed being distributed largely along the southern and eastern strips of sections. These ridges are sharply defined, generally less than a mile long, irregularly placed and extend in no uniform direction. Since some of them may be of the nature of bars and others of dunes, it is difficult to separate the two sets from one another. The slack drainage caused by these sand accumulations is responsible for a rather extensive swamp in sec. 29, which extends southward into sec. 32. Numerous deposits of ochre ("bog iron ore") in the central and western sections indicate that the swamps were more extensive formerly than at present. The Warren, or Forest beach, is not well defined, consisting of a faint, gravelly sand ridge, just above the 680-foot contour. It cuts across the northern half of sec. 7 to the NE. corner, curves across the southern half of sec. 5 and cuts the NW. ¼ of sec. 4, entering Van Buren township. Some little clay soil and loam are found in secs. 25, 26, 35 and 36. Throughout the gravel and sand areas shallow wells (6 to 16 feet) yield a supply, generally sufficient, of water variously reported as hard, soft and medium. Sometimes all that is necessary is to dig or drive to the vicinity of the underlying clay; when greater supplies are desired, a reservoir in the clay is made into which the water collects from the overlying sand and gravel. In the SE. quarter, where the sand is largely concentrated into ridges, it is necessary to enter the clay to depths ranging from 30 to 70 feet, in some cases water being obtained from a stratum of gravel just over bedrock. Water, some what sulphury, and rising under artesian head to near surface. In 1903 one flowing well existed at the SW. ¼ SE. ¼ sec. 25. The rock ranges in depth from 35 feet at the SE. comer of the township to about 100 feet at the NW. corner, so far as may be judged from the meager records. The actual elevation of the rock surface does not vary greatly from 560 to 580 feet above sea level. The underlying rock of the SE. half is probably Dundee limestone, similar to that seen on the Macon, Monroe County, and at Sibley; the NW. half is probably the limestone and bluish shale ("soapstone") of the Traverse formation, which is liable to yield water more or less charged with salt. The original forest growth corresponded very largely with that of Van Buren over the northern area and much scrub oak over the heavily sanded areas, along with some chestnut.

Huron township. T. 4 S., R. IX E. Named from the river which received its name from the tribe of Indians that occupied the region. West township line surveyed in 1815 by Alexander Holmes; north; east and south lines in 1816 by Joseph Fletcher; subdivisions in 1816 by Fletcher. Township established in 1827 and later reduced to form Van Buren (1835), Romulus (1835), and Sumpter (1840). While the latter was known as "West Huron," this township was known as "East Huron." Area 35.790 square miles; population 1690. The township as a whole is characterized by sandy soil, the western half carrying numerous, irregularly placed sand ridges; the

NE. ¼ carries an even dressing of sand without ridging; the NE. ¼ contains minor knolls and ridges of sand, considerable loam and some clay. Isolated patches of clay and loam occur also in the other quarters of the township. The general slope of the township is from NW. to SE. (about 650 to 600 feet), or at the average rate of about six feet to the mile, neglecting the ridges. Between the SW. and NE. corners of the township there is slight difference in elevation. The Huron crosses the township diagonally and receives most of the drainage, through short, largely intermittent streams. The banks are dropping to the eastward, being about 34 feet above the bed at New Boston and 20 to 22 feet at Flat Rock. The SW. comer of the township is crossed by one branch of Swan Creek and receives drainage from a few sections. In spite of the sand covering, a belt of boulders and cobbles ("Scofield boulder belt") may be traced from N. to S. along the Pere Marquette Ry., believed by the writer to mark a stage of halt of the ice sheet in its Anal retreat across the township. The ice front at this time may then have served as a dam for the waters of Lake Maumee during one of its temporary stages. The further retreat of the ice to the NE. allowed the glacial waters to drop to successively lower levels and the township began to emerge during the first stage of Lake Lundy, when the waves threw up the ridges across the NW. corner of the township (elevation about 635 feet). The sands upon drying were heaped still higher by the wind and scattered over the clay surface. In secs. 7 and 18 some of the ridges are high enough to have been formed during the preceding Lake Wayne stage, rising about 650. In the vicinity of Willow and Waltz the strongest of the sand ridges have a NW.-SE. trend, from 615 to 625 feet in elevation, and were apparently formed by wave and wind action during the Elkton stage of Lake Lundy. The shore line extended NE. through secs. 22, 23, 24 and 13, but made no definite ridge. Two sets of wells are used; the shallow (7 to 20 feet) from the sand deposits and the deeper wells into the clay, ranging ordinarily from 30 to 85 feet, and in some cases entering rock. The former wells are hard to soft, the latter yield water with some sulphur.

The depth to rock ranges from about 20 feet in the neighborhood of Flat Rock, to 80 to 90 feet in the NW. corner. The actual elevation of the rock surface is about 580 feet above sea level, near Flat Rock, dropping from 10 to 20 feet only towards the northwest and not varying greatly from horizontality. The well records give limestone only for the bedrock, not distinguishing between the real limestone and the dolomitic variety. The NE. portion of the township must, however, be underlain by the Upper Monroe dolomites, with their strong sulphur waters and the northwestern portion by the Dundee limestone, with its occasional suggestion of oil. the test well at the NE. ¼ of sec. 17 proved a disappointment. The township consisted largely of the "oak openings" of pioneer days.

Romulus township. T. 3 S., R. IX E. Named presumably from the reputed founder of Borne. West township line surveyed in 1815 by Alexander Holmes; north, east and south township lines by Joseph Fletcher in 1816; subdivisions by Fletcher in 1817. Township established in 1835, being derived from Huron. Area 35.660 square miles; population 1538. Romulus township is closely related to Huron just described so far as soils, topography and geological history are concerned. It, however, contains much more clay and loam over its eastern half; flat and poorly drained by intermittent streams giving an easterly or southeasterly course to the Ecorse and Brownstown Creek. The Scofield boulder belt enters from Huron township at about sec. 32 and takes a N. NE. course across the center of the township, leaving at sec. 3, marking a position of halt of the ice front. The belt is about 1½ miles broad and contains boulders and cobbles, especially abundant in the northern half of the township. Neglecting the sand ridges the general slope is to the southeastward, from an elevation of approximately 670 feet to 620 feet, or about six feet to the mile as in Huron township. The NE. comer of the township is about 25 feet lower than the SW., the latter having been built up by delta material from the Huron, during the glacial lake series of the Arkona and Warren stages. A set of sand ridges between secs. 29 and 30 may be traced northward through the western part of the village of Romulus (sec. 17), veering NE. into secs. 9 and 4, and ranging from 655 feet to 670 in elevation. These ridges were apparently formed by the waves of Lake Wayne and then heaped up by wind into dunes. A second set of similarly formed dunes marks the first stage of Lake Lundy, some 25 to 30 feet lower. They cut through the southern half of secs. 31, 32 and 33 and then beginning in the SW. ¼ sec. 34 form a peculiar series of approximately parallel NW.-SE. ridges as far as the eastern margin of the village of Romulus and determining the course of the diagonal road through secs. 34, 33, 28 and 21. From Romulus NE, the ridging is less well defined but may be seen in secs. 10, 11, 12, 1 and 2, separated by areas of clay and loam, suggesting weaker wave action than that in the SW. ¼ of the township. The SE. ¼ of the township was submerged but the water was only 10 to 15 feet deep and received some sprinkling of sand over much of the clay. The slack drainage to the westward of these heavy ridges wag responsible for swamp conditions in the past in which muck soil was formed. Such a deposit lies between secs. 5, 6, 7 and 8, the muck sometimes taking fire and burning to a depth of 6 to 8 feet. The sand of the NW. portion of the township is slightly pebbly, suggesting that the ancient delta of the Huron may extend this far east and north. Most of the wells are of the shallow, sand type, 8 to 20 feet, furnishing limited quantities of hard, medium and soft water. When the quantity is insufficient, deeper wells are sunk and this is invariably demanded in the clay and loam areas, and where the sand is too thin to furnish water in quantity. The wells of this character range, in general, from 40 to 80 feet and the water is more or less impregnated with iron or sulphur, especially when obtained from near bedrock. In 1903 only one flowing well existed in the township, NW. ¼ NW. ¼ sec. 36; depth 48 feet to "hard pan." The bedrock is buried by 60 to 140 feet of clay, gravel and sand, deepening from SE. to NW., the actual elevation not differing greatly from 520 to 560 feet above sea level. The SE. corner is probably underlain by the Dundee limestone, which gives traces of gas and oil in a few wells; the remainder of the township lines the Traverse formation for its foundation, consisting of limestone and shale ("soapstone"), the water from which gives some salt. The deep well put down upon the Twark farm (SE. ¼ NW. 14 sec. 12) reached rock salt at a depth of 925 feet and penetrated successive layers of salt and lime to a depth of 1820 feet.

Taylor township. T. 3 S., R. X E., (in part). Named from Gen. Zachary Taylor. Township lines and subdivisions surveyed in 1816 and 1817 by Joseph Fletcher. Established in 1847, being derived from Ecorse. Area 23.825 square miles; population 1258. The township is flat and sand covered in large part, receiving its deposits during the life of Lake Lundy, both stages. Isolated patches of clay and loam occur and a strip of stiff glacial clay extends along the very flat eastern boundary, which ranges in elevation from 600 to 604 feet in the six miles. This clay area is part of the till plain which covers the greater portion of Ecorse township. The western boundary ranges from 620 to 630 feet, the slope being eastward and averaging from 5 to 7 feet to the mile. The northern half of the township is drained eastward into the Ecorse, the southern half by three drains, somewhat south of east, into Brownstown Creek. A set of short, disconnected sand ridges passes from N. to S. through the center of the township. lying mainly eastward of the central meridian, and formed during the Elkton stage of Lake Lundy, at an elevation of 610 to 620+ feet. The N. to S. road through secs. 16 and 21 was evidently shifted 14 mile west of its proper position in order to get the advantage of this sand belt. Some ridging occurs in the eastern part of secs. 20 and 17 and runs through the northern part of secs. 8 and 9. The sand along the western strip of sections may represent blown sand from the Elkton shore and also that deposited in the shallow waters of the first stage of Lake Lundy. The sand areas, especially where deepest, yield water at depths of 7 to 20 feet, ranging from, hard to soft, and often sufficient for farm purposes. The clay wells range from 60 to 100 feet, yielding water charged with some iron and sulphur, under artesian pressure. In 1903 flowing wells were found at the SW. ¼, SW. ¼ sec. 34; SW. ¼ SW. ¼ sec. 28; NE. ¼ NE. ¼ sec. 15; NE. ¼ NE. ¼ sec. 10; belonging to the belt of flowing wells passing northward from Brownstown and Monguagon, through Ecorse. The depth to rock ranges from 60 feet at the SW. corner to 90 feet at the NW., the shallower having a surface elevation, of about 550, the deeper an elevation of about 535 feet above sea level. At the SE. corner, the rock surface drops to about 620 feet. From all the information available, the bedrock is largely limestone of the Dundee (Onondaga) formation, similar to that seen at Sibley. The Traverse probably crosses the NW. corner giving alternating limestone and shale ("soapstone"). The water from it is not highly charged with either salt or sulphur. After penetrating the limestone, the Upper Monroe dolomites are reached which invariably yield water highly mineralized and charged with sulphur.

Nankin township. T. 2 S., R. IX E. Named from city of China. Township lines surveyed in 1815 by Alexander Holmes and Joseph Fletcher; subdivided in 1816 by Fletcher. Established in 1829; derived from "Bucklin" and originally included Livonia. Area 35.940 square miles; population 3966. The eastern and southeastern portion of the township extends into the flat till plain type of topography, with soil of loam or glacial clay, upon which have been superposed some minor ridges of sand, as the result of wave and wind action. The NW. corner of the township extends into the delta region of the Middle Rouge (Arkona and Warren stages) and is coated with a pebbly sand, similar to that described for Livonia to the northward. Between these two areas extends a broad belt, 3 to 4 miles broad, from NE. to SW., of heavy sand, more or less ridged, especially along the eastern margin of the belt. The general slope of the township is from NW. to SE., dropping from about 693 to 626 feet, above sea level, or at an average rate of about 8 feet to the mile. The NE. corner of the township is about 28 feet lower than the SW. corner (667-630 feet). The drainage is eastward (Middle and Lower Rouge) the streams being more or less deflected by the sand accumulations. The Scofield boulder belt, one to two miles broad, crosses the middle of the township, from N. to S., lying mainly to the eastward of the middle meridian. Many of these boulders and cobbles have been collected and utilized in foundations. During the Maumee, Whittlesey and two higher Arkona stages, the township was completely submerged by the glacial waters. When the level had fallen to the lowest Arkona stage, a poorly defined sand ridge was built across the NW. ¼ of sec. 6, at an elevation of about 693 or 4 feet above sea level. An advance of the ice front is then believed to have forced the water to the middle stage of Lake Arkona, raising it some 7 to 8 feet. At the time of its next recession, a drop to about the level of 650 feet occurred and the broad sandy beach of Lake Wayne was formed with elevation of 655 to 650 feet, except where wind blown to greater height. Ridging occurred north and northeastward of the village of Wayne in secs. 28, 27, 22 and 23, reaching northward into 14, 15 and 10, marking the approximate shore line of the lake waters. During this stage the lake extended around the "thumb," the ice dam being some 25 to 30 miles NE. of Bad Axe, but the drainage is believed to have been into the Mohawk, near Syracuse, N. Y. An advance of the ice front, until it again covered the tip of the "thumb," forced the water up some 30 feet to the level of Lake Warren, and the drainage was shifted to the Pewamo, Ionia and Grand River valleys into Lake Chicago. This increased elevation brought the level to about 680 feet, extending across the NW. ¼ of sec. 6, very near the Lowest Arkona, but without leaving a very definite record. The sand found along the N.-S. road between secs. 5 and 6, 7 and 8, may represent bar deposits in Lake Warren, or possibly a temporary shore line corresponding to that observed northward in Livonia township at this same approximate level. In subsiding from the Warren stage, during which time the Wayne beaches were submerged, the water dropped to the Lundy stage and made a series of sand ridges in secs. 35, 26 and 25, extending to the village of Inkster and reappearing again in secs. 1 and 2. The most of the sand ranges in elevation from 635 to 640 feet, above sea level, but some of it was heaped into still higher dunes by wind action. The slack drainage caused by the sand deposits is responsible for an extensive swamp, involving some 160 acres, but originally much more extensive, in the vicinity of the SE. ¼ of sec. 18, extending into secs. 17, 19 and 20. The sand that mantles the clay attains a thickness of 10 to 12 feet and shallow wells are the rule over the western half of the township. These yield sufficient water, as a rule, which ranges from hard to soft. About the center of the township and over much of the eastern half, where the sand is scantier, it is necessary to enter the clay and to varying depths (40 to 140 feet), securing water which carries some salt and sulphur. In the SW. corner of the township, the artesian pressure is sufficient to bring the water very near or quite to the surface causing flows to the west and northwest of Wayne. Upon the old Proctor Estate also, a well has been flowing (NW. ¼ NW. ¼ sec. 15) for a number of years. The depth to bedrock is about 100 feet at the SE. corner and about 125 feet at the NW. corner, with a trough-like depression of 120 to 160 feet cutting across the southern half of the township. Just south of Perrinville the well records indicate that the rock rises to 50 feet, forming a rock knoll on the northern side of the depression and attaining an elevation of about 585 feet. Just west of Inkster the rock surface in the trough-like depression referred to drops to about 480 feet above sea level, this being a part of the same feature which enters from Van Buren and extends into Dearborn, probably representing an old pre-glacial drainage valley, modified by ice action. The rock elevation at the extreme SE. corner is about 520 feet, and about 560 feet at the NW. corner. The bulk of the township appears to be underlain with the black (Antrim) shales ("slate"), which give more or less gas when entered. The SE. corner is probably the Traverse formation of limestone and light colored shale ("soapstone"), which generally yields water containing some salt. The original forest growth was white, yellow and black oak and whitewood, some chestnut, over the "oak openings;" beech, elm, hard and soft maple, ash, basswood on the lower land; some hickory and walnut on the flats.

