ferent wells from 5 to 33 feet in thickness, was penetrated. This well indicates the exact southern limit of the salt beds.

Grosse Isle. Judge James Swan in 1903-04 drilled a deep well[3] for oil or gas in the southwestern part of Grosse Isle just opposite Snake Isle and about three quarters of a mile from the extreme southern point of the island. No oil or gas in any noteworthy amount was struck, though the well reached a depth of 2375 feet. Enormous flows of water were struck at various depths. The first considerable flow was at 420 feet, and the second at 450 feet was much larger. Both were fresh though the water had an odor of "sulphur" probably from sulphur dioxide gas. The deeper flows were much smaller and sulphuretted. The water, which is potable, at first escaped from the 13 inch casing to the enormous quantity of 4,320,000 gallons in 24 hours—enough to supply the whole water front from Detroit to Lake Erie several times over.

A partial record of this well was obtained by Mr. Forest H. Brown for the Michigan Geological Survey in July 1903, when it was about 785 feet deep. According to the record then obtained, the well had penetrated 14 feet of clay, 300 feet of "limestone" and 70 feet of "sand." The latter is the Sylvania. This would give an elevation of 268 feet above tide for the top of this formation, the mouth of the well being about 580 feet A. T. Across Detroit river at Elliot's Point, Ontario, the Sylvania is struck at a depth of 69 feet and on the farm just north of the Point at 42 feet. This indicates that the Sylvania dips sharply to the northwest, the dip being over 60 feet per mile. It must be remembered, however, that this formation is very variable in thickness within short distances, hence abnormal dips may be due merely to local thickening or thinning.

Romulus Township. In 1903, a well 1820 feet deep was drilled by Newell for Laurence and Griffith on the Emil Twark farm, section 12, Romulus township.

[3]W. H. Sherzer, Geology of Wayne County, Pub. 12, Geol. Surv. 9, 1911, p. 249.

E. TWARK WELL.

Loc.: Emil Twark farm, S. E. ¼ of N. W. ¼, sec. 12, Romulus Twp.

Elevation 620 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Drift	92	92
Gravel	3	95
Lime	21	116
Gray limestone	25	141
Bell (Marcellus) shale:		
Coal (black bituminous shale probably)	2	143
Black slate	7	150
White lime	7	157
Black slate	15	172
Black shale	10	182
Dundee (Corniferous) limestone:		
Lime	63	245
Black shale	5	250
Lime	36	286
Black lime	12	298
Upper Monroe or Detroit River Series:		
Gray lime	24	322
White lime	63	385
Sylvania (Middle Monroe):		
White sand	5	390
Black slate	8	398
White sand	65	463
Sand rock	22	485
White lime	15	500
Sand rock	45	545
Lower Monroe or Bass Island Series:		
White lime	240	785
Blue lime	10	795
White lime	75	870
Brown shale	12	882
White lime	43	925
Salina:		
Salt rock	35	960
White lime	25	985
Brown shale	15	1000
Salt rock	46	1046
Slate	7	1053
Salt rock	34	1087
White lime	30	1117
Salt rock	25	1142
White lime	32	1174
Fine white salt	24	1198
Lime	7	1205
Salt rock	53	1258
Lime	5	1263
White lime	7	1270
Salt	20	1290
Lime	25	1315
Shells and slate	62	1373
Lime	26	1398
Salt rock	27	1423
Shells and slate	30	1453
White lime	23	1476
Salt rock	45	1521
Slate	20	1541
Salt rock	27	1568
White lime	15	1583
Salt rock	20	1603
Lime	20	1820

Wyandotte. Many years ago a well was drilled at Wyandotte to the Trenton, which was reached at 2610 feet. According to A. C. Lane, the record is that of the driller and is apparently not very trustworthy. Notes in parenthesis are by Lane and A. Winchell.

WYANDOTTE WELL.

Lancy and Churchill, contractors. Record from C. E. Wright and A. Winchell. Driller's record.

Elevation 580 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Clay and gravel	75	75
Dundee (Corniferous):		
Dark limestone	15	90
Light brown limestone	10	100
Gray limestone	25	125
Upper Monroe or Detroit River Series:		
Brown sand with "slate"	30	155
Brown sand and lime	5	160
Brown and white limestone	70	230
Sylvania (Middle Monroe):		
Free-stone	60	290
Lower Monroe or Bass Island Series:		
White and brown limestone (white and black sand. W.)	70	360
Gray limestone	5	365
Shelly limestone	30	395
Brown limestone	5	400
Muddy limestone	30	430
Very dark limestone, struck sulphur water	104	534
Limestone and "slate"	66	600
Slate and soapstone (caved to this point. W.)	15	615
Limestone and "slate" (? how far gypsum. L.)	75	690
White limestone and slate	40	750
Salina:		
White lime and salt mixed	70	800
Pure white salt	30	830
Salt and lime, shelly	40	870
Light brown limestone	30	900
Light brown shaly limestone	20	920
Dark brown shaly limestone	20	940
Pure salt	15	955
Sand and lime	5	960
Pure salt	5	965
Salt and lime shell	5	970
Lime and "slate," shaly	75	1045
Pure limestone	10	1055
Slate and brown limestone	5	1060
Pure brown limestone	20	1080
Pure brown salt	10	1090
Pure white salt	100	1190
Salt and brown limestone	45	1235
Dark shaly limestone	5	1240
Dark limestone	90	1330
Very dark limestone	5	1335
Brown limestone	5	1340
Blue limestone	10	1350
Brown limestone	10	1360
Brown limestone, very hard	5	1365
Hard dark limestone	5	1370
Brown and blue limestone	5	1375
White and blue limestone mixed	50	1425
White crystalline limestone	15	1440
Brown and white limestone. Water	35	1475
Fine brown limestone. Gas	25	1500
Fine brown limestone	10	1510
Niagara at 1510 ft., Guelph and Lockport:		
Limestone (dolomite)	350	1860
Rochester:		
Slate (shale)	10	1870
Clinton:		
Limestone	20	1890
Red rock (red shale or clay) Medina?	110	2000
Medina, Richmond:		
Black slate	20	2020
Red rock (red shales)	80	2100
Slate	95	2195
Red rock (red shales)	5	2200
Lorraine:		
Gray sand	10	2210
Slate (shale)	40	2250
Dark grayish shale; no eff	250	2500
Trenton at	.....	2610