Redford township. T. 1 S. R. X E. Named from the ford of the "Rouge," original name being Pekin. Township lines and subdivisions surveyed in 1816 by Joseph Fletcher. Established in 1829, being derived from "Bucklin" township. Area 35.680 square miles; population 2176. Although almost all of the SE. ¼ of the township is clay soil, of the flat till plain type, the bulk of it is strewn with sand, much ridged in parts, which places it geologically with the preceding townships of this division. Even over the sand region, isolated patches of clay and loam make their appearance. Neglecting the ridges of largely wind-blown sand, the general slope of the township is southward, dropping from the highest elevation 668, on the Base Line, sec. 1, to about 618, near the center of the southern boundary line; or at the average rate of about 8 feet to the mile. The SW. corner is 39 feet lower (668-639) than the NE. corner, and the SE. corner lies 30 feet lower (651-621) than the NW. corner, while the drop near the middle of the township from N. to S. is 37 feet (659-622), or about 6 feet to the mile. The surface drainage is entirely into the Upper Rouge, by means of short, more or less intermittent tributaries. The rise of land in the NE. corner of the township is due to the crossing there of the Detroit moraine, which runs from Birmingham to Detroit and was formed *sub-glacially* between the Erie and Huron lobes of the Late Wisconsin ice sheet. This feature deflects the drainage to the SW., the average slope amounting to about 9 feet to the mile in the NE. ¼ of the township. Although morainic, the surface was very-smooth and received a surface dressing of sand during the three stages of the two glacial lakes, Wayne and Lundy. The shore lines, beach ridges, bars and dunes of the two can not be clearly separated although with the help of the contour map the most prominent may be identified. The older of the two lakes (Wayne) was responsible for the ridging seen in secs. 1, 2, 11 and 12 and for a gravelly soil; the result of wave action on the till, seen about the SW. corner of sec. 12. The heavy sand ridges in the vicinity of Sand Hill, as well as those to the west and south, with a general N. to S. trend, are to be referred to the Lake Lundy, first stage. The sand was In part washed directly from the till; and in part delivered to the lake by the Upper Rouge, the month of which was in the vicinity of the present village of Bedford. The waves of this lake built up ridges to a height of 635 to 640 feet. The most prominent of these dunes are seen in secs. 7, 8, 9, 10, 11, 15, 16, 20, 21 and 29. As a further result of wave and wind action, a dressing of sand was spread over the general surface of the country obliterating most of the glacial clay. This general deposit reaches a thickness in places of 10 to 12 feet and famishes well water at-shallow depths (10 to 20 feet), the water ranging from hard to soft, insufficient to abundant. Where the soil is clay or loam, and where the sand deposit is thin, it is necessary to enter the glacial deposit known as till and depths of 25 to 80 feet are required to obtain a sufficient supply. This water is often charged with gas and mineral ingredients (sulphur, salt, etc.) from the underlying bedrock, although it may be derived from beds of gravel and sand. The rock itself must sometimes be entered a few feet especially in the SE. ¼ of the township in order to insure a sufficient quantity. These deeper wells furnish water under artesian pressure in all cases, rising to near the surface but not actually flowing. The depth to bedrock ranges from 80 to 100 feet over the township and, although some of the well records indicate differently, the bedrock is very probably nearly all black shale (Antrim formation), which so commonly yields temporary flows of gas, often, under great pressure when first struck. The salt reported in some of the wells in the southern portion of the township, in which direction the shale thins out, is probably derived from the underlying Traverse. The elevation of the rock surface at the SE. corner is not far from 550 feet above sea level; rising slightly towards the NW. The original forest growth was beech, hard and soft maple, black and white ash, elm, walnut, hickory, oak and basswood.

Greenfield township. T. 1 S., R. XI E. Name alludes to the appearance of the fields. Township lines surveyed in 1816 by Joseph Fletcher; subdivisions in 1817 by Fletcher. The SE. quarter of the township Includes the "Ten thousand acre tract," surveyed in 1816 by Fletcher and sold to provide the territory with a courthouse and jail. Established in 1833, being derived from Springwells. Area 34.782 square miles; population 4995. Although much of the southern third of the township is glacial clay or loam, the bulk of the township is veneered with sand, much of which has been heaped into conspicuous ridges. The clay is of the till plain type and practically free from surface boulders. From NW. to SE. the township is crossed by the broad, smooth swell of clay which constitutes the Detroit moraine. The highest elevation noted is at the NW, corner (668 feet above sea level) and following along the axis of the moraine drops to about 630, at the SE. corner, or at an average rate of 4¾ feet to the mile. The slope to the NE. and SW. from the axis of the moraine Is considerably more rapid, deflecting the drainage accordingly by many, short intermittent streams, those to the south of the moraine going to the Rouge; those to the north to Conners Creek, the moraine serving as the divide. Just upon the crest the drainage is slack and an extensive marsh enters sec. 5, from 32 of Royal Oak township {Oakland County), extending into sec. 4. Along the western town line the descent is from 668, at the NW. corner to about 618, at the SW. corner, 50 feet in the 6½ miles, or at the average rate of nearly 8 feet to the mile. The higher land caused by this morainic extension across the township formed a broad peninsula during the Lake Wayne and Lake Lundy stages of the glacial lakes. before which time the township was submerged and after which it was dry land. The first of these lakes threw up a series of beach and bar ridges, from the tip of the peninsula in sec. 20, around on the eastern margin through secs. 21, 10, 9 and 4, at elevations ranging from 655 to 665 feet, above sea level. The westernmost two of these approximately parallel ridges may be traced rather continuously for some 4 to 5 miles, the lower and outer is more scrappy and irregular, curving through the SE. ¼ of sec. 20 and across the western half of 21 into sec. 10. As the water rose from the level of Lake Wayne to that of Warren, owing to an advance of the ice front, these beaches and the NW. ¼ of the township were again submerged and the crest of the moraine here strewn with sand, which is slightly pebbly in places. The level of the lake waters subsequently fell to that of Lake Lundy, first stage, and formed a complicated set of irregular ridges in the vicinity of Palmer Park, at elevations ranging from 635 to 645 feet. A sand ridge of this stage, some two miles in length, crosses Woodward Avenue in Highland Park, between Highland and Glendale avenues. Irregular ridging and small amounts of gravel occur to the southwest between Woodward and Grand River, as in SE. ¼ sec. 28; SW. ¼ sec. 28; SE. ¼ sec. 29; westward through sec. 30. In receding from the first stage to the second, or Elkton stage, a somewhat poorly defined! and! disconnected sand ridge was formed at an elevation of about 610 to 612 feet, extending eastward through the southern margin of sec. 31 and the northern portions of secs. 5, 4 and 3 of T. 2 S., R. XI E. As in the case of the other townships of this class, the sand strewn portions yield water at shallow depths (6 to 18 feet), which ranges from hard to soft, is sometimes sufficiently abundant, at other times scanty in amount. In entering the clay for water, depths ranging from 25 to 135 feet are required, approaching the bedrock. In general, this water is hard but, at times, surprisingly soft; abundant as a rule, but sometimes the head is insufficient to bring the water to the surface, rising usually from 12 to 20 feet of the ground level. When the bedrock is entered, gas often accompanies the water, along with more or less sulphur and iron. By entering the deeper strata, the water is generally impregnated with salt. The bedrock underlying the greater portion of the township is undoubtedly the black (Antrim) shale. Across the SE. corner there is probably a narrow strip of the limestone and shale which constitute the Traverse formation. This rock ranges in depth from 80 to 140 feet, being greatest along the east township line and least towards the SW. corner, where the elevation of the rock surface rises from 520 to 530 feet, as compared with about 500 feet at the SE. corner. The original forest growth was black ash, basswood, elm, oak, soft maple, beech, hickory, some walnut, hard maple, whitewood and sycamore.

Hamtramck township. T. 1 S., R. XII E., (in part). Named from Col. John Francis Hamtramck. Township lines and subdivisions surveyed in, 1816 by Joseph Fletcher. Contributed to Grosse Point, Gratiot and city of Detroit. Area 16.888 square miles; population 7122. The southern half of the township is rendered irregular by the French claims along Couriers Creek, the "Park lots" and "Ten thousand acre tract," lying to the eastward of Woodward Avenue. Passing from Warren township (Oakland County), there extends southward across the township the obscure, water laid Mt. Clemens moraine, formed at the ice front of the Huron lobe, during one of the Lake Maumee stages, while the water had a depth of 140 to 160 feet. A little ridging of the clay may be seen in the NE. ¼ of sec. 4 and a few cobbles and boulders southward towards Detroit, but in the main the morainic features and glacial clay are disguised by a covering of beach and dune sands formed about the margin of the glacial Lake Lundy, first stage (elevation 630 to 640 above sea level). This sand is much more abundant over the northern half of the township, the southern portion being mostly clay and loam. The elevations over the township are quite uniform, ranging from about 620 to 640 feet, the crests of the dunes alone reaching the latter height. These ridges are arranged with very little regularity, being short, straight, or curved, irregularly placed and orientated, but with a tendency to a NE.-SW. trend. The land was not high enough to receive any of the Lake Wayne beach, nor, low enough for the second, or Elkton stage, of Lake Lundy. The sand deposits supply water at shallow depths which ranges from hard to soft and varies considerably in amount. The water may be obtained directly from the sand, or by forming a reservoir in the clay and allowing the water from the sand to seep in. When this is insufficient in amount, the clay must be entered until a waterbearing stratum of sand or gravel is reached. This requires depths ranging from 10 feet to bedrock, which may reach 180 feet. When so obtained the water is generally hard and abundant and, except in the quite shallow wells, only slightly affected by seasonal variations. I n entering the rock (limestone or shale), water is obtained often charged with gas, sulphur or salt. In a few instances it is surprisingly soft. In all the deeper wells the water rises under artesian head and may come to within 4 to 5 feet of the surface, but nowhere flows, within the limits of the township. The bedrock is deeply buried by the so-called "drift," ranging from 140 to 160 feet in the western part of sec. 5, where there appears to be a decided depression in the rock surface, the elevation of which is approximately 450 feet above sea level, rising to about 480 feet along the southern township line. The original forest growth was oak, elm, soft maple, black ash, basswood, sycamore and some beech.

1. At the cemetery, a driller reports having gone to a depth of 250 ft. without striking rock. If this is not an error it would Indicate either a fissure in the rock filled with drift, or a great trough having a depth below the general rock surface of at least 150 feet. Further records are required to settle this point.

2. A good point from which to view this lower beach is just west of the Waterworks, on Park View Avenue, where it may be found about 300 paces toward the river from Jefferson Avenue. From same point the cut First St. Clair beach is in sight upon the opposite side of Jefferson.

CHAPTER X. PRELIMINARY REPORT ON THE FAUNA OF THE DUNDEE LIMESTONE OF SOUTHERN MICHIGAN.

BY PROFESSOR AMADEUS W. GRABAU OF COLUMBIA UNIVERSITY, NEW YORK CITY.

INTRODUCTORY.

From the collections so far made, about 80 species of invertebrates have been identified. This is by no means a complete list of the species of this fauna; there is a considerable number of species still unidentified, on account of their fragmentary character, while future collections will undoubtedly increase the total number.

In the present report, the species are discussed briefly;* their illustration and full description with discussion of variations and relationships will appear in the monograph on the Traverse fauna of Michigan, which is in preparation, since these fossils are intimately related to those of the other Middle Devonic beds of Michigan. In the monograph, the "Dundee" of Northern Michigan will also be discussed. Much of the details, therefore, on which the present report is based is here omitted, but will be included in the final discussion.

*For descriptions and illustrations of the common forms, see Grabau and Shimer, North American Index Fossils, 2 vols. This report was submitted in 1910. Since then further study has shown that some of the species listed herein are new, but since it is not possible to give at present a complete revision, it is thought best to publish this preliminary report as written. The full discussion of the Michigan Devonic faunas will appear in due time.

SUMMARY OF THE FAUNA.

The order of arrangement of the classes and genera is that followed in Grabau and Shimers North American Index Fossils.

INVERTEBRATA.

Class I. PROTOZOA.

None have been recorded from the Michigan beds so far, though in the closely related Columbus, limestone of Ohio, *Calcisphaera robusta* Williamson is abundantly represented, often making up masses of the rock. This fossil closely resembles the organs of fructification of the freshwater stonewort, or Chara, with which it is sometimes identified. It is a nearly spherical body 1 mm. in diameter, and banded by nine spiral ridges.

Class II. PORIFERA.

This class is likewise unknown, so far, in the Dundee of Michigan, but in the Columbus limestone of Ohio it is represented by *Receptaculites devonicus* Whitfield. (Pal. Ohio VII., pi. VI., fig. 10).

Class III. HYDROZOA.

Division HYDROCORALLINES.

This division, represented by a number of genera and species in the Columbus limestone of Northern Ohio, is more sparingly represented in the Dundee of Southern Michigan. From the collections so far made, the genus *Clathrodictyon* has alone been identified. This is represented by a species closely related to, if not identical with, *Clathrodictyon cellulosum* Nicholson and Murie, characterized by the coarseness of its meshwork, and common in the Onondaga limestone of Canada, and occasionally occurring in New York.

In Ohio, the following species have been recorded from the Columbus limestone:

Actinostroma nodulatum (Nicholson).

Stylodictyon columnare Nicholson.

Stromatopora granulose Nicholson.

S. ponderosa Nicholson.

S. sanduskyensis Rominger.

S. substriatella Nicholson.

S. (Syringostroma) densa Nicholson.

Class IV. ANTHOZOA (Corals).

This class is fairly well represented in some parts of the Dundee, though it is not known to form reefs, such as are characteristic of the Onondaga of Western New York and of the Jeffersonville limestone of the Falls of the Ohio. As will be shown later, the horizon of the Dundee is probably above that of the coral reefs of the Onondaga, a fact further emphasized by the marked dissimilarity of the coral faunas of the two regions. The species so far obtained from the Dundee of Southern Michigan are as follows:

Genus ZAPHRENTIS Rafinesque.