The Morton Salt Co. of Wyandotte drilled a well a few years ago to the bottom of the "Big Salt." A very complete set of samples was obtained from which the following record was compiled by Dr. Lane. The first salt was struck at 730 feet and the Sylvania at 197 feet, or about 40 feet higher than at Trenton, indicating a low arch in the vicinity of Wyandotte.

MORTON SALT CO. WELL.

Elevation 574 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Muck, thin clay. Surface deposits	62	62
Upper Monroe or Detroit River Series:		
Light buff dolomites at 10 ft., perhaps oolitic	75	137
At 82 to 92 ft. rather brisk eff., generally moderate to slow, some rounded sand grains.		
Dolomites dark brown, bituminous, with sulphur and sometimes pyrites, with moderate eff. Compare Church No. 5 down to 290 ft	60	197
Sylvania (Middle Monroe)	65	262
Quartz sand, clear, very fine, most of the grains from .5 to .2 mm., rounded down to some where between .1 and .25mm. Compare Ford 23, 235-325; Mt. Clemens, 965.		
Dolomite, light, eff. moderate, in specks (due to crystals perhaps). Compare Ford 23, 325-340	20	282
Silicious dolomite	35	317
Dark brown, with red, rusty quartz sand and pyrites in spots, and very cherty at the base. Compare Ford No. 23, 375-435.		
White sand like that above	35	352
Sandy dolomite	10	362
Grains rounded down to .16 mm.		
Lower Monroe or Bass Island Series:	.....	362
Cherty dolomite	50	412
Dolomite, dove colored, with relatively little chert	20	432
Dolomite	30	462
Bluish, buff, massive.		
Coarse chips at 337-447. Compare Edison 462-377.		
Brown dolomite	15	477
Light dolomite	15	492
Dark dolomite	35	527
Light dolomite	25	552
Stylolitic with black specks.		
Impure gypsum	45	597
Bluish, with some dolomite and nearly pure at 587 ft.		
Compare Edison, Fort Wayne, 900-950, especially 925 with 587.		
Compare Church No. 2 at 720 ft.		
Anhydrite is quite abundant at 627 ft.		
Compare Edison, Fort Wayne, 1000 ft.		
Dolomite	20	617
Oolitic at 602 ft.		
Bluish dolomite and anhydrite	113	730
Salina:		
Salt and dolomite	60	792
At 730 ft. is the first salt. The Edison Fort Wayne well seems to have salt at higher levels, the first salt there at 1010 ft., belonging to the upper part of this group apparently. Compare Church No. 5 at 890 ft.		
Eureka, Wyandotte, 730-800.		
Ford No. 1, 830.		
Solvay No. 13, 880.		
Solvay No. 16, 890.		
Romulus, 925.		
Tecumseh Salt Co., 828.		
River Rouge Imp. Co., 815.		
River Rouge Salt Co., 871.		
Detroit Salt Co., 906.		
Stroh Brewery, 1150.		
Royal Oak, 1543.		
New Baltimore, 1600.		
Saint Clair, 1600.		
Marine City, 1604.		
Port Huron, 1500.		

MORTON SALT CO. WELL—Concluded.

Elevation 574 ft. A. T.	Thickness, feet.	Depth, feet.
Salt	50	842
Dolomite, hard	80	922
Compare Wyandotte 870-900 ft.		
Dolomite with anhydrite	10	932
Anhydrite with salt	10	942
While this is the second salt in this well, and would thus correspond to 940 ft. at Wyandotte, Eureka well, and 852 ft. at Ford No. 23 (probably really to 1027 ft.) it is probable that these salt beds are not persistent. Edison, Fort Wayne, 1280-1292 ft., may also correspond. Ford No. 1 is the same.		
Dolomite	5	947
This is merely a parting, but seems fairly persistent. Compare Ford No. 1, 968-976; Wyandotte, 960.		
Salt	15	962
Dolomite, anhydrite and clay	100	1062
Almost solid anhydrite	5	1067
Compare:		
Edison, Ft. Wayne, 1400 ft.		
Wyandotte, 1045.		
Dolomite and anhydrite	50	1117
The base of this is the top of the main and, it seems to me, the most persistent salt bed. We should then compare:		
Church No. 6, Trenton, 1280.		
Wyandotte Eureka, 1080-1235 (less 45 ft.)		
Morton, 1119-1323.		
Romulus, 1475-1600 with partings.		
Milan, 1540-1545.		
Zug Island, 1290-1528.		
Solvay No. 11, 1370-1602 with parting.		
Edison, Ft. Wayne, 1445-1636.		
Stroh, 1565-1815.		
Royal Oak, 2115-2475.		
Port Huron, 1991-2190.		
Salt, dolomite and anhydrite mixed	5	1122
Salt, samples to 1137 ft	201	1323