Zaphrentis convoluta Hall.

This appears to be the most abundantly represented form in Southern Michigan. It is a rapidly expanding curved cone showing the tetrameral arrangement of the septa by the septal striae on the outside of the coral, and characterized by uniting and more or less twisting septa. The fossula is scarcely indicated, though in a few cases, it is discernable. The species is close to Streptelasma. It has been found in the Sibley quarry in beds: A. (6 ft. bed), B. (7 ft. bed), D. (5 ft. bed), E. (6 ft limestone), I. (9 ft. bed) and elsewhere.

Zaphrentis prolifica Billings.

This species is similar to the preceding, and when the calyx is filled by matrix, can scarcely be distinguished from it. The septa are less strongly twisted, often scarcely at all, and the fossula is well developed. This probably occurs with the preceding, though none of the specimens in the collections I have examined appear to conform to it; but it has been reported from the Dundee of Southern Michigan. It is not uncommon in the lower Traverse of Northern Michigan.

Zaphrentis gigantea Lesneur.

This large species, characteristic of the Onondaga of Western New York and of the Falls of the Ohio, has been reported from the Dundee of Michigan and the Columbus of Ohio. Its cylindrical growth, large size, well developed tabulae which bend down marginally, and well marked fossula are distinctive characteristics. At present, no specimens of this species are contained in the collections of Dundee limestone fossils.

Zaphrentis corniculum E. and H.

This has been recorded from the Dundee of Michigan and the Columbus of Ohio.

Other species of Zaphrentis obtained from the Columbus limestone of Ohio are: *Z. edwardsi* Nichols and *Z. wortheni* Mich.

Genus AULACOPHYLLUM E. and H.

Aulacophyllum sulcatum E. and H.

This species, common in the Jeffersonville limestone of the Palls of the Ohio and also found in the Hamilton group, is sparingly represented in the Dundee of Southern Michigan. It is characterized by the converging septa on either side of the well developed cardinal fossula, in which a thin cardinal septum occurs. The species also occurs in the Columbus limestone of Ohio.

Genus CYSTIPHYLLUM Lonsdale.

Cystiphyllum vesiculosum Goldfuss.

This species is represented mostly by medium-sized individuals, most of the specimens collected being much worn. The cysts are large and the form moderately tapering. No specimens of the size of the prevailing Hamilton form have been found so far.

The species is common in the Onondaga of New York, Canada, and the Falls of the Ohio. It occurs in the Columbus limestone of Ohio, where another, smaller species, with fine cysts, *C. ohioense* Nicholson, also occurs. The latter species has not yet been found in Michigan.

In the Dundee of Southern Michigan, *C. vesiculosum* has been found in the Sibley quarry in Bed A (6 ft. bed), B (7 ft bed), D (5 ft. bed), I (9 ft, bed) and above, as well as in some of the other horizons.

Genus ACERVULARIA Schweigger.

Acervularia rugosa E. and H. (*Cyathophyllum rugosum*).

This species is not uncommon in the Dundee of Southern Michigan. It has been obtained from 15 to 20 ft. above the bottom of the Sibley quarry in bed I (9 ft. bed) and in bed A (6 ft. bed). It has also been found more generally distributed.

This species occurs in the Sellersburg (Hamilton) limestone of the Falls of the Ohio and in the Columbus limestone of Ohio. It has not been reported from any horizon in Western New York. The species seems to be represented in the Traverse of Northern Michigan, where *Acervularia davidsoni* is the common reef coral. The separation of Acervularia from Cyathophyllum, merely on the ground of the possession of an inner wall is ill advised, since Acervularia has no true inner wall. It seems likely, with our present knowledge, that both *Cyathophyllum rugosum* and *Acervularia davidsoni* belong to Acervularia, and that they are closely related.

Acervularia davidsoni is a characteristic Hamilton species of Michigan, Iowa, and westward. The genus as such seems foreign to the true Onondaga fauna, and the occurrence of *A. rugosa* in the Dundee and Columbus seems to argue for a post-Onondaga age of these formations. This idea is borne out by the fact that the species occurs in post-Onondaga beds (Sellersburg or Lower Hamilton) at the Falls of the Ohio. The origin of the genus seems to be a western one.

Genus PHILLIPSASTRAEA d'Orbigny.

Phillipsastraea gigas Owen.

This species with calices 20 mm. in diameter has been reported from the Dundee of Michigan, but seems to be confined to the northern area. No specimens have been observed in our collections. It is also a typical Hamilton species in Michigan, Ohio, and the Falls of the Ohio, but in New York and Canada it seems to be confined to the Onondaga.

P. verneuilli E. and H.

This form, with smaller corallites, (10 to 15 mm. in diameter), has been reported from the Onondaga of Canada and the Dundee of Michigan, but appears also to be confined to the northern Dundee. It is likewise reported from the Hamilton of Thedford, Ontario, but this identification needs verification.

Genus ERIDOPHYLLUM E. and H.

Eridophyllum verneuillianum E. and H.

This form occurs in the Columbus limestone of Ohio, and will probably be found in the Dundee of Southern Michigan. I have not seen it among the collections.

E. colligatum (Billings) has been reported from Northern Michigan, and occurs in the Jeffersonville of the Falls of the Ohio and the Onondaga of Canada.

Genus SYNAPTOPHYLLUM Simpson.

This genus differs from the preceding in the absence of the central wall, but agrees with it in the connections between corallites.

Synaptophyllum simcoense Billings.

A small part of a colony of this species has been obtained from the Sibley quarry. It is not abundant but characteristic. The diameter of the corallites is about 4 or 5 mm. It occurs in the Columbus limestone of Ohio, the Onondaga of Canada and Western New York, the Jeffersonville of the Falls of the Ohio, and the "Dundee" or Mackinac limestone of Northern Michigan

Genus FAVOSITES Lamarck.

Favosites emmonsi Rominger.

This species, with tubes 1 to 1½ mm. in diameter, and crowded tabulae seems to be represented in the Dundee of the Sibley quarry. It is not an abundant form, but is most characteristic of the Onondaga of Western New York and Canada. In Ohio, it occurs both in the Columbus and the Delaware. At Louisville, Ky., it is found in the Jeffersonville beds, and in Northern Michigan in the Mackinac limestone. It has also been recorded from Iowa.

Favosites turbinatus Billings.

This species is the most abundant of any in the Dundee of Southern Michigan. It is of turbinate form, curved, and resembles in outline some Cyathophylloid coral or the mold of some large pelecypod shell. The tabulae of our specimens are rather distant, as are also the mural pores.

The species occurs pretty generally distributed through the Dundee of the Sibley quarry. It has been collected from Bed I (9 ft. bed) and from the 12 ft. bed above the lower 20 ft. bed.

This species is found in the Onondaga of Canada and New York, and in the Columbus of Ohio. It is, however, more distinctively a Hamilton type, occurring in that formation in New York, Ohio, Louisville (Falls of the Ohio), Thedford, Ont., and the Traverse of Michigan.

Other species of Favosites found in the Columbus limestone of Ohio are: *F. basaltica* Goldfuss; *F. hemispherica* Yand, and Shum.; *F. invaginata* Nich.; *F. pleurodictyoides* Nich.; and *F. polymorpha* Goldf. *F. hemispherica* also extends into the Hamilton.

Genus CLADOPORA.

Cladopora cryptodens (Billings) (?)

This is a round-stemmed, branching species, the branching being chiefly a bifurcation. The branches are from 5 to 10 mm. in diameter, and the corallites are scarcely curved. Tabulae few and incomplete. The identification of our specimens with Billings' species is provisional. The specimens are all broken, showing the corallites but not their orifices. They were found in Bed I (9 ft. bed) and in the 12 ft. of beds above the lower 20 ft; also in the upper 5 ft. of the lower 20 ft.

The species is widely distributed, occurring in the Onondaga of Canada, New York, the Falls of the Ohio, and in the Mackinac limestone of Northern Michigan. Many other species have been obtained from the Mackinac limestone, but no other from the Dundee or Columbus.

The following table shows the distribution elsewhere of the corals obtained from the Dundee of Michigan and the Columbus of Ohio.

TABLE LXV.—SUMMARY OF THE CORAL FAUNA.

	Dundee of Michigan.	Columbus of Ohio.	Jeffersonville of Kentucky.	Onondaga of New York.	Onondaga of Ontario.	Mackinac Limestone.	Sellersburg of Kentucky.	Hamilton of New York.	Hamilton of Thedford, Ont.	Hamilton of Ohio.	Traverse Group of Michigan.	Mid-Devonic of Iowa.
1. *Zaphrentis convoluta*	×						?				?	
2. *Z. prolifica*	×	×			×	×	×		×		×	
3. *Z. cornicula*	×	×		×	×	×	×		×	×		
4. *Z. edwardsi*		×										
5. *Z. gigantea*		×	×	×	×	×		×				×
6. *Z. wortheni*		×										
7. *Aulacophyllum sulcatum*	×	×	×									×
8. *Cystiphyllum vesiculosum*	×	×	×	×	×	×	×	×	×	×	×	×
9. *C. ohioense*		×					×			×		
10. *Hadrophyllum d'orbignyi*		×					×			×		
11. *Cyathophyllum zenkeri*		×			×				×			
12. *C. robustum*		×	×					×	×			
13. *Heliophyllum halli*		×	×				×	×	×		×	×
14. *H. confluens*		×					×	×	×		×	
15. *Acervularia rugosa*	×	×				×	×				?	
16. *A. davidsoni*	?						×		×	×		×
17. *Stylastraea annae*	?	×										
18. *Phillipsastraea gigas*					×	×	×			×		
19. *P. verneuilli*					×	×			×			
20. *Eridophyllum verneuillianum*		×			×	×	×					
21. *E. strictum*		×			×		×		×			
22. *E. colligatum*		×			×	×						
23. *E. simcoense*	×	×	×	×	×	×						
24. *Aulopora cornuta*		×			×	×	×		×			
25. *A. filiformis*		×			×							
26. *A. tubiformis*		×						×	×		×	
27. *Syringopora hisingeri*		×	×		×	×						
28. *S. maclurii*		×			×	×						
29. *S. tabulata*		×					×					
30. *Favosites basaltica*		×									?	
31. *F. hemispherica*		×	×	×	×		×			×	×	
32. *F. invaginata*		×										
33. *F. pleurodictyoides*		×										
34. *F. polymorpha*		×										
35. *F. turbinata*	×	×		×	×		×	×	×	×		
36. *F. emmonsi*	×	×	×	×	×	×				×		×
37. *F. limitaris*		×				×		×			×	
38. *Michelina convexa*		×	×		×	×						
39. *M. maxima*		×										
40. *M. cylindrica*		×	×			×						
41. *Cladopora cf. cryptodens*	×		×		×	×						
42. *Alveolites squamosus*		×	×		×	×						
43. *Trachypora elegantula*		×					×	×	×	×	×	

A study of this table which is based on the best available data, shows some interesting results. Of the 43 species listed, 8, or 18.6 per cent., are known elsewhere only from the Hamilton beds; while 10, or a little over 23 per cent., are elsewhere in the eastern province known only from the Onondaga. One of these, however, *Aulacophyllum sulcatum*, is found also in the post-Onondaga beds of Iowa. The other Onondaga species include, moreover, some of the most characteristic species of Eridophyllum, Synaptophyllum, Syringopora, Michelinia, Cladopora, and Alveolites. On the other hand; it should be noted that it is just these species that are sparingly represented in Ohio; and that only two of them, *Synaptophyllum simcoense* and *Cladopora cryptodens*, occur in the Dundee of Michigan, the first represented by one small specimen, the other doubtfully identified. Moreover, it is these species which may still be found among the coral fauna of the Traverse Group when the study of it is completed, and too much weight should therefore not be placed on this apparent preponderance of Onondaga types. Among exclusively Hamilton species, such characteristic species as *Heliophyllum halli*, *Heliophyllum confluens*, *Aulopora tubaeforumis*, and *Trachypora elengantula* occur. Of other species generally most characteristic of the Hamilton fauna occur: *Zaphrentis prolifica*, *Heliophyllum halli*, *Acervularia rugosa*; and, doubtfully, *A. davidsoni*, *Favosites hemispherica*, *F. turbinata*, and *F. limitaris*. On the other band, species more characteristic of the Onondaga fauna are: *Zaphrentis gigantea*, *Phillipsastraea gigas*, *P. verneulli*; various species of Eridophyllum, Synaptophyllum, and Syringopora; and *Favosites emmonsi*. All of these, however, have been found in typical Hamilton strata. Such typical Onondaga species as *Favosites epidermatus*, *F. canadensis*, *Cystiphyllum sulcatum*, *Acrophyllum oneidense*, *Amplexus yandelli*, *Chonophyllum magnificum*, etc., are wanting. While not conclusive, the evidence of the coral fauna points to a higher horizon than typical Onondaga for the Columbus of Ohio and the Dundee of Michigan, and its closer affiliation with the Hamilton of the eastern province.

Class V. BRYOZOA.

Bryozoa are common in the Dundee of Michigan, some parts of the coarser limestones (calcarenites) abounding in fragments of Fenestella and others. Owing to their fragmentary character, only a few have been identified so far.

Genus FENESTELLA Lonedale.

Various species of this genus seem to be represented among the fragments, including, apparently, *F.* (*Semicoscinium*) *planidorsatum* Ulrich, also found in the Sellersburg of the Falls of the Ohio.

Genus CYSTODICTYA Ulrich.

Cystodictya gilberti (Meek).

This species, originally described from the Columbus limestone of Ohio, and abundant in that horizon as well as in the overlying Delaware, is very common in the Dundee of Southern Michigan, occurring in nearly all the outcrops. It is readily recognized by its flat, repeatedly branching stems, and the rapidly increasing number of rows of apertures and separating ridges. The species occurs in the Hamilton (Sellersburg) of the Falls of the Ohio and of Indiana.

SUMMARY OF THE BRYOZOA FAUNA. So far as studied, the Bryozoa indicate a closer relationship of the Columbus and Dundee to the Hamilton than to the true Onondaga. The most abundant and most typical species, *Cystodictya gilberti*, is elsewhere found only in the Hamilton.

Class VI. BRACHIOPODA.

Genus STROPHEODONTA Hall.

Stropheodonta inaequiradiata Hall.

This typical Onondaga species is represented by a few individuals from the Sibley quarry. It is recognized by its coarse, unequal striae and moderate convexity of the pedicle valve. It occurs in the Columbus of Ohio and is known from the Onondaga of New York and Quebec, and appears to be represented in the Devonic of Nevada.

Stropheodonta dundeense sp. nov.

This species is extremely convex, of the average size of *S. demissa*, but with the striae crowded, and often fasciculate. It resembles somewhat a diminutive *S. hemispherica*, but its convexity is too great for it to represent the young of that species. From *S. inaequiradiata* it differs in its greater convexity, and in the more crowded condition of its striae. It is not unlike some of the extreme forms of Stropheodonta from the Hamilton of Missouri. In the Sibley quarry, this species is most abundant in beds G (6 ft. bed) and I (9 ft. bed), and again in the 12 feet of the strata above the lower 20 feet.

Stropheodonta hemispherica Hall.

This large, convex Stropheodonta is abundant in the Dundee of Southern Michigan. Often it is extremely convex and large, but there are many small or half grown individuals. The brachial valves, are very gently concave in the younger part, and then become abruptly bent or even geniculate. The striae are sometimes fasciculate, but not sharp, as in *S. demissa*. The median septum of the brachial valve and the cardinal septum are well marked. The pedicle valve is uniformly and strongly convex, often with a median ridge-like accentuation, and sometimes with rude irregular folds in addition. It occurs throughout the series of strata in the Sibley quarry, and has been noted in the other outcrops, and in the equivalent beds near Windsor, Ontario, as well as in the Columbus of Ohio. Elsewhere this species occurs in the Schoharie and Onondaga formations, having been found in New York, Ontario, etc.

Stropheodonta concava Hall.

This species seems to be represented by a number of specimens with the characteristic sharp striae and the strongly muscular impressions of this Hamilton species. It is found in several of the beds in the Sibley quarry (Bed G, and the bottom 20 ft. bed), and occurs also in the Columbus limestone of Ohio. In New York, it is chiefly confined to the Hamilton, where it abounds, though it has been reported also from the Onondaga. In Indiana it occurs in the Sellersburg and Jeffersonville.

Stropheodonta costata Owen.

This species, probably the *S. erratica* of Winchell, is represented by a few individuals easily recognizable by their small size and coarse plications. It is an abundant form in the Lower Traverse beds of Northern Michigan.

Stropheodonta fissciosta Winchell.

This species is another typical Traverse form in which formation it abounds. A single specimen has been obtained from the Dundee of the Sibley quarry. It is readily recognized by its divided costae, otherwise resembling the preceding. A closely related species is figured by Kindle from the Jeffersonville of the Falls of the Ohio, as *S. plicata* Hall.

Stropheodonta demissa (Conrad).

This characteristic Hamilton species is represented by a considerable number of specimens which show the typical form and bundled striae. They occur in coarse calcarenyte scattered through the section. A variety somewhat less convex than the normal form, and with a shorter hinge line with more rounded ends also occurs in the lower beds. On the whole, the specimens resemble more closely those found in the lower shales of the Traverse beds to the north, than the coarser striated New York form.

The species is recorded from the Onondaga of New York, but the individuals are small and not typical. Those from the Dundee and the Columbus resemble more the Hamilton type than the variety from the Onondaga. The species is widely distributed In the Hamilton of North America.

Stropheodonta alpenensis sp. nov.

This species is the most abundant of any in the Traverse Group of Michigan, occurring throughout, with several modifications. It is about half the size of *S. demissa*, and looks not unlike a dwarfed representation of that species. Its uniform size, together with its ornamentation, however, show it to be distinct.

The species is not uncommon in the Dundee of Michigan, the specimens from this horizon agreeing in all respects with those from the Traverse Group. They often become very robust, and this is also true of the Traverse species. In such cases, the muscular impressions become strongly marked. This species probably occurs in the Columbus limestone of Ohio, as well as in the Dundee of Western Ontario.

Stropheodonta (*Leptostrophia*) *perplana* (Conrad).

This species is not uncommon in the Dundee of Southern Michigan, and the Columbus of Ohio. It is readily recognized by its flat character and the fine radiating striae. Not. infrequently, concentric undulations, recalling the characters of *Leptaena rhomboidalis* occur, especially on the younger individuals.

The species is rather generally distributed through the formations. Its range elsewhere is from the Schoharie to the Chemung.

Stropheodonta (*Pholidostrophia*) *iowaënsis* (Owen).

(*Stropheodonta nacrea* Hall).

This characteristic Hamilton species is abundantly represented in the Dundee of Southern Michigan and the Columbus of Ohio. The limestone specimens rarely show the nacreous lustre observed in the specimens of the shales, but the characteristic form and absence of striae permit ready identification. Though reported from the Onondaga, it is most typical of the Hamilton in all the exposures of the latter from New York to Iowa. It occurs in the Sellersburg and Jefferson vi lie of Indiana.

Stropheodonta pattersoni Hall.

This Onondaga species is reported from the Columbus limestone of Ohio. Its convexity, extended hinge line with deflected angles, and distant striae alternating with finer ones, characterize the species. Some of the other limestone species might be mistaken for this, and there is some possibility that the identification is not absolute.

In any case, it has not been found in the material from Michigan.

Genus STROPHONELLA Hall.

Strophonella ampla Hall.

This large, reversed form, with the pedicle valve convex in the young, but strongly concave in the adult, has been found in the Columbus limestone of Ohio, but has not yet been reported from Southern Michigan. It is a characteristic Onondaga species in New York and Ontario.

Genus LEPTAENA Dalman.

Leptaena rhomboidalis (Wilckins).

This widespread species is represented so far by a single specimen in the Dundee of Michigan, but appears to be more abundant in the Columbus limestone of Ohio. Its concentric wrinkles and sudden rectangular anterior deflections are sufficiently distinctive features. Its great range (Trenton to Waverly) makes it of little value as a horizon marker.

Genus SCHUCHERTELLA Girty.

(ORTHOTHETES of most authors.)

Schuchertella arctostriata Hall.

This species, with its irregular form, long hinge line, and alternating striae, seems to be well represented in the Dundee of Southern Michigan, where it occurs at several horizons, it has not been reported from Ohio, but is common in the Hamilton of New York, Ontario, and occurs in the Jeffersonville of Indiana, etc.

Schuchertella pandora Billings.

This Onondaga species occurs in the Columbus limestone of Ohio, and may also be represented in the Dundee of Michigan. Its regular form, fine, sharp striae, strong curvature, and straight beak distinguish it. It is characteristic of the Onondaga of New York, Ontario, and elsewhere, and has been reported from the Devonic of Nevada.

Schuchertella (*Orthothetes*) *flabellum* Whitfield.

This small, strongly plicate species was described from the Columbus limestone of Ohio. It is unlike any other known Devonic form, but one from the Upper Monroe of Michigan agrees quite closely with this. Since Monroe species have before been described as Onondaga types, the horizon of this species should be verified. It occurs in the Sibley quarry, and also in the upper 100 feet of the Detroit shaft.

Genus CHONETES. Fischer de Waldheim.

Chonetes mucronatus Hall.

This is the most abundant and characteristic species of Chonetes in the Dundee of Southern Michigan. It is of medium size, with deflected cardinal angles, and with finer striae than is usual for this species in the Onondaga limestone of New York, etc. In this respect, the species agrees entirely with the specimens from the Marcellus shale of New York, the number of striae approximating 24-26. The spines are long, slender, and parallel to the hinge line. Altogether, the mutation of this species here presented agrees so closely with, the Marcellus types as to lead to the supposition that they were contemporaneous, and that the species was eurylithic, or capable of occupying a wide range of bottom facies, i.e., from calcareous sand and mud to highly carbonaceous muds unsuited to most forms of organisms. The range of this species as a whole is rather wide, beginning in the Oriskany and continuing into the Hamilton. The various mutations, however, seem to be restricted to narrow stratigraphic zones.

In the Dundee of Southern Michigan, it is most abundant in the chert beds A and II (6 ft. and 2 ft. beds), and the chert bed over the 9 ft bed. It is also found in the limestones at various levels in the Sibley quarry and in the upper layers penetrated by the salt shaft at Oakville, Detroit. It is also found in the Columbus of Ohio, and in the same rock in the region about Windsor, Ont. It occurs in the Sellersburg and Jeffersonville of Indiana, etc.

Chonetes gibbosa Hall.

This species is represented by a single specimen obtained from the lower beds of the Sibley quarry. It is very convex, with more numerous striae than in *C. mucronatus*, and with strong spines bent outward. The species elsewhere occurs in the Hamilton.

Chonetes deflecta Hall.

This species, with the convexity and general characters of *C. mucronatus*, but with much finer striae, more strongly deflected cardinal extremities, and rather more oblique spines, also occurs in the limestones of the Sibley quarry, and in the Columbus limestone of Northern Ohio. It is essentially a Hamilton species.

Other species recorded from the Columbus limestone of Ohio are: *C. acutiradiata* Hall, *C. arcuata* Hall, and *C. yandellana*, Hall. Elsewhere these species are distributed as follows: *C. acutiradiata* from the Onondaga of New York, and the Jeffersonville of the Falls of Ohio, *C. arcuata* from the Onondaga of New York and *C. yandellana* from the Jeffersonville of the Falls of Ohio.

Genus STROPHALOSIA King.

Strophalosia truncata Hall.

This characteristic Marcellus species seems to be common in certain of the beds in the Dundee of Southern Michigan, especially the chert beds. The pedicle valve is convex, with a strong umbonal truncation, and with spinous ridges running for some distance and ending in spines of moderate length. The range of this species is from the Marcellus to the Portage, but it has not been reported from any lower horizon. It has so far remained unrecorded from the Columbus limestone of Ohio.

Genus PRODUCTELLA Hall.

Productella spinulicosta Hall.

This species is not uncommon in the limestones, where it is strongly convex, with rather strong spinous ridges and long spines. Some of the specimens have the character of *P. shumardiana* of the Onondaga limestone, these occurring in the upper beds of the Sibley quarry. The typical forms occur in the 2 ft. chert bed (Bed H) and in the chert bed above the 9 ft. bed. It is also found in other non-cherty beds of the quarry. Elsewhere it is most characteristic of the Hamilton beds, though it has been recorded from the Onondaga.

Genus RHIPIDOMELLA Oehlert.

Rhipidomella variabilis sp. nov.

This is the commonest species of the Dundee limestone. It is transverse, varying in proportional height and width, approaching on the one hand *R. vanuxemi*, and on the other *R. penelope*. The pedicle valve varies from convex to nearly flat, while the brachial valve is strongly arched. Generally a well-marked, broad, but ill-defined sinus occurs toward the front of the pedicle valve, and a flattening, rarely a depression, in the brachial valve. The muscular impressions are like those of *R. vanuxemi*.

This species seems to have been the stock from which *R. vanuxemi*, *R. penelope,* and *R. livia* were derived, the various mutations leaning towards one or another. Some specimens are scarcely distinguishable from *R. penelope*, except that they do not reach the size of that species.

The young of typical *R. vanuxemi* is proportionately broader than the adult, a feature characteristic of the adult of *R. variabilis*, which, therefore, fulfills the requirements of an ancestral form in this respect.

The common form of this species is distinguished by its breadth and its median pedicle sinus. Some of the specimens approach *Schizophoria propinqua* in outline, but the hinge is always shorter and the muscular impressions are distinctive. The species is pretty generally present in the various beds of the Sibley quarry. It also occurs in other exposures of this formation in Southern Michigan and the adjoining Canadian region. It is found also in the Columbus limestone of Ohio.

Rhipidomella vanuxemi Hall.

This characteristic Hamilton species appears to be represented by a number of individuals from the Dundee of Southern Michigan. In this horizon, it has more the value of a fluctuating variety, but becomes well fixed in the succeeding Hamilton. It has been reported from the Onondaga, but its chief development is in the Hamilton of New York, etc. The species is also reported from the Columbus limestone of Northern Ohio.

Rhipidomella penelope Hall.

Several of the mutations of *R. variabilis* are sufficiently modified and increased in size so that they may virtually he regarded as *R. penelope*. The distribution seems general. Elsewhere this species is known only from the Hamilton.

R. livia Billings.

This species has been reported from the Columbus limestone of Ohio, and appears to be likewise represented from the Dundee of Southern Michigan. It occurs elsewhere in the Onondaga, as in Ontario. It is doubtfully reported from the Sellersburg of Indiana.

Genus SCHIZOPHORIA King.

Schizophoria iowaensis Hall.

This form is not uncommon in the Dundee limestone. It is large, robust, and very convex in the brachial valve, which bears a well marked median depression towards the front. The muscular impressions are small and deep. The species, on the whole, agrees most closely with the commoner forms of the Traverse Group, though some approach *S. propinqua* Hall. It is also found in the Columbus limestone and in the Onondaga of New York, etc. This species is especially abundant in Bed I (9 ft. bed) and in the beds above the lower 20 ft. of the Sibley quarry.

Genus PENTAMERELLA Hall.

Pentamerella arala Conrad.

This species has been recorded from the Columbus of Ohio, but the specimens are not typical, as are those of the Schoharie and Onondaga of New York. It is not definitely known from the Dundee of Michigan, though a fragmental specimen suggests its possible presence.

Pentamerella cf. pavilionensis Hall.

This species seems to be represented by a brachial valve having the characteristic form and plication. It was obtained above the 9 ft. bed. The species is a widely distributed Hamilton form.

Genus CAMAROTOECHIA Hall and Clarke.

This genus is represented by several species not fully identified. In the Columbus limestone occur *C. dotis* Hall, *C. billingsi* Hall, *C. carolina* Hall, and *C. thetis* Billings. The first of these is a Marcellus and Hamilton form; of the others *C. billingsi* occurs in the Onondaga of New York and Canada, *C. carolina* at the Falls of the Ohio, and *C. thetis* in the Onondaga of New York, the Sellersburg and the Jeffersonville of the Falls of the Ohio and the Devonic of Nevada.

Genus TROPIDOLEPTUS Hall.

Tropidoleptus carinatus Conrad.

This characteristic and diagnostic Hamilton species of Eastern North America has been reported from the Columbus limestone of Ohio. It has not been noticed in the Dundee, but it may prove to be present. If correctly identified, it furnishes a further link in the relationship of these strata to those of New York; for this species has, in North America, been found only in the Marcellus and Hamilton, though also occurring higher up.

Genus ATRYPA Dalman.

Atrypa reticularis Linnaeus.

This species is abundantly represented by normal individuals. It is also common in the mutation *elegans*, mut. nov., which is always small, but becomes very robust, often approaching a globular form. The muscular impressions are strongly marked, and the surface feature comprise fine, uniform striae, repeatedly bifurcating and crossed by very distant, strong, concentric lines, which produce a slight nodosity at the crossing. Repeated bifurcation of the striae keeps them fine and greatly increases their number.

The pedicle valve is rather more strongly convex than in the normal form, and in outline it is often somewhat elongate. Sometimes there is a faint flattening down the middle of the brachial valve, giving this form some resemblance to *A. impressa* of the Schoharie.

The species occurs in the chert bed and in the limestones of the quarry. It has also been reported from the Columbus limestone of Ohio.

Atrypa spinosa Hall.

This species is abundantly represented, being more numerous than the preceding. It has moderately coarse plications, which, in some cases, are seen to continue as tubular spines beyond the edge of the shell. In some forms, the plications are few and coarse, with strong concentric lines, as in the typical Hamilton specimens. The number of primary plications is not over 8 or 10, and they increase by repeated division. This species ranges pretty nearly throughput the limestone. It has not been recorded from the Columbus of Ohio, and elsewhere it is chiefly confined to the Hamilton, though it is said to range up into the Chemung. It occurs in the Sellersburg of the Falls of the Ohio and Charlestown, Ind.