Many other wells have been drilled at Wyandotte for salt, of which the Michigan Alkali Company have about twenty-five. The record of one of these wells (known as the Ford wells) shows five salt horizons, the first salt coming in at about 830 feet.

J. B. FORD No. 1 WELL.

Loc.: Michigan Alkali Co. Plant, Wyandotte.

Elevation about 580 A. T.	Thickness, feet.	Depth, feet.
Surface, clays, etc	63	63
Upper Monroe:		
Limestone	199	262
Sylvania sandstone	110	372
Lower Monroe:		
Limestone (dolomite)	458	830
Salina:		
Salt	46	876
Limestone (dolomite)	92	968
Salt	8	976
Limestone (dolomite)	8	984
Salt	9	993
Limestone (dolomite)	133	1126
Salt	87	1213
Limestone (dolomite)	10	1223
Salt at	.....	1300

Delray. In Delray, the Solvay Process Co. have a large number of wells down to the Salina for salt, which, in the vicinity of their Delray plant, is struck from 865 to 890 feet. No noteworthy amounts of oil or gas were struck in any of the drillings. The Niagara is apparently over 1600 feet deep. The "Big Salt" is near the bottom in all of the wells, but according to Sherzer, this bed in the Eureka Iron Company's well is underlain by over 300 feet of dolomite, hence it is near the middle of the Salina. In such case, all of the wells in the vicinity of Detroit represent only partial sections of the Salina. The records of only three of the wells are given below. The others are very similar.

The Sylvania sandstone was reached at 415 feet, considerably deeper than in River Rouge and Wyandotte.

SOLVAY PROCESS COMPANY WELL, NO. 13.

Loc.: Near Delray plant.

Elevation about 575 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Alluvium (clay, sand, etc.)	86	86
10-in. casing.		
Dundee and Upper Monroe or Detroit River Series:		
Limestone	64	150
Slight flow of sulphur water.		
Limestone	150	300
Large flow of sulphur water.		
Limestone	51	351
8-in. casing.		
Limestone	71	422
Large flow of water.		
Sylvania (Middle Monroe):		
Sandstone	90	512
Lower Monroe or Bass Island Series:		
Very hard limestone	368	880
Salina:		
Salt	40	920
Limestone	5	925
Salt	5	930
Limestone	15	945
Salt	30	975
Limestone	5	980
Salt	25	1005
Limestone	25	1030
Salt	25	1055
Limestone	15	1070
Salt	65	1135
Limestone	37	1172
6-in. casing.		
Limestone	53	1215
Salt	10	1225
Limestone	140	1365
Salt	120	1485
Limestone	10	1495
Salt	105	1600
3-in. casing.		
*Limestone	3	1603
Bottom of well.		

*All of the "limestone" in the Lower Monroe and most of it in the Upper Monroe is probably dolomite.

SOLVAY PROCESS COMPANY WELL, NO. 16.

Elevation about 575 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Alluvium (clay, sand, etc.)	87	87
Bottom 10-in. casing.		
Dundee and Upper Monroe or Detroit River Series:		
Limestone	38	125
Slight flow of sulphur water.		
Limestone	100	225
Increased flow of sulphur water.		
Limestone	100	325
Large flow of sulphur water.		
Limestone	30	355
Bottom 8-in casing.		
Limestone	75	430
Sylvanian or Middle Monroe:		
Sandstone	60	490
Hard limestone	35	525
Sandstone	15	540
Lower Monroe or Bass Island Series:		
Very hard limestone	20	560
Limestone	330	890
Salina:		
Salt	43	933
Limestone	6	939
Salt	12	951
Limestone	19	970
Salt	28	998
Limestone	7	1005
Salt	25	1030
Limestone	35	1065
Salt	35	1100
Limestone	20	1120
Salt	30	1150
Limestone	19	1169
Bottom 6-in. casing.		
Limestone	76	1245
Salt	12	1257
Limestone	5	1262
Salt	5	1267
Limestone	138	1405
Salt	203	1608
Limestone	4	1612
Salt	6	1618
Bottom 3-in. casing.		
Salt, bottom of well	7	1625
Well commenced flowing Aug. 6, 1906.		

ZUG ISLAND WELL.

Elevation about 575 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Clays and surface earth	73	73
Dundee and Upper Monroe or Detroit River Series:		
Dolomite?	52	125
Shale	35	160
Dolomite?	60	220
Sylvania (Middle Monroe):		
Sandstone, 94 per cent SiO	22	342
Sandy lime	88	430
Lower Monroe or Bass Island Series:		
Soapstone (Calcareous shale?)	125	555
Brown lime	30	585
Gray lime	55	640
Lime	35	775
Limestone	25	800
Salina:		
Salt	40	840
Mixed lime	32	872
Salt	56	928
Lime	27	955
Salt	20	975
Lime	10	985
Salt	55	1040
Lime	88	1128
Salt	16	1144
Lime	6	1150
Salt	15	1165
Lime	25	1190
Shales	17	1207
Slate	83	1290
Salt	228	1528

River Rouge. In the River Rouge, but at some distance toward Wyandotte, the River Rouge Improvement Company drilled a well for the United Alkali Company, striking salt at 815 feet. Near the River Rouge, Mr. Dalton put down wells for the Tecumseh Salt Company, in which the Sylvania sandstone was struck from 365 to 492 feet and yielded heavy flows of sulphuretted water. In a well at Brownlee & Company's sawmill (578± feet A. T.), Ecorse, the salt was struck at 875 feet and the Sylvania at 395 feet.

Oakwood. One of the most important records showing the exact nature of the rock formations, their thickness and the water horizons, is that obtained from the Oakwood salt shaft near Detroit. The first attempt[4] to sink a shaft for mining rock salt was made in 1902, but this was a failure owing to the collapse of the brick drop casing. The second attempt was successful only after the greatest difficulty in overcoming suffocating gases and floods of water. When the shaft was 420 feet in depth Mr. E. Bradt, the engineer, estimated that the total flow into the shaft was 2,000,000 gallons per minute. The Dundee limestone yielded so much hydrogen sulphide gas that the workmen were overcome or their eyes painfully affected. Operations were stopped for some months from this difficulty.

[4]Sherzer: Geology of Wayne county, Pub. 12, Geol. Ser. 9, 1911, pp. 279-280.

Strong flows of water were struck at six different horizons, viz.: In the drift, just over the bed rock, in the Dundee, and in the Upper Monroe. There was also a seepage flow in the Sylvania. The great flow of water from a 5 foot horizontal opening was finally shut off by forcing in a slush of concrete cement under a pressure of 1200 pounds per square inch. No gas outside of the H_2S gas was observed at any of the horizons, but asphaltum streaks occurred in the Lucas dolomites of the Upper Monroe.

SECTION OF OAKWOOD SALT SHAFT.[5]

Loc.: One-half mile south of the River Rouge in Oakwood, a small suburb of Detroit.

Elevation of mouth of the shaft, 575.2 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or surface deposits:		
Blue boulder clay	73	73
Sand just above rock, water	10	83
Dundee (Corniferous):		
High grade limestone with some chert nodules	63	146
Quite heavy flow from 86 to 88 ft.; rank in hydrogen sulphide gas; small flow at 135 ft.		
Upper Monroe or Detroit River Series:		
Lucas	170	316
Bluish to brownish gray porous dolomite much of it finely laminated, with streaks of asphaltum. Small amount of gypsum. Poor in fossils. Flow from 155 ft. to 168 ft.; flow continuing down to 181 ft. Sulphurous; temperature at 180 ft. was 49.5° F. (Cooper). Remarkably heavy flow at 191 ft. from a horizontal opening extending across the shaft. Water strong in sulphur and under a pressure of 90 lbs. per square inch, causing the shaft to fill in 3 to 4 hours.		
Amherstburg:		
Brownish, laminated dolomite	19	335
Anderdon:		
High grade limestone, rich in fossils. Some celestite	38	373
Flat Rock:		
Dark drab dolomite, with few casts and moulds of fossils. Some concretions and gypsum	47	420
Sylvania (Middle Monroe):		
Snow white sandstone more or less cross bedded. Generally incoherent compacted into sandstone from about 490 to 510 ft	113	533
Seepage flow of sulphur water throughout Sylvania sandstone, except for 27 foot stratum of dry siliceous dolomite (Sylvania dolomite).		
Mr. Bradt, the engineer, estimated the total flow above the base of the Sylvania as 2,000,000 gallons per 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 sq. in. The vein at the depth of 191 ft. required several carloads of cement before the flow could be controlled, and the services of a driver 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.		
Lower Monroe, Bass Island Series:		
Raisin River:		
Bluish gray or brownish laminated dolomite with occasional oolitic strata. Line of separation between this and Sylvania very distinct. "Like a floor from which sand could be swept." Some chert nodules and pyrite. Bed of breccia encountered about 580 ft. Some fossils	124	657
Put-in-Bay (Possibly including Tymochtee):		
Bluish to brownish dolomite with seams of fossils. Thin strata of breccia and oolite. Some selenite, alabaster, anhydrite, calcite, asphaltum, and pyrite. Shaly and carbonaceous in places. Dolomite shows "gashed structure" at certain levels. Veins of salt encountered near bottom	220	877
Salina:		
Salt and dolomite irregularly mixed. No fossils found	83	960
Salt	10	970
Salt and dolomite	50	1020
Salt, slightly blotched with dolomitic slime	20	1040
Present bottom of shaft at 1060 ft.		
Salt and dolomite	70	1110
Salt	30	1140
Salt and dolomite	199	1339
Salt	25	1364
Dolomite	73	1437
Salt	369	1806
When entered, this bed will probably be found to be divided by minor strata of dolomite.		