Genus CYRTINA Davidson.

Cyrtina hamiltonensis Hall.

This characteristic Hamilton species is also represented in the Dundee of Southern Michigan and the Columbus limestone of Ohio. It is typical, with moderately curved hinge area, and occurs in beds I and J of the Sibley quarry, as well as in the upper 100 feet penetrated by the Detroit salt shaft. The variety recta, with straight hinge area, is also represented. Though reported to range from the Onondaga to the Portage, this species is most typically represented in the Hamilton, where it is a diagnostic fossil. Both occur in the Sellersburg and Jeffersonville of the Falls of the Ohio.

Genus SPIRIFER Sowerby.

Spirifer bidorsalis Winchell.

This is a small species characteristic of some of the lower beds of the Traverse Group of the Traverse Bay region. It is elongate, with a moderate hinge area, rounded, strong plications, about 9 on each side of the sinus, and a low plication in the sinus. The fold is divided by a sharp median groove. In the specimens from the Traverse shales, strong concentric striations occur, but, in the specimens from the limestone, these are seldom visible. The species is scattered through the upper layers in the Sibley quarry. A variety occurs which is larger proportionally, and more robust, and has fewer plications. This variety is found also in the Columbus of Ohio.

Spirifer gregarius Clapp.

This species seems to be represented by several small individuals with rather weak plications. They are strongly convex and have a profound median sinus and strongly overarching beak of the pedicle valve. They are smaller than the normal forms from the Onondaga of New York and the Sellersburg and Jeffersonville of the Falls of the Ohio, and seem to be confined to the upper beds in the quarry. The form occurs in the Columbus limestone.

Spirifer grieri Hall.

This species is readily recognized by the plications on the fold and sinus. It is represented by a number of individuals, the distribution of which through the beds of the Sibley quarry and the upper part of the Detroit salt shaft show it to be a rather common form. It is also found in the Columbus limestone and in the Onondaga of New York and the Jeffersonville of the Falls of the Ohio.

Spirifer manni Hall.

This species, originally described from the Columbus limestone of Ohio, is common in the Dundee of Southern Michigan. It is generally elongate, with moderate area, and a marked flattening or median depression on the fold of the brachial valve. Genetically it appears to be closely related to *S. johnsoni* Grabau Mss. of the Lower Traverse, the only difference being in the faint lateral plications in the sinus of *S. johnsoni*. Through the last named species, this species is related to *S. oweni*, which is approached by some accelerated individuals of *S. manni* in form, but the plications of the sinus are scarcely developed. Once in a while, the faint plications are formed, so that the specimens may be referred either to *S. johnsoni* or to *S. oweni*. This is the common Spirifer of the Dundee, occurring more or less abundantly throughout the series.

S. manni occurs in the Columbus limestone, and in the Onondaga of Western New York and the Jeffersonville of the Falls of the Ohio.

Spirifer oweni Hall.

Some of the Dundee specimens of Spirifer approach *S. oweni* so closely that they may be regarded as representing that species. These are the accelerated derivatives, of *S. manni*. They have been found in the upper beds. Elsewhere the species occurs in the Hamilton (Sellersburg), of the Falls of the Ohio and the

Lower Traverse of Michigan. Other species of Spirifer recorded from the Columbus of Ohio are: *S. acuminatus* Conrad, *S. duodenarius* Hall, *S. euryteines* Owen, *S. fimbriatus* Conrad, *S. macra* Hall, *S. machrothyris* Hall, *S. segmentus* Hall, *S. varicosa* Hall, and *S. raricostus* Conrad.

OTHER GENERA.

The genus MERISTELLA Hall is represented in the Columbus limestone by two species. *M. nasuta* Conrad and *M. scitula* Hall. An unidentified fragment of a species of this genus occurs in the Dundee of Michigan. The genus NUCLEOSPIRA Hall is represented by *N. concinna* Hall in the Columbus limestone, and the genus EUNELLA by *E. sullivanti* (Hall). Finally, the genus RFEMERELLA is represented by *R. grandis* Vanuxem, a characteristic Hamilton form, found in New York, Indiana and Kentucky; and the genus CRANIA by *C. crenistriata* Hall and *C.* (*Creniella*) *hamiltoniae* Hall, both Hamilton species, though the former also occurs in the Onondaga of New York, and the latter in the Jeffersonville of the Falls of Ohio.

The following table shows the range of the species in the Dundee and Columbus limestones:

TABLE LXVI.—SUMMARY OF THE BRACHIOPOD FAUNA.

	Dundee.	Columbus.	Typical Onondaga.	Typical Marcellus and Hamilton.
1. *Stropheodonta inaequiradiata*	×	×	×	
2. *S. dundeensis*	×			
3. *S. hemispherica*	×	×	×	
4. *S. concava*	×		×	×
5. *S. costata (solidicosta)*	×			×
6. *S. finicosta*	×			×
7. *S. demissa*	×	×	?	×
8. *S. alpenensis*	×	?		×
9. *S. perplana*	×	×	×	×
10. *S. (Pholidostrophia) iowaensis*	×	×	×	×
11. *S. pattersoni*		×	×	
12. *Strophonella ampla*		×	×	
13. *Leptaena rhomboidalis*	×	×	×	×
14. *Schuchertella arctostriata*	×			×
15. *S. pandora*		×	×	
16. *S. flabellum*		×		
17. *Chonetes mucronatus*	×	×	×	×
18. *C. gibbosus*	×			×
19. *C. deflectus (C. vicinus)*	×	×		×
20. *C. acutiradiata*		×	×	
21. *C. arcuata*		×	×	
22. *C. yandellanus*		×	×	
23. *Strophalosia truncata*	×			×
24. *Productella spinulicosta*	×	×	×	×
25. *Rhipidomella variabilis*	×			
26. *R. vanuxemi*	×	×	×	×
27. *R. penelope*	×			×
28. *R. livia*	×	×	×	
29. *Schizophoria iowaensis*	×	?		×
30. *S. propinqua*	×	×	×	
31. *Pentamerella arata*	?	×	×	
32. *P. cf pavilionensis*	×			×
33. *Camarotoechia dotis*		×		×
34. *C. billingsi*		×	×	
35. *C. carolina*		×	×	
36. *C. thetis*		×	×	×
37. *Tropidoleptus carinatus*		×		×
38. *Atrypa reticularis*	×	×	×	×
39. *A. spinosa*	×		×	×
40. *Cyrtina hamiltonensis*	×	×	×	×
41. *C. hamiltonensis var. recta*	×			×
42. *Spirifer bidorsalis*	×			×
43. *S. gregarius*	×	×	×	×
44. *S. grieri*	×	×	×	
45. *S. manni*	×	×	×	
46. *S. oweni*	×	×		×
47. *S. acuminatus*		×	×	×
48. *S. duodenarius*		×	×	×
49. *S. euryteines*		×		×
50. *S. (Reticularia) fimbriatus*		×	×	×
51. *S. macrus*		×	×	
52. *S. macrothyris*		×	×	
53. *S. segmentus*		×	?	
54. *S. varicosus*		×	×	×
55. *S. raricostus*		?	×	
56. *Meristella nasuta*		×	×	
57. *M. scitula*		×		
58. *Nucleospira concinna*		×		×
59. *Eunella sullivanti*		×	×	
60. *Roemerella grandis*		×		×
61. *Crania cranistriata*		×	×	×
62. *Craniella hamiltoniae*		×		×

From the foregoing table it will be seen that the Hamilton species predominate. Of the 62 species recorded, 24, or 38 per cent. are unknown outside of the Onondaga elsewhere, while 28, or 45 per cent., are either restricted to or most characteristic of the Hamilton group. Moreover, such very typical New York Hamilton or Marcellus fossils as *Stropheodonta demissa*, *S. iowaensis*, *Schuchertella arctostriata*, *Chonetes mucronatus*, *Strophalosia truncata, Productella spinulicosta*, *Rhipidomella vanuxemi*, *R. penelope*, *Camarotoechia dotis*. *Tropidoleptus carinatus*, *Cyrtina hamiltonensis*, *C. recta, Reticularia fimbriata*, *Nucleospira concinna*, *Roemerella grandis*, and *Craniella hamiltoniae* strongly suggest Hamilton affinities. Such is also the case with the species identical with those of the Traverse fauna of Michigan, as *Spirifer bidorsalis*, *S. euryteines*, *S. oweni*, *Stropheodonta alpenensis*, *S. plicata*, and *S. fissicosta*. The abundance of Onondaga types shows that the fauna is not true Hamilton, but rather a transitional fauna.

Class VII. PELECYPODA Goldfuss.

(LAMELLIBRANCHIATA de Blainville).

Genus SANGUINOLITES McCoy.

Sangumolites sanduskyensis Meek.

This species, occurring in the Columbus limestone in Northern Ohio, appears to be represented in the Dundee by a large specimen, an internal mold about 55 mm. high. So far as can be ascertained from the fragmentary character, it can be referred to this species.

Genus PTERINEA Goldfuss.

Pterinea flabellum (Conrad) ?

This species is doubtfully identified from the Columbus limestone, the specimens being large, coarse forms, very unlike the Hamilton types.

Genus ACTINODESMA Sandburger.

(GLYPTODESMA HALL).

Actinodesma erectum Conrad.

This large and coarse species is represented by several left valves in the Dundee of Michigan. It is characterized by an extended hinge line, slightly defined wing, ending in an acute point, and by coarse concentric growth striae and undulations. The species occurs in the coarser rock of the upper beds (Bed I) and 12 ft. above the lower 20 ft. in the Sibley quarry. Elsewhere, it is a typical Hamilton form though occurring in the Jeffersonville of the Falls of Ohio. A closely related species, *A. subrectum* Whitfield, occurs in the Delaware limestone of Ohio.

Genus PLETHOMYTILUS Hall.

Plethomytilus ponderosus Hall.

This large species is represented in the Columbus of Ohio and the Onondaga of New York and Ontario. It has not been noted as yet in the Dundee.

Genus MYTILARCA Hall.

Mytilarca percarinata Whitfield.

This species is known only from the Columbus limestone of Dublin, Ohio.

Genus CONOCARDIUM Bronn.

Conocardium trigonale Hall.

This is a well represented species abounding in some of the layers of the Dundee in Southern Michigan. It occurs both as shells and internal molds. It is equally common in the Columbus of Ohio and occurs at the Falls of the Ohio. It is found in the Schoharie and Onondaga of New York. A closely related form occurs in the Traverse beds of Michigan.

Conocardium ohioense Meek.

This small species with sharply separated, produced posterior extremity, occurs in the Columbus limestone of Ohio, and the Jeffersonville (?) of the Falls of the Ohio. It has not yet been reported from Michigan.

Genus ACTINOPTERIA Hall.

Actinopteria decussata Hall.

This large and characteristic Hamilton species is represented by specimens on the average somewhat smaller than those found in the Hamilton beds. They have the characteristic form and obliquity, but generally lack the pronounced radii owing to the exfoliation of the shell. They are more or less scattered through the Dundee of the Sibley quarry, having been found in the 12 ft. bed above the lower 20 ft.; in Bed D (5 ft. bed); in Bed I (9 ft. bed); and in the beds above this. The species elsewhere is known only from the Hamilton beds.

A small specimen with strong concentric wrinkles decussating the striae, has been obtained from the 9 ft. bed. The striae are round and thicker than is general in the Hamilton specimens, but the form and obliquity are normal. The end of the wing projects slightly beyond the shell below.

Genus AVICULOPECTEN McCoy.

Aviculopecten similis (Whitfield).

This species, described by Whitfield from "the thin, shaly layers of bituminous limestone from above the 'bone bed' at Smith and Price's quarry near Columbus, Ohio," and referred to the Marcellus, is represented by a single left valve agreeing in all respects, including size, with the type. Its alternating striae and extreme convexity and small size are characteristic features.

Whitfield compares this with *Actinopteria decussata*, but the comparison is not apt. That species is more oblique and more elongate and the striae are interrupted. The hinge is unknown, but in form the species resembles an Aviculopecten. It is not improbable, however, that this is the young of *Aviculopecten sanduskyensis*.

Aviculopecten sanduskyensis Meek.

This species is described from the Columbus of Ohio, but has not been obtained from Michigan.

Aviculopecten crassicostatus Hall and Whitfield.

This occurs likewise in the Columbus limestone, but is still unrecorded from the Michigan Dundee. It was originally described from the Sellersburg of the Falls of the Ohio.

Aviculopecten sp.

A form with distant striae and strong concentric undulations has been obtained from the Sibley quarry above the 9 ft. bed. It is too poorly preserved for specific determination.

Genus MODIOMORPHA Hall.

Modiomorpha elliptica?

Recorded doubtfully from the Columbus limestone of Ohio.

Modiomorpha perovata (Meek and Worthen).

This species, described from Ohio, has so far not been found in Michigan, though there are indications that it may occur there.

Genus GONIOPHORA Phillips.

Goniophora perangulata Hall.

This acutely angular species, characteristic of the Schoharie beds of New York, has also been reported from the Columbus limestone of Ohio, but is still unknown in Michigan.

Genus PARACYCLAS Hall.

Paracyclas elliptica Hall.

This large species, with irregular and lame-Hose concentric striae, is abundantly represented in the Dundee of Southern Michigan and the Columbus of Ohio. The specimens are mostly compressed or distorted and are generally over an inch in diameter (1½ to 1¾ in. is more nearly the average). When perfect, they approach a circular form, while the depth or transverse diameter is one-half the vertical or over. Some specimens suggest in their striae an approach to *P. lirata* of the Hamilton Group. The species occurs in the Onondaga of New York, but is more abundant in the Mackinac limestone of Northern Michigan. It occurs more rarely in the Hamilton of New York. In the Falls of the Ohio region, it occurs in the Jeffersonville and Sellersburg.

The Dundee specimens are distributed more or less throughout the series exposed in the Sibley quarry. The species also occurs in the adjoining region of Ontario.

Paracyclas ohioensis Meek.

This small species, described from the Columbus limestone of Ohio, has also been obtained from the Sellersburg limestone of the Falls of the Ohio region. It has not been definitely identified from Michigan.

Summary of the Pelecypod Fauna. The pelecypod fauna of the Dundee and Columbus is more individualized than the brachiopod fauna, having proportionally more species peculiar to it. Nevertheless, there are a number of distinct Hamilton species present, such as *Actinodesma erectum* (Conrad), *Actinopteria decussata* Hall, and the small *Aviculopecten similis* Whitfield, described from the "Marcellus" of Ohio and *Paracyclas ohioense* from the Sellersburg of Indiana. Against these must be placed the number of distinctive Onondaga and Schoharie species, as *Plethomytilus ponderosus* Hall, *Conocardium trigonale*, *Goniophora perangulata* Hall., and *Paracyclas elliptica* Hall. On the whole, it seems as if the fauna inclines more to the Onondaga-Schoharie type than to the Hamilton type, since the most abundantly represented species belong to the former.