[5] Sherzer: Geology of Wayne Co., Pub. 12, Geol. Ser. 9. Fig. 21.

Fort Wayne. Just below Fort Wayne, Detroit, the Edison Power and Light Company have put down a number of deep wells, of which a log of their No. 1 is given below.

EDISON POWER AND LIGHT CO., NO. 1 WELL.

Loc.: At plant just below Ft. Wayne. Record by A. C. Lane from samples.

Elevation 585 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Drift	97	97
S. 25-90 ft. blue eff. calcareous clay, 10 in. casing to 102 ft.		
Dundee (Corniferous) limestone:		
Limestone	203?	300?
S. 160 moderate eff.; S. 185 fierce eff.; S. 300 fierce, chipping, bluish. A piece which may have broken from above is large and characteristic Corniferous with A. reticularis, Fenestella, etc. If there is not some mistake in the samples it seems quite probable that the 300 ft. sample happens to be from a coral reef in the Lucas. Eight inch casing to 350 ft.		
Upper Monroe or Detroit River Series:		
Lucas Dolomite	150	450
S. 400 brown, slow eff.; S. 440 same.		
Sylvania sandstone (Middle Monroe)	175	625
S. 450 pyritic sandstone, with some dolomite, secondary quartz addition; S. 500 clear white sand rock; S. 600 the same; compare Ford No. 4, 257-375, Wyandotte Eureka 230-360, Church 290-475; River Rouge 350-500; Solvay 410-490; Oakwood 418.		
Lower Monroe or Bass Island Series:		
Dolomite, brown	75	700
S. 625 cherty dolomite, with numerous white grains of solid chert as well as dolomite; S. 650 dolomite, granular, sandy looking, brown, a few grains of sand.		
Dolomite, blue	25	725
S. 700 Mainly dolomite, slow eff., a few grains of selenite, bluish.		
Dolomite, brown	50	775
S. 725 slow eff., dark, chipping; S. 750 massive brown coarse chips.		
Dolomite, light	125	900
S. 775 slow eff.; S. 800 pure dolomite; S. 845 almost wholly dolomite, a little anhydrite under microscope; S. 875 mainly dolomite and anhydrite in a trace.		
Anhydrite mainly	50	950
S. 900 about half dolomite, half anhydrite; S. 925 almost all anhydrite, a little gypsum.		
Dolomite	50	1000
S. 1000 mainly anhydrite with flakes of selenite and dark dolomite.		
Salina:		
Salt	25	1035
S. 1010 brown salt; S. 1025 white salt.		
Limestone	5	1040
Salt	30	1070
S. 1040 brownish white salt.		
Limestone	22	1092
S. 1080 mainly dolomite, a little anhydrite.		
Salt	25	1117
S. 1115 white salt.		
Limestone	5	1122
S. 1112 dolomite mainly, a little anhydrite.		
Salt	38	1160
S. 1140 clear, coarse grained salt, beds from 1010-1160 compare with Wyandotte 730-870.		
Limestone	120	1280
Six inch casing to 1180 ft.		
This probably marks the interval between the first and second epochs; (Volume V, 1895, p. 28), compare.		
S. 1160 is dolomite salt, anhydrite and quartz.		
S. 1165 is half dolomite, half anhydrite.		
S. 1200 and 1200b are reddish brown, rusty with some sand, but mainly dolomite, no anhydrite.		
S. 1250 gave slow eff., is stuck together and has more dolomite, than anhydrite.		

EDISON POWER AND LIGHT CO., NO. 1 WELL.—Concluded.

Elevation 585 ft. A. T.	Thickness, feet.	Depth, feet.
Salt	12	1292
Compare Wyandotte 940-970.		
Limestone.		
S. 1300 is mainly dolomite with some anhydrite.		
Argillaceous limestone "Shale"	55	1365
S. 1310 greenish, earthy, with a granular calcite powder.		
Limestone	80	1445
S. 1400 light buff, slow eff., with some anhydrite.		
Salt	191	1636
S. 1445 not clean, brown salt, at 1500 ft. and 1600 ft. clean salt.		
Compare Wyandotte 1080-1235.		
Limestone and anhydrite	20	1656
S. 1655 Strong reaction for SO_3, brilliant polarization colors. 1656 feet of 3-inch tubing.		

Windsor, Ontario. Across the Detroit river in Windsor the Canadian Pacific railroad drilled a number of wells. Their No. 11 well shows that the Sylvania is 590 feet below the surface and the first salt at 1167 feet. This indicates a rapid deepening north from Wyandotte.

CANADIAN PACIFIC R. R. WELL NO. 11, WINDSOR.