Class VIII. SCAPHOPODA Browne.

Genus DENTALIUM Linnæus.

Dentalium (*Laevidentalium*) Martini Whitfield.

This smooth, rapidly enlarging and moderately curved species is the earliest known from American rocks. It has been described from the Columbus limestone of Ohio, and not yet noted elsewhere.

Class IX GASTROPODA.

The gastropods as a whole are poorly preserved in the Dundee limestone of Michigan, occurring mostly as internal molds with the shell removed. As a result, identification of species is difficult, especially if, as is generally the case, compression has distorted the mold. The following determinations are subject to revision if better material is obtained.

Genus PLEUROTOMARIA.

Pleurotomaria (*Pleurorima*) *lucina* Hall.

This large species seems to be well represented by internal molds, which are commonly compressed, so that the spire appears lower than normal. The "band," when visible, seems to be near the middle of the whorl and vertical. Some of the compressed forms resemble *P.* (*Spiroraphe*) *arata*, but the superior-placed "band" of that species has not been observed. No surface markings are shown. The specimens are most abundant in Bed A (the 6 ft. bed) of the Sibley quarry, but occur also higher up (top beds and Bed G). They have also been collected from the Dundee of the salt shaft between 83 and 105 ft. from the top. *P. lucina* has been obtained also from the Columbus limestone of Ohio, and is characteristic of the Hamilton of New York; but it is reported likewise from the Onondaga of that state. It occurs in the Sellersburg beds (?) and the Jeffersonville limestone of the Falls of the Ohio, etc.

Pleurotomaria (*Euryzone?*) *hebe* Hall.

This species, found in the Columbus of Ohio, is represented in the Dundee of Southern Michigan by two internal molds. These show only the form and apical angle of the species, the ornamentation being lost. The specimens are one from Bed A (6 ft. bed), and the other from the beds above the 9 ft. bed in the Sibley quarry.

Elsewhere this species is found in the Onondaga of Western New York.

Pleurotomaria (*Lophospira*) *adjutor* Hall.

This ornamented species has been found in the Columbus limestone of Ohio and the Onondaga of New York, but has not been observed in the Dundee of Michigan.

Genus HORMOTOMA Salter.

Hormotoma (*Hormotomina*) *maia* (Hall).

This slender turreted species with rounded whorls is represented by fragments of internal molds in the Dundee of Southern Michigan (Bed I or 9 ft. bed). The characteristic duplicate character of the band is not well shown, though in one case the central carina is indicated. It was originally described from the Columbus limestone of Ohio, and has not been found elsewhere.

Hormotoma desiderata Hall.

This species, associated with the preceding in the Columbus limestone of Ohio, and distinguished from it by its greater apical angle, flatter shoulder of whorls, and simple band, has been doubtfully reported from the Onondaga of New York, but is still unknown from other localities. It probably occurs in the Dundee of Michigan; a mold approaching it has been obtained from the upper beds of the Sibley quarry. It has also been recorded from the Jeffersonville of Indiana.

Genus COELIDIUM Clarke and Ruedemann.

This genus seems to be represented by the internal mold of an unidentified species. The obliquity of the whorls is very slight, and there is a hollow axis from loose coiling. The whorls are round and the band is just below the periphery. It was obtained from the Dundee of the Sibley quarry; exact level not noted.

Genus EUOMPHALUS Sowerby.

Euomphalus (*Pleuronotus*) *deceici* Billings.

This species is most characteristically developed in the Columbus limestone of Ohio, but has also been obtained from the Onondaga of New York and Canada from the Jeffersonville of the Falls of the Ohio, etc, and from the Mackinac limestone of Northern Michigan. Its rapidly enlarging whorls, flat or sunken spire, and sharp keel readily distinguish it. In the collections of Dundee forms, it is represented by two young specimens showing depressed spire, a flat periphery, and rather rounded angles. Found in the upper beds.

Genus TROCHONEMA Salter.

Trochonema meekanum S. A. Miller (*T. tricarinatum* Meek).

This species, found in the Columbus limestone of Ohio, is represented by a single crushed specimen in the collections of Dundee material from Southern Michigan, recognizable from its carinated shoulder angle. From Bed I (9 ft. bed) of the Sibley quarry. It has also been found in the Jeffersonville limestone of Indiana.

Genus PLATYCERAS Conrad.

Platyceras dumosum Conrad.

A spiny species, represented by a number of individuals in the Dundee limestone, having considerable variation in form and spinosity. Spines generally represented by irregular nodes; the shell as a whole expanding rapidly. The apex is always strongly enrolled. Obtained from the lower beds, A (9 ft. bed) and D (5 ft. bed), and elsewhere in the Sibley quarry. It is found in the Columbus limestone of Ohio, in the Onondaga of New York and Ontario, and in the Sellersburg limestone of the Falls of the Ohio.

Platyceras attenuatum Meek.

This species, originally described from the Columbus limestone of Ohio, also occurs in the Dundee of Michigan. It is slender and narrow, with slight enlargements and rough nodes. It occurs some distance above the bottom of the beds (above the lower 20 ft.) in the Sibley quarry. The species has also been recorded from the Sellersburg bed of Charlestown, Ind.

Platyceras carinatum Hall.

This species, characterized by a sharp, carinated periphery, is represented in the Columbus limestone of Ohio, and by a small specimen in the Dundee of Southern Michigan. It occurs in the Hamilton of New York and the Sellersburg and Jeffersonville limestones of Indiana. Other species of Platyceras found in the Columbus limestone of Ohio, and probably also occurring in the Dundee of Michigan, are: *P. bucculentum* Hall, found besides in the Hamilton of New York and the Sellersburg and Jeffersonville limestone's of Indiana; *P.* (*Igoceras*) *conicum* Hall, found also in the Hamilton of New York (also Onondaga?), and at the Falls of the Ohio (Jeffersonville and Sellersburg); *P. multispinosum* Meek also found in the Jeffersonville at the Falls of the Ohio; and *P.* (*Palaeocapulus?*) *squalodens* Whitfield.

Genus CALLONEMA Hall.

Callonema bellatulum Hall.

(*Isonema bellatulum* Hall).

This species, described from the Columbus limestone of Ohio, and occurring also in the Jeffersonville limestone of the Falls of the Ohio, is represented by a single internal mold from the Dundee of the upper five feet of the lower 20 ft. of the limestone of the Sibley quarry. The form of the whorls and the apical angle correspond exactly with those of the type specimen from Ohio, but no trace of the ornamentation is retained.

Besides the species already noted, the following have been recorded from the Columbus limestone of Northern Ohio.

TABLE LXVII.

	Range elsewhere.
1. *Collonema lichas* Hall.	Onondaga of Western New York, Jeffersonville of Ind.
2. *Callonema humile* Meek.	Sellersburg of Falls of the Ohio.
3. *Palaeotrochus kearneyi* Hall.	
4. *Turbinopsis shumardi* (Vern).	Jeffersonville of Falls of Ohio and New York?
5. *Isonema depressum* M. and W.	Hamilton of Illinois.
6. *Xenophora antiqua* Meek.	
7. Naticopsis aequistriatus Meek.	
8. *N. cretacea* H. and W.	
9. *N. laevis* Meek.	Jeffersonville (?) of Falls of Ohio.
10. *Loxonema leda* Hall.	
11. *L. hamiltoniae* Hall.	Hamilton of New York, Sellersburg of Ind.
12. *L. parvulum* Whitfield.	
13. L. pexatum Hall.	Onondaga of New York.
14. *Macrocheilus priscus* Whitfield.	
15. *Cyclonema (?) doris* Hall.	Schoharie of New York,
16. *Hormotoma (?) obsoleta* Meek.	
17. *Bellerophon newberryi* Meek.	
18. *B. propinquus* Meek.	
19. *B. pelops* Hall.	Schoharie and Onondaga of New York, Jeffersonville of Indiana.

Summary of the Gastropod Fauna of the Dundee and Columbus Limestones.

While the majority of species are so far known only from these limestones, and are therefore of no immediate significance in correlation, a large number are elsewhere represented. Out of a total of about 15 species found in other localities, the division between the Hamilton and Onondaga is nearly equal. Most of the seven or eight Hamilton species are typical of that horizon, showing that the gastropod fauna must be considered intermediate. Probably many of the distinctive species will be found in the Traverse fauna of Northern Michigan, when the study of the latter is completed.

Class X. CONULARIDA Miller and Gurley.

(*Pteropoda* of authors).

Genus TENTACULITES Schlotheim.

Tentaculites scalariformis Hall.

This is a common species of certain layers of the Dundee of Southern Michigan. It has been found at various levels in the Sibley quarry, including Bed G (6 ft. bed), H (2 ft. bed), J (6 ft. bed) and above the lower 20 ft. It occurs most abundantly in the Dundee of the salt shaft, at about 105 ft. below the surface. It is likewise common in the Columbus limestone of Ohio, and has been recorded from the Onondaga of New York and from the Sellersburg and Jeffersonville of Indiana.

Genus CONULARIA Miller.

Conularia elegantula Meek.

This has been described from the Columbus of Ohio, but has not been noted as yet from the Dundee of Michigan.

Class XI. CEPHALOPODA Cuvier.

Genus ORTHOCERAS Breynius.

Several species of Orthoceratites occur in the Dundee of Southern Michigan, but no specimens sufficiently well preserved for specific identification have so far been found. From the Columbus of Ohio have been recorded *O.* (*Spiroceras*) *nuntium* Hall, known also from, the Hamilton of New York; *O. ohioense* Hall, and *O.* profundum Hall, also known from Onondaga of Western New York.

Genus TREMATOCERAS Whitfield.

Trematoceras ohioense Whitfield.

This species, described from the Columbus limestone of Ohio, probably also occurs, in the Dundee of Michigan, as indicated by several imperfect specimens.

Genus GYROCERAS Meyer.

Gyroceras (*Ryticeras*) *cyclops* Hall.

This species occurs in the Columbus limestone of Ohio, including the beds of Kelley's Island. It also occurs in the Onondaga of New York, but so far has not been recorded from Michigan.

Gyroceras (*Ryticeras*) *columbiense* Whitf.

This species, described from the Columbus of Ohio, has not been found elsewhere so far, but probably occurs in Michigan, since it is a common species.

Gyroceras (*Centroceras*) *ohioense* Meek.

This large species, described from the Columbus of Ohio, is also found in the Dundee of Michigan. In the specimens observed, the coiling is somewhat loosened toward the aperture, and the ornamentation of some individuals appears coarser than in the type.

They occur in Bed I (9 ft. bed) and elsewhere.

Gyroceras (*Gigantoceras*) *inelegans* Meek.

This large species, originally described from the Columbus limestone of Ohio, also occurs in the Dundee of the Sibley quarry. A single large specimen has been obtained, with roundish smooth whorls enlarging rapidly. It has also been reported doubtfully from the Jeffersonville of the Falls of the Ohio.

Gyroceras seminodosus Whitf.

This appears to be a young form, possibly of *Discites inopinatus*. It has been found in the Columbus limestone of Ohio.

Genus NAUTILUS.

Nautilus (*Discites*) *ammonis* Hall.

A large nautilicone with deeply concave septa apparently belongs to this species. It was obtained from the Sibley quarry. It has not been recorded from Ohio, but has been found loose in Southern Michigan.

Nautilus (*Discites*) *inopinatus* Hall.

This nautilicone, characterized by sparse oblique nodes, on the ventrol-lateral angles, and smaller nodes on the umbilical margin, is represented by a single specimen from the Dundee of the Sibley quarry. It is quadrangular in section, but does not preserve the shell. The species has been found in the Columbus limestone of Sandusky, Ohio.

Genus POTERIOCERAS McCoy.

Poterioceras amphora (Whitf).

This species, described from the Columbus limestone of Ohio, also occurs in the Dundee of Michigan. Specimens were found in Bed B (7 ft. bed) of the Sibley quarry which correspond closely to the type specimen, having the aperture rather strongly contracted, the axis of the aperture being transverse to that of the rather strongly compressed shell. The species is unknown outside of these two formations, but closely similar, if not identical ones, occur in the Traverse group of Northern Michigan.

Poterioceras hyatti (Whitf).

This species was likewise described from the Columbus limestone of Ohio. It appears to be not uncommon in the Dundee of South Michigan. The curved form, and aperture contracted below the top, where it again slightly expands, characterize the species. The axis of the aperture is parallel to the broad axis of the shell. This species has not yet been recorded from other horizons.

Poterioceras eximium (Hall).

This species has been recorded from the Columbus limestone of Ohio, but has not been found in Michigan.

It was originally described from the Onondaga limestone of New York.

Poterioceras sciotense Whitf.

This species is at present known only from the Columbus limestone of Ohio.

Summary of the Cephalopod Fauna of the Dundee and Columbus limestone. The cephalopoda more than any other class seem to be represented by peculiar species not yet found elsewhere. Of those known from other localities, however, only one (*Spiroceras nuntium*) is a typical Hamilton form, while three or four have previously been recorded from the Onondaga of New York or elsewhere. So far as the cephalopods seem to indicate, the fauna is less advanced than we should suppose from other classes of organisms.

Class XII. CRUSTACEA.

Order TRILOBITA.

Genus PROETUS Steininger.

Proetus conicus sp. nov.

This species is represented by a single cranidium. It is characterized by a conical glabella resembling that of *P. curvimarginatus* from the Schoharie of Pendleton, Ind., but has only three lateral furrows, the posterior one curving strongly backward to the occipital furrow, the middle curving slightly backward, while the upper scarcely curves at all. This species was figured and described by the author from the Hamilton shales of Eighteen-Mile Creek. It was provisionally and doubtfully referred to *P. curvimarginatus*. (Bull. Buffalo Soc. Nat. Sci. vol. VI., p. 316, fig. 261, 1898). *Proetus prouti* from the Hamilton of Iowa has a somewhat similar but less conical glabella. The specimen was obtained from Bed I (9 ft bed).

Proetus crassimarginatus Hall.

This species, described from the Onondaga of New York and Ontario, is abundantly represented in the Dundee of Southern Michigan and the Columbus limestone of Ohio. It occurs mostly as pygidia, which are readily recognized by their strong convexity, the elevated, rounded axis, and strongly downcurving sides with rounded margins. The species ranges throughout the beds of the Sibley quarry and occurs in the other exposures of the Dundee and Columbus. It is known from the Jeffersonville and Sellersburg of Indiana and the Falls of the Ohio.

Proetus planimarginatus.

This species is readily distinguished from the preceding by its large flat pygidium with its gently convex axis, semi-elliptical outline, and pronounced margin. It occurs in the Columbus limestone of Ohio and is not uncommon in the Dundee of Southern Michigan.

Genus DALMANITES Emmrich.

Dalmanites (*Chasmops*) *calypso* Hall and Clarke.