Elevation about 610 ft. A. T.	Thickness, feet.	Depth, feet.
Surface and hard white dolomite (Dundee absent?):	235	235
Monroe or Detroit River series:		
Dolomite, hard fawn colored	15	250
Dolomite, marly, drab	50	300
Limestone, dark color, petroliferous	25	325
Dolomite marly	10	335
Dolomite marly, drab	30	365
Dolomite marly, gray	25	390
Dolomite vesicular, drab	20	410
Limestone	30	440
Dolomite, crystalline, fawn colored	20	460
Limestone, drab	75	535
Sylvania (Middle Monroe):		
Sandstone, quartzose (Sylvania)	55	590
Lower Monroe or Bass Island Series:		
Dolomite, fawn	10	600
Dolomite, with gypsum, gray	40	640
Dolomite, shaly, drab, somewhat arenaceous	30	670
Dolomite, drab gray	90	760
Dolomite, fawn (dolomite? 670-700)	40	800
Dolomite, hard, drab gray	25	825
Dolomite, shaly, gray	15	840
Dolomite, fawn	40	880
Dolomite, drab gray	80	960
Dolomite, fawn gray	70	1030
Dolomite, drab gray with gypsum	40	1070
Dolomite, shaly, drab gray	30	1100
Dolomite, drab gray	27	1127
Salina:		
Salt	40	1167

Detroit. The Stroh Brewing Company's well, excepting the Wyandotte well, is the deepest boring along Detroit river and may have reached the Niagara. The record as given below is one obtained from verbal reports and is lacking in detail.

STROH'S BREWERY WELL.

Loc.: At plant on Gratiot Ave., Detroit.

Elevation about 620 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Blue clay	110	110
Hard pan	30	140
Boulders	14	154
Traverse Formation	164	300
Dundee limestone and Upper Monroe, or Detroit River dolomites, with sulphur water in the latter	315	615
Sylvania sandstone	85	700
Lower Monroe, or Bass Island Series:		
The lime rock hard at 730 ft., sandy at 80 ft., and hard pan 900 to 1150 feet.		
Salina:		
Salt	55	1205
Limestone	201	1406
Salt	250	1815
Limestone (Lower part Niagara?)	282	2097

North Detroit. The Detroit Natural Gas Co. drilled a well in North Detroit to the depth of 770 feet striking a small quantity of gas with water in the surface gravels and in the Antrim black shales just below the drift.

DETROIT NATURAL GAS CO. WELL.

Loc.: 7 mi. N. and 3 E(?) of Jefferson Ave.

Elevation about 630 ft.? A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Gravel and gas (would burn)	100	100
Gravel	25	125
Antrim:		
Black shale	8	133
Hard shale	7	140
Gas and water (would light) at 165 ft.		
Black slate	52	192
Traverse (Hamilton) Formation:		
Shelly sandstone	34	226
Limestone	14	240
Soapstone (calcareous shale)	160	400
Hard slates and limestone	75	475
Dundee (Corniferous):		
White sandstone, quite hard (Probably cherty limestone shales).	105	580
Limestone (Monroe) Still in limestone.	190	770

Eloise. An 850 foot well was drilled for gas by C. C. Nims at the Wayne County Infirmary at Eloise. The well (625 ft. A. T.) struck the Traverse formation at 130 feet and this yielded a flow of fresh water. A strong mineralized brine was struck in the Monroe Group with some indications of oil.

LOCAL STRUCTURES IN SOUTHEASTERN MICHIGAN.

The strike of the rock formations from the Ohio line through Monroe county is in general northeast, but in Wayne county it becomes almost due east, the strata apparently lapping around the end of the Cincinnati anticline in Essex and Kent counties, Ontario. The general dip of the Sylvania in Monroe county is therefore northwest, and from the quarries of the National Silica Company (Sec. 2, Raisinville Twp.) to Ann Arbor the average is over 38 feet per mile. In Wayne[6] county, however, the average dip of the strata cannot be accurately determined owing to the lack of reliable data. Northward along Detroit river the dip of the Sylvania varies from 27 to 32 feet per mile, and westward from Detroit to Ann Arbor, a distance of 32.5 miles, the Dundee and Sylvania dip respectively 15.7 and 14.7 feet per mile. The Royal Oak and Pontiac wells are nearly in the proper position from Detroit to give the true dip of the formations, but unfortunately comparison cannot be made for the Dundee in either the Royal Oak or the Pontiac well, since the formation cannot be distinguished from the Monroe. If the Sylvania is taken as a basis for comparison, the dip north-northwest from Detroit into Oakland county is about 21 to 22 feet per mile, therefore the average dip of the rocks in Wayne county is probably not over 25 feet per mile in the same general direction.

Wyandotte Anticline. While the general dip of the rock strata in Monroe county is to the northwest at not over 40 feet per mile, and in Wayne county is north-northwest at perhaps less than 25 feet per mile, the local dips are not only discordant but much greater, indicating local warping and folding. At South Rockwood, the Sylvania is about 565 feet above sea level, but to the northeast in the Swan well, Grosse Isle, it is only 266 feet A. T. From the latter well northward to Trenton and beyond the Sylvania rises to 290 and 300 feet A. T. in the Church wells, to 350 feet A. T. at the Eureka Iron Works, and 388 feet A. T. in the Morton Salt Company wells, Wyandotte. Northeastward from the latter place, the Salina begins to deepen, being struck in the Ford wells at Ford City at 345 and 230 feet A. T., 180 feet and 142 feet A. T. in Ecorse, and 155 feet A. T. in the Oakwood salt shaft. At River Rouge, there is a rise to 210 feet A. T.,

[6]W. H. Sherzer: Geology of Wayne county, Pub. 12, Geol. Surv. 9, 1911, pp. 206.

but to the north and northeast the descent is rapid, as at Fort Wayne the Sylvania occurs at 135 feet A. T., in Windsor 60 to 70 feet A. T., and at Stroh's Brewery on Gratiot avenue, Detroit, the Sylvania is 5 feet below sea level. The salt horizons show a similar rise from Trenton to Wyandotte, and then a sudden deepening to the northeast. (See references in record of Morton Salt Company well.)