This species is readily recognized by the angular, high and tuberculated axis of the pygidium with the pleurae grooved. The Michigan specimens resemble more nearly those figured by Kindle from the Sellersburg beds of Ohio than those from the Onondaga of New York. (Compare Fig. 3, Pl. 30, Ind. Geol, Surv., 25th Ann. Rep't; and Pal. N. Y. Vol. VII., Pl. XI. A, Fig. 19). In some specimens, the spines are less marked and the pleura! grooves fainter. This is more like the type figured by Ball and Clarke. The species has also been recorded from the Columbus limestone of Sandusky, Ohio.

Dalmanites selenurus Green.

This species, known from the Onondaga limestone of New York, and the Jeffersonville of the Falls of Ohio, has been recorded from the Columbus of Ohio. It is thus far unknown in the Dundee of Michigan.

Dalmanites ohioensis Meek.

This species occurs in the Columbus limestone of Ohio.

Genus PHACOPS Emmrich.

Phacops rana Green.

This common Onondaga and Hamilton species occurs in the Columbus limestone of Ohio and is represented by pygidia in the Dundee of Southern Michigan.

Summary of Trilobite Fauna of the Dundee and Columbus Limestones.

So far as the Trilobites permit correlation, the Dundee-Columbus fauna must be considered an intermediate one between Onondaga and Hamilton, with a leaning toward the Hamilton side. Species of Hamilton affinity are: *Proëtus conicus* Grabau, *Chasmops calypso* Hall and Clarke var., and *Phacops rana* Green. Species of Onondaga affinities are: *Proëtus crassimarginatus* Hall and *Dalmanites selenurus* Green. The *Proëtus crassimarginatus* type seems to be a long lived one, for it is already represented in Southern Michigan in the Upper Monroe (Siluric). Against this may perhaps be offset, at least in part, the fact that both *Chasmops calypso* and *Phacops rana* occur elsewhere in the Onondaga as well as in the Hamilton.

VERTEBRATA.

Class I. PISCES.

Remains of Fishes are not uncommon in the Columbus limestone of Ohio and the Dundee of Michigan. A number of species have been described from the Columbus limestone. In the Dundee, so far, have been recognized fragments of Onychodus, Machaeracanthus, and Rhynchodus.

GENERAL SUMMARY OF THE DUNDEE-COLUMBUS FAUXA OF SOUTHERN MICHIGAN AND NORTHERN OHIO.

The Protozoa and Stromatoporoids furnish at present little evidence for the age of the limestones, since the only recorded Protozoan (*Calcisphæra robusta* Williamson) is a long lived form continuing into the Carbonic, while the Stromatoporoids are not yet fully identified. The same is true of the Bryozoa, Scaphopoda, Conularida, and fish remains. The other classes, however, furnish more or less conclusive evidence regarding the age of this fauna as a whole. The corals and gastropods indicate an intermediate position for the fauna; the Brachiopods and Trilobites show a leaning to the Hamilton fauna; while the Pelecypoda and Cephalopoda incline to the Onondaga. In the Monroe formation, the Cephalopoda were found to be mostly of Lower Silurian (Niagaran) types, while the gastropods, corals, brachiopods, and trilobites were advanced forms. It is, therefore, safe to consider this fauna as strictly intermediate between the typical (New York) Onondaga and the typical (New York) Hamilton.

THE STRATIGRAPHIC POSITION OF THE DUNDEE-COLUMBUS.

Whitfield has shown that on the Sciota River and near Dublin, Ohio, the Delaware (Hamilton) and Columbus are separated by a thin bed of black shale with a fauna like that of the Marcellus shale of New York. The species found in this shale were: 1. *Lingula manni* Hall; 2. *L. ligea?* Hall; 3. *Orbiculoida minuta* Hall; 4. *O. lodiensis* Hall; 5. *Chonetes scitula* Hall; 6. *C. reversa* Whitfield; 7. *Spirifer maia* (Billings); 8. *Leiorhynchus limitaris* Vanuxem; 9. *Aviculopecten? equilatera* (Hall); 10. *Pterinea* (*Aviculopecten*) *similis* Whitfield. Of these, Nos. 3, 4, 8 and 9 are typical Marcellus fossils of New York; Nos. 1, 2 and 5 are Hamilton species; No. 7 is an Onondaga form, and the others are new.

WhitAeld's conclusion that these shales represent the Western extension of the Marcellus of New York is undoubtedly correct, as is clear from the fauna, as well as from the bituminous character of the sediments. These deposits seem to disappear northward, though the relationship of the Dundee and the overlying Traverse of Southern Michigan is not yet understood. Clarke* has recently shown that the base of the Marcellus of Eastern New York is stratigraphically lower than that of the same formation in Western New York. At least 50 feet of black "Marcellus" shale overlying the Onondaga in the Schoharie region is represented in Western New York by Upper Onondaga, This is shown by the fact that the Agoniatite limestone, which in the Schoharie region is separated from the Onondaga by the above mentioned 50 feet of black shale, is an integral part of the Upper Onondaga limestone in Western New York. Clarke has interpreted these facts as representing the momentary eastward migration of the Upper Onondaga fauna of Western New York, where limestones continued to form after black shale sedimentation had commenced in the Helderberg of Eastern New York. In comparing the New York sections with those of the Appalachian region, it appears that this equivalency is much more extensive. Thus at Cumberland, Maryland, the Romney shale, succeeding the Oriskany, probably with a hiatus, represents not only Hamilton and Marcellus of New York, but probably also the greater part, if not the whole of the Onondaga. The Agoniatite limestone has been found by Prosser in this section 170 feet above the base of the black shale. From analogy with the New York sections, we may argue that black shale sedimentation was going on here, while limestones were forming in New York, and that the shales, gradually spread northward and westward over the limestones. Just before they reached Western New York, a reversal of conditions seems to have occurred, the limestone conditions spreading eastward and southward, permitting the Agoniatite fauna to spread over territory which was previously the field of black shale sedimentation.

*N. Y. State Mus. Bull. 49, p. 115.

From the foregoing considerations it would appear that the thin bed of Marcellus shale of Central and Northern Ohio, represents the westward limit of spreading Marcellus conditions. These black muds overlie the Onondaga of Western New York to the extent of 55 feet, followed by the thin Stafford limestone (8 ft.) and about 45 ft. of Cardiff or Upper Marcellus shale. It seems highly probable that these Marcellus shales are represented westward by the limestones of the open sea and pure water, just as the muds of Eastern New York and of Maryland .are represented westward by the limestones of the Onondaga. This would make the Columbus-Dundee the stratigraphic equivalent of the Marcellus shales of New York, and would place them stratigraphically above the Onondaga limestone, and since these limestones are thinner than the Onondaga of Western New York, it seems not unreasonable to assume that limestone sedimentation in the Ohio-Michigan region began long after it had set in, in the Western New York region. This assumption would compel us to regard this region as one of non-deposition during all or most of Onondaga time. It may be that this region was the sea bottom under an ancient ocean current, with water sufficiently shallow to prevent sedimentation under it by its scouring action. Or else what is more likely, this may have been a land area during Onondaga time. In any case, the general absence of reef building corals from these limestones is significant, and argues for a later date for these sediments.*

The study of the Mackinac region has developed the fact that at the beginning of Onondaga time that region was in the state of a semi-desert, surrounded by limestone cliffs which furnished debris to be spread over the valley floor.† This limestone debris was derived from the Monroe formation and is incorporated with the succeeding Mackinac limestone, which, as a result, is brecciated to a high degree. The brecciated phase may be seen on the Island of Mackinaw and on the mainland to the west (Pt. St. Ignace). To a slight extent, it is still visible east of Mackinac City, where, however, the Mackinac limestone is largely made up of the finer sand and mud resulting from the breaking up of the limestone of the cliffs which surrounded the desert area.

The age of the limestone about Mackinac is probably greater than that of the Dundee of Northern Michigan. For this reason, and because the faunas are to a certain extent distinct, it is well to use a distinctive name for this formation. The name Mackinac limestone would seem to apply, and is so used in this report. This limestone appears to be more nearly equivalent to the Onondaga of New York, and it is at its base that the Schoharie fauna of Northern Michigan has been discovered.‡

On the view that the Mackinac limestone (the so-called Dundee of the Mackinac region) is the approximate equivalent of the Onondaga and Schoharie of New York, the succeeding Bell shales of Northern Michigan represent in part the horizon of the Marcellus, but with a different type of sedimentation. It is to this shale series that the Dundee-Columbus of Southern Michigan and Ohio corresponds, at least in part. Whether it began earlier, during the later stages of sedimentation of the Mackinac limestone, or whether the base of the Dundee and that of the Bell shale are approximately synchronous, will probably appear from further study of the northern faunas. In the latter case, the Dundee is probably also represented in part by the Lower Traverse limestones; and; in any case, it appears as if the Dundee is probably to be regarded as a member of the Traverse Group as developed in Northern Michigan.

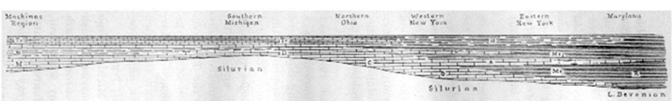

Figure 22. Ideal section from Maryland to Northern Michigan, crossing western New York, Ohio, and Northern Michigan.

A. Agoniatite limestone.
B. Bell shale (Lower Traverse).
C. Columbus limestone of Ohio.
D. Dundee limestone of Southern Michigan.
H. Hamilton of New York.
M. Mackinac limestone of Northern Michigan.
MS_1 Lower Marcellus of Eastern New York.
MS_2 Upper Marcellus of Eastern New York.
O. Onondaga of New York.
R. Romney shale of Maryland.
Tr. Traverse of Michigan—Delaware of Ohio.

Summary of Results. Summarizing the results so far obtained by the study of the fauna of the Dundee limestones of Southern Michigan, we find that both palæontology and stratigraphy point to an intimate relationship between it and the Traverse (Hamilton), and that it is probably the stratigraphic equivalent of the Lower Traverse. This relationship and that with the Marcellus and Onondaga of New York is brought out by the following diagram.

*See the discussion of Devonic Coral Reefs in the author's Principles of Stratigraphy—A. E. Seller & Co., 1913.

†Grabau, A. W. Subaerial erosion cliffs and talus in the Lower Devonic of Michigan. Science, N. S., vol. 25. pp. 295-296. See also Principles of Stratigraphy, chapter XIII.

‡Grabau, A, W. Discovery of the Schoharie fauna in Michigan. G. S. A. Bull., vol. 17, pp. 718, 719: 1907.

SUPPLEMENTARY NOTE.

After the preceding report had been submitted, the admirable bulletin on The Middle Devonian of Ohio, by Clinton E. Stauffer has appeared.* It comprised a historical sketch of the study of the Middle Devonian of Ohio, with a brief review of the corresponding horizons of adjoining districts, followed by a detailed study of the various sections in Ohio with list of the species obtained from the various beds. A chapter, discussing the relationships of the Middle Devonian of Ohio with palæogeographic maps, and one giving descriptions and illustrations of new or important species completes the work.

This discussion is of the greatest interest and. significance in connection with the study of the Dundee, as well as the Traverse fauna, for this is the latest and most detailed information regarding the characters and faunas of the Ohio extension of our Michigan formations, and we are fortunate to have such a timely contribution. Extensive use will be made of it in the discussion of the Traverse faunas as a whole, but, for the present, reference will be made only to the section and faunas of the Columbus limestone of Northern Ohio and their bearing on the problem of the Dundee of southern Michigan.

In northwestern Ohio, where the rocks represent the direct continuation of the Michigan beds, the Columbus limestone is a fossiliferous gray limestone in the upper part, passing downward into a sparingly fossiliferous brown limestone, resembling the lower part of the same formation in central Ohio. The total thickness probably does not exceed 60 feet. The series rest disconformably upon the Lucas dolomite of the Monroe, and is overlain by the limestones and shales of the Traverse formation, there being no marked lithic change from the Columbus to the Traverse, the dividing line being indicated by the introduction of a large number of Hamilton species. There is thus no evidence of Marcellus sedimentation in this section which was beyond the reach of the mud-bearing currents from the east. The Black Shale overlies the Traverse disconformably as everywhere in this region.

*Geological Survey of Ohio, 4th Series, Bull. 10, dated Nov., 1909, issued June, 1910.

In the vicinity of Silica, Ohio, just north of the Michigan line and 2¼ miles southwest of Sylvania, a number of quarries furnish good sections of the Dundee as well as the Upper Monroe beneath it. These were all visited by the writer in company with Prof. Sherzer, and the similarity of this rock to that of Monroe county, Michigan, was noted. The fossiliferous crystalline gray limestone of this section is 13 feet or more in thickness and underlain by 42 feet of compact brown limestone in marine beds, with a few fossils in the upper part. The rock is especially characterized by the large discs of the stein of an undescribed species of Hexacrinus and from it Stauffer records the following species:

FORAMINIFERA.

1. *Calcisphaera robusta* Williamson.

HYDROCORALLINES.

2. *Stromatopora ponderosa* Nicholson.
3. *Syringostroma densa* Nicholson.

ANTHOZOA.

4. *# *Acervularia davidsoni* E. & H.
5. # *Cyathophyllum rugosum* E. & H. (*Acervularia rugosa*) E. & H.
6. *Cladopora frondosa* Nicholson.
7. # *Favosites emmonsi* Rominger.
8. * *F. hemisphericus* (Troost).
9. *F. polymorphus* Goldfuss.
10. *# *Zaphrentis cornicula* E. & H.
11. *Z. gigantea* (?) Rafinesque.
12. *Zaphrentis* sp.

BRYOZOA.

13. *# *Cystodictya gilberti* (Meek).
14. *Monotrypa tenuis* (Hall).

BRACHIPODA.

15. *Amphigenia elongata* (Vanuxem).
16. *Anthyris vittata indianensis* Stauffer.
17. *# *Antrypa reticularis* (Linn).
18. *# *A. speciosa* Hall.
19. *Camarctoechia billingsi* Hall.
20. *Chonetes arcuatus* Hall.
21. *Chonetes hemisphericus* Hall.
22. *# *Chonetes mucronatus* Hall.
23. * *Chonetes* sp.
24. * *Cryptonella lens* Hall.
25. *# *Cyrtina hamiltonensis* Hall.
26. * *Cyrtina umbonata alpenensis* Hall.
27. * *Eunella lincklaeni* Hall.
28. * *Nucleospira concinna* Hall.
29. # *Orthothetes* (*Schuchertella*) *pandora* (Billings).
30. # *Pentamerella arata* (Conrad).
31. *Pholidops patina* Hall and Clarke.
32. *# *Pholidostrophia iowaensis* (Owen).
33. *# *Productella spinulicosta* Hall.
34. * *Rhipidomella cyclas* Hall.
35. *# *R. vanuxemi* Hall.
36. # *Schizophoria propinqua* Hall.
37. *Spirifer acuminatus* (Conrad).
38. # *Sp. gregarius* Clapp.
39. # *S. grieri*. (?) Hall.
40. # *Spirifer manni* Hall.
41. *S. segmentum* Hall
42. *S. varicosus* Hall.
43. * *Spirifer* sp.
44. *# *Stropheodonta demissa* (Conrad).
45. *# *S. hemisphaerica* Hall.
46. # *S. inaequiradiata* Hall.
47. *# *S. perplana* (Conrad).
48. *Strophonella ampla* Hall.