From the foregoing facts, it appears that the crest of an anticline crosses Detroit river from Ontario and passes near Wyandotte. According to Sherzer,[7] the axis of the anticline strikes south 60° west through a point about five miles north of the Woolmith quarry (sec. 29, Exeter Twp.), Monroe county.

Stony Island Anticline. In deepening the Livingston channel at the Lime Kiln Crossing in Detroit river, a cofferdam was constructed exposing the river bed for more than a mile. In excavating the channel through the ledge of limestone, which crosses the river at this point, a cut 3500 feet long was made through limestone strata which dip steeply toward the southwest instead of northeast, as indicated by the drillings along Detroit river. In the northern portion of the exposed area near the head of Stony Island, a pronounced anticlinal fold[8] extends across the river in an east-west direction. The dip on the south limb, according to Sherzer, is 1°58′, or about 180 feet per mile in a direction S. 50° W. Eastward in the Anderdon quarry on the Canadian side of Detroit river the dip is much steeper, being over 300 feet per mile in a direction S. 23° W., and, in the Patrick quarry on the south end of Grosse Isle, the dip is S. 30° W., and ranges from 1½ to 2°, or about 140 to 185 feet to the mile. The extent of the area over which the steep southwesterly dips prevail indicate that the fold is of considerable magnitude, apparently much larger and more pronounced than the anticline near Wyandotte.

In the Sibley quarry, the rock strata have been disturbed as the strata dip in a direction 5° south of west instead of north-northwest, and at 200 to 230 feet per mile. In the Christiancy or Bullock quarry on the Macon river two miles northeast of Dundee, the dip is only about 25 feet per mile west-northwest, while at Dundee it is nearly 120 feet. Such striking irregularities in dip, and the presence of at least two anticlines, are indicative of favorable conditions for the occurrence of oil and gas, but so many holes have been drilled to the Salina horizon in Monroe and Wayne counties without striking any noteworthy amounts of either oil or gas, that the chances for finding these mineral products in large quantity in strata above the Niagara do not seem promising. A few miles east of Detroit river in Ontario, oil and gas have been found in great quantities in the Niagara and

[7]The Monroe Formation, Pub. 2, Geol. Ser. 1, Geol. and Biol. Surv., 1909, p. 57.
[8]W. H. Sherzer: Geology of Wayne county, Pub. 12, Geol. Ser. 9, p. 214.

the Medina especially. Possibly these formations, particularly in the vicinity of the Stony Island and Wyandotte anticlines, may likewise contain oil and gas in large amounts.

WASHTENAW COUNTY.

West and northwest of Detroit toward the center of the Michigan Basin wells have been drilled at Ann Arbor, Ypsilanti, Royal Oak and Pontiac.

Ypsilanti. A number of wells have been drilled at Ypsilanti for sulphuretted brines derived from the mixture of brines from the Berea grit, the Traverse and Dundee limestones. The oldest well is the Cornwell mineral well, 750 feet in depth, on the flats along Huron river. Only a poor record of this is available; and of the Moorman well, about 965 feet deep, there is only the record of the casing. Fresh water was struck in the latter between 125 and 150 feet, and the first flow of mineral water was struck at 400 feet, which was saltier than the lower one. Gas (H_2S) was struck at about 550 feet.

It is to be noted in the Atlantis and the Banner Oil Company wells that the Berea sandstone at the base of the Coldwater is not a definitely recognizable horizon, though at Ann Arbor in the Court House well Rominger correlated 92 feet of coarse gray brine bearing sandstone with this horizon.

ATLANTIS WELL.[9]

Loc.: North of State Normal College Campus, Ypsilanti. T. C. Owen, owner.

Elevation 785 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand, clay, gravel, etc., unconsolidated	185	185
Antrim:		
Shale, soft	4	189
Sandstone, fine, slightly calcareous, fresh water	10	199
Limestone, fine—all dissolves in acid	10	209
Shale, dun, dark; lower 74 ft. black	84	293
Shale, sandy, dun	64	357
Traverse?:		
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. Brine at 404 ft. directly beneath a very hard streak	43	419
Shale, bluish to dun, in places gritty	22	441
Limestone, varying from silicious to pure	24	465
Shale	21	486
Dundee? (Top uncertain but probably below 525ft. Cf. Banner Oil and Gas Co. well.):		
Limestone, varying from pale to dun, with some shaly partings, portions magnesian, others silicious; contains sulphurous (H_2S) water	138	624
Unrecorded	184	808
Monroe probably below 680 ft		808

[9]Record from A. Winchell's Mss., by W. H. Sherzer, Geol. of Wayne County, Pub. 12, Geol. Ser. 9, 1911, p. 189.

In 1904 the Banner Oil and Gas Company and the Ypsilanti Development Company drilled another well at Ypsilanti on the Cramer farm about 300 feet from the old Cornwell well and near the city water works.