PELECYPODA.

49. * *Actinopteria boydi* (Conrad).
50. * *Aviculopecten* sp.
51. *# *Conocardium cuneus* (Conrad). (*C. trigonale*. Hall).
52. *Glyptodesma occidentale* Hall.
53. *Limopteria pauperata* Hall.
54. *Paracyclas ettiptica* Hall.
55. *Modiomorpha concentrica* (Conrad).
56. *Penenka alternata* Hall.
57. * *Pterinea flabellum* (Conrad).
58. *Schizodus* sp.

GASTROPODA.

59. *Callonema lichas* (Hall).
60. # *Euomphalus decewi* Billings.
61. *Isonema* (*Collonema*) *humile* Meek.
62. *Loxonema robustum* (?) Hall.
63. # *Murchisonia* (*Hormotoma*) *desiderata* Hall.
64. # *Platyceras carinatum* Hall.
65. # *Platyceras dumosum* Conrad.
66. * *Platyceras* sp.
67. *Pleurotomaria arata* Hall.
68. # *Pleurotomaria lucina* Hall.
69. # *Trochonema meekanum* Miller.

CONULARIDA.

70. *Coleolus crenatocinctus* Hall.
71. # *Tentaculites scalariformis* Hall.

CEPHALOPODA.

72. *Gyroceras* sp.
73. *Orthoceras ohioense* Hall.
74. *Orthoceras* sp.

TRILOBITA.

75. *Phacops cristata* Hall.
76. # *Proetus planimarginatus* Meek.
77. *Proetus rowii* (Green).

BLASTIODEA.

78. *Nucleocrinus verneuili* (Troost).

CRINOIDEA.

79. * *Megistocrinus spinulosus* Lyon.

PISCES.

80. *Dipterus eastmani* Stauffer.

Of this series of 80 species, those marked with an asterisk (*) also occur in the Traverse group immediately overlying in north-western Ohio. Thirty species (marked with #) or 37.5% have been obtained from the Dundee of southern Michigan, where a number of species, not yet recorded from northwestern Ohio, occur. Allowing for the personal element in identification, it probably remains true that 50% of the species identified from northwestern Ohio have not yet been found in Michigan, but will undoubtedly be found. At the same time, about 52 species out of 85 species identified from Michigan, or 61%, have not been obtained from the Ohio section. Again allowing for the personal element, we may say that 50% of the Dundee species of northern Michigan have not yet been recorded from northwestern Ohio. The total number of species which we may consider identified from the Dundee of southern Michigan and northern Ohio is very near 125. Of these, the largest number of species is found among the brachiopods of which there are over 50 species or about 40% of the total number. Several of those found in the upper beds of the Sibley quarry, classed with the limestone as Dundee, were recorded by Stauffer only from beds referred to the Traverse in the Ohio extension. Among these is the form described in the preceding pages as a larger variety of *S. bidorsalis* Winchell, which Stauffer describes as a new species, *S. lucasensis* Stauffer. This form, in Lucas county, is found in the Traverse and it is not improbable that the upper layers of the Sibley quarry are their equivalent. Whether or not this is the case their ultimate relationship between the lower beds—the true Dundee, and the upper beds—typical Traverse, is undoubted, and there can be no doubt that continuous deposition of calcareous sediments was going on in the southern Michigan area while the black Marcel his muds of eastern New York and Pennsylvania were accumulating. The only question to be determined is, Did the lower or Dundee beds accumulate in the Michigan-Ohio area during the deposition of the post-Onondaga black muds of New; York, or was this period synchronous with the pre-Dundee beds of southern Michigan, i.e. during the time when the beds referred to the Traverse in southern Michigan were accumulating? It seems almost certain that the former was the case as indicated by the more advanced character of the Dundee fauna and its comparative dissimilarity to the Onondaga.

In central Ohio, occurs the true Columbus fauna which is much richer in corals than is the Dundee. It seems as if we have here a somewhat earlier fauna than that of the Dundee, a fact further indicated by the Marcellus character of the upper Columbus beds of this region as already noted. The lists given, by Stauffer greatly amplify that published by Whitfield, which was used as the basis of discussion in the preceding part of this report. In addition to the species listed by Whitfield the following have been obtained by Stauffer:

HYDROZOA.

1. *Dictyonema leroyensis* Gurley.

ANTHOZOA.

2. *Aulacophyllum convergens* Hall.
3. *Blothrophyllum cinctutum* Davis.
4. *Chonophyllum magnificum* (?) Billings.
5. *Cladopora frondosa* Nicholson. (Traverse in northern).
6. *C. pulchra* Rominger.
7. *C. robusta* Rominger.
8. *C. tela* (?) Davis.
9. *Cyathophyllum multigematume* (?) Davis.
10. *C. validum* Hall.
11. *C. sulcatum* (?) Billings.
12. # *Craspedophyllum archiaci* Billings.
13. *Diphyphyllum bellis* (?) Davis.
14. *Eridophyllum stramineum* Billings.
15. *Favosites goldfussi* d'Obigny.
16. *F. maximus* (Troost).
17. *F. radiciformis* Rominger.
18. *Heliophyllum porcilatum* Hall.
19. *Pleurodictyum problematicum* Goldfuss.
20. *Syringopora perelegans* Billings.
21. *Zaphrentis spissa* (?) Hall.
22. *Z. ungula* (?) Rominger.

BRYOZOA.

23. *Coscinium striatum* Hall & Simpson.
24. *Fenestella erectipora* (?) Hall.
25. *F. parallela* (?) Hall.
26. *Fistulipora substellata* (?) Hall.
27. *Monotrypa tenuis* (Hall).
28. *Nemataxis fibrosus* Hall.
29. *Polypora celsipora* (Hall).
30. *P. celsipora minina* (?) Hall,
31. *P. flabelliformis* (?) (Hall).
32. *P. robusta* (Hall).
33. *Prismopora triquetra* Hall.
34. *Semicoscinium bi-imbricatum* (Hall).
35. *S. semi-rotundum* (?) (Hall).
36. # *Unitrypa lata* (Hall).
37. *U. tegulata* (Hall).

BRACHIOPODA.

38. *Amphigenia elongata* (Vanuxem).
39. # *Athyris vittata indianaensis* Stauffer.
40. # *Camarospira eucharis* Hall.
41. *Centronella glansfagea* Hall.
42. *Charionella scitula* Hall.
43. *Chonetes hemisphericus* Hall.
44. *Cryptonella lens* Hall.
45. *Cyrtina crassa* Hall.
46. # *Eunella lincklaeni* Hall.
47. *Meristella rostrata* (?) Hall.
48. *Metaplasia disparilis* (Hall).
49. *Pholidops patina* Hall & Clarke.
50. *Rhipidomella cleobis* Hall.
51. *Rhynchonella* (*?*) *raricosta* Wliitfield,
52. *Spirifer divaricatus* Hall.
53. *Spirifer fornacula* Hall.
54. *Strophalosia cf. truncata* (Hall).
55. # *Stropheodonta concava* Hall.
56. # *S. inaequistriata* (Conrad).
57. # *S. parva* (?) Hall.

PALECYPODA.

58. # *Actinopteria boydi* (Conrad).
59. # *Aviculopecten cleon* Hall.
60. *Aviculopecten cf. pecteniformis* (Conrad).
61. # *Aviculopecten princeps* (Conrad).
62. *Clinopistha antiqua* Meek.

63. *Conocardium cuneus attenuatum* (Conrad).
64. *C. cuneus subtrigonale* d'Obigny.
65. *Glossites teretis* (?) Hall.
66. *Glyptodesma occidentale* Hall.
67. *Goniophora cf. hamiltonensis* Hall.
68. *Grammysia arcuata* (Conrad).
69. *Grammysia secunda* (?) Hall.
70. *Grammysia subarcuata* (?) Hall.
71. *Limopteria pauperata* Hall.
72. *Modiomorpha concentrica* (Conrad).
73. *Nucula niotica* Hall & Whitfield.
74. *Panenka alternata* Hall.
75. # *Schizodus appressus* (Conrad).
76. *S. contractus* Hall.
77. *S. tumidus* Hall.
78. *Solemya vestuta* Meek.

GASTROPODA.

79. *Bellerophon acutilira* (?) Hall.
80. *Bellerophon hyalina* Hall.
81. *Bellerophon rotalinea* (?) Hall.
82. *Callonema bellatulum* (Hall).
83. *C. clarki* Nettelroth.
84. *C. imitator* Hall & Whitfield.
85. *C. lichas* (Hall).
86. *Coelidium strebloceras* (?) Clarke,
87. *Cyclonema crenulatum* Meek.
88. *Loxonema gracillium* Whiteaves.
89. *Loxonema pexatum obsoletum* Hall.
90. *L. robustum* Hall.
91. *L. sicula* (?) Hall.
92. *Macrocheilus hebe* (?) (Hall).
93. *M. macrostoma* (Hall).
94. *Hormotoma eversolensis* (Stauffer).
95. *H. intermedia* (Stauffer).
96. *H. leda* Hall.
97. *H. quadricarinata* (Stauffer).
98. *Naticopsis comperta* Hall.
99. *Platyceras blatchleyi* Kindle.
100. *P. cymbium* Hall.
101. *P. erectum* (Hall).
102. *P. rarispinosum* Hall.
103. *P. rictum* Hall.
104. *P. thetis* Hall.
105. *P. lineatum* Conrad,
106. *P. subglobosa* Stauffer.
107. *Pleurotomaria cancellata* Stauffer.
108. *Pleurotomaria dublinensis* Stauffer.
109. *P. hyphantes* Meek.
110. *P. insolita* Hall.
111. *P. plena* Hall.
112. *P. procteri* Nettelroth.
113. # *P. regulata* (?) Hall.
114. *P. sciotoensis* Stauffer.
115. *Porcillia sciota* Hall & Whitfield.
116. *Pseudophorus antiquus* Meek.
117. *Straparollus corrugatus* Stauffer.
118. *Strophostylus varians* Hall.

CONULARIDA.

119. *Coleolus crenatocinctus* Hall.

CEPHALOPODA.

120. *Agoniatites discoideus* (Hall).
121. *Anarcestes cf. lateceptatus* Beyrich.
122. *Cyrtoceras cretaceum* Whitfield.
123. *Cyrtoceras metula* (?) Hall.
124. *Cyrtoceratites ohioensis* Meek.
125. *Gomphoceras arcuatum* Hall.
126. *G. gomphus* Hall.
127. *G. impar* Hall.
128. *G. mitra* Hall.
129. *G. plenum* Beecher.
130. *Gyroceras cyclops* Hall.
131. *Orthoceras dagon* Hall.
132. *Orthoceras molestum* Hall.
133. *O. sirpus* Hall.
134. *O. thoas* Hall.
135. *O. winchelli* Meek & Worthen.
136. *Tornoceras ohioense* Whitfield.

TRILOBITA.

137. *Chasmops anchiops* Green.
138. *Coronura diurus* (Green).
139. *Odontocephalus aegeria* Hall.
140. *O. bifidus* Hall.
141. *Phacops cristata* Hall.
142. # *Proetus rowii* (Green).

BLASTOIDEA.

143. *Codaster pyramidatus* Shumard.
144. *Nucleocrinus verneuili* (Troost).

CRINOIDEA.

145. *Dolatocrinus caelatus* (?) Miller & Gurley.
146. # *D. glyptus* (Hall).
147. *D. greenei* (?) Miller & Gurley.
148. *D. lacus* Lyon.
149. # *D. livatus* (Hall).
150. *D. major* Wachsmuth & Springer.
151. *D. ornatus* Meek.
152. *Megistocrinus depressus* (Hall).
153. *M. rugosus* Lyon & Casseday.
154. *M. spinulosus* Lyon.

PISCES.

155. # *Acanthaspis armata* Newberry.
156. # *Acantholepis fragilis* Newb.
157. *Cladodus prototypus* Eastman.
158. *Cyrtacanthus dentatus* Newberry.
159. *Dinichthys precursor* Newberry.
160. # *Machaeracanthus major* Newberry.
161. # *M. peracutus* Newberry.
162. # *M. sulcatus* Newberry.
163. # *Macropetalichthys rapheidolabis* Norwood & Owen.
164. # *Onychodus sigmoides* Newberry.
165. # *Palaeomylus crassus* (Newberry).
166. # *P. frangens* (Newberry).
167. *Psammodus antiquus* Newberry.
168. # *Rhynchodus secans* Newberry.
169. *Thelodus* sp.

A study of this table will show that, in spite of the abundance of Onondaga species, many typical Hamilton forms occur. Those marked with a # also occur in the Hamilton (Delaware and Prout) of Ohio. One of the striking features of this fauna is the abundance of the corals and hydrocorallines which, as pointed out by Stauffer, make extensive reefs in central and southern Ohio. These reefs are probably of the same age as those of the Falls of the Ohio region, and both may be contemporaneous with the reefs of western New York. The higher beds of the Columbus and the Jeffersonville limestones as well, probably represent in part, at least, the Marcellus of western New York and this is most certainly true of the Dundee of northern Michigan and northwestern Ohio. Here the corals are absent or but slightly developed, and this seems to be due to the fact that the coral horizon here is overlapped by the higher beds of the series, which here come to rest directly upon the Silurian. It is these higher beds, the typical Dundee, which are regarded as the representative of the Marcellus of western New York.

It thus appears that the further knowledge gained by the detailed study of the Columbus fauna, as presented in Stauffer's admirable bulletin, bears out the conclusions reached by the study of the Dundee fauna of southern Michigan. Stauffer suggests that the difference of the two faunas is in part accounted for by the occurrence of a land barrier. On the interpretation above given, this barrier becomes unnecessary, for the Michigan-northern Ohio area was land during the growth of the coral reefs in southern Ohio, western New York and the Falls of the Ohio region, as well as the northern Michigan and Canadian regions, and only became submerged by the slow northward and southward transgressions of the sea during the succeeding period, and the overlapping of the later over the earlier strata. A few further facts given by Stauffer agree well with this interpretation. Thus *Spirifer gregarius* becomes an abundant fossil in the middle part of the Columbus limestone of central Ohio, but, in the northern Ohio and southern Michigan areas, its place is at the base of the formation. *Meristella nasuta* is another species holding a similar relationship. This does not in any way negative Stauffer's conclusion that the coral fauna of the Onondaga came from the north. That conclusion may be well founded, as shown by the distribution of the corals. But the absence of the coral elements in the southern Michigan and northern Ohio areas is to be regarded as due to non-deposition there, rather than distinctness of waters, and to subsequent overlap of the higher beds of this series.

The full discussion of this problem is reserved for the monograph on the Middle Devonian Faunas of Michigan now in preparation.

Columbia University,

New York City
June, 1910.