BANNER OIL & GAS CO. WELL.

Loc.: Three hundred feet from Cornwell well near Ypsilanti Water Works plant. Banner Oil & Gas Co. and Ypsilanti Development Co. A. H. Marsh, contractor. Samples at 700, 1150 and 1200 ft.

Elevation 682 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene	90	90
At base of gravel water flows with T. 50.2°. T. 49.7° at 90 ft., 10 inch drive pipe to 91 ft., T. 51.2° at 128 ft.		
Devonian Antrim:		
"White shale"	51	141
"Some gas" at 135 ft.? A little water, no odor.		
Black shale	150	291
Traverse Formation:		
Limestone shale	25	316
With a flow of gas. Hard shells at 300 ft. T. 53° F.		
Brown shale	204	520
This Traverse is also reported as 50 ft. limestone, then blue shale, then black shale, then limestone, then black shale, and the change to Dundee at 525 ft. At 520 ft. T. 57.2° F.		
Dundee limestone:		
Limestone	160	680
S. at 600 tests limestone according to Sherzer. Mineral water at 525 ft., 530 ft. with gas H_2S, also at 570 ft.		
Upper Monroe:		
Dolomite	80	760
S. at 700 ft. slow eff. dolomite; at 680 ft., more water quite salty with some gas and traces of oil, e. g., at (730 ft.) or 720 ft., at which point it was fruitlessly shot with nitroglycerin, Nov. 16, 1904.		
At 710 ft. T. 59.4° F	400	1200?
Sylvania:		
White sandstone "375 ft. to 390 ft." of it at 1150 ft.		
S. 1150 ft. typical Sylvania sandstone, white, Dec. 17, 1904.		
S. water at 1175 ft.		
S. 1200 brownish sandstone, Feb. 9, 1905, looks like the samples near the bottom of the Sylvania.		
Well 1210 ft. deep. Ypsilanti Press, Oct. 4, 1905. ("Has it been deepened?"—Lane.)		

Ann Arbor. There are two wells at Ann Arbor; one, known as the old Court House well, was reported by Winchell and Rominger and the other, the Campus well of the University, is given below. Samples were taken for the Survey by Prof. Russell and careful notes were made by Prof. H. D. Campbell of the University and Mr. Frueauff of the Ann Arbor Argus.

CAMPUS WELL.

(Drilled in 1899–1900.)

Loc.: Campus of University of Michigan, Ann Arbor. Record by Dr. A. C. Lane.

Elevation 875 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Soil, fine sand	45	45
Gravelly, 10 ft., large boulder at 80 ft., casing to 90 ft	45	90
Bluish clay, large boulder at 113 ft	145	235
Coldwater shales:		
Bluish shales	30	265
Red shale	15	280
Plugged at 287 ft. and water above analyzed 4.3 per cent salt.		
Blue shale	75	355
Fine soft gray and black shale	20	375
Fine gray sandy shale	10	385
Fine bluish shale	15	400
Berea grit:		
Fine gray sandstone	15	415
(No water noted).		
Fine sandy shale	25	440
Glossy black shale	5	445
Fine gray sandy shale	75	520
Salt water at 515 ft. and below.		
Antrim shales:		
Fine black and green 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 pyrite	5	685
Gray calcareous shale	60	745
Dundee limestone:		
Gray cherty limestone	30	770
Light gray limestone	30	800
Gray argillaceous limestone, some gas indications	130	930
Upper Monroe:		
Light gray dolomite	40	970
Limestone at 950 feet struck a mineral water charged with H_2S which rose 300 ft. and contained 13 per cent salts, according to Eberhard.		
Light gray dolomite, sandy	60	1030
Nov. 18th operations were suspended for a month at the end of the first 1000 ft. in an oily dolomite or limestone.		
Light gray dolomites with Sylvania sand grains	205	1235
Jan. 5th at 1065 ft. a red rock with much iron was struck.		
Sylvania sandstone:		
Pure white friable sandstone	35 +	1270 +
According to newspapers at 1275 ft. on Feb. 10th another mineral water strong of H_2S with 17 per cent salts (Eberhard) was struck in limerock.		
At 1300 ft. the rock is said to have been a little softer. The well was shut down Feb. 26, 1900, at 1326 ft., plugged at 283 ft. and tested. Then a cement plug of 25 ft. was put on top, but the analysis of the water remained practically the same.		

OAKLAND COUNTY.

Royal Oak. Two wells have been drilled at Royal Oak, one 1400 feet in depth and the other 2502 feet penetrated the Salina for more than 900 feet. The record of the deeper well is given below. Little or no signs of oil or gas were noted anywhere in the drilling, although there were numerous shale gas wells in the drift in southeastern Oakland county.

ROYAL OAK WELL.

Mfg. & Gas Co., Hugh Monroe, driller.

Elevation 678 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or Surface:		
Clay	40	40
Gravel	5	45
Clay	25	70
Quicksand and gravel	94	164
Antrim (Huron):		
Black shale	141	305
Traverse (Hamilton):		
Limestone	85	390
Brown shale	130	520
Dundee (Upper Monroe or Detroit River Series in lower part):		
Salt water at 548 ft. and 583 ft.		
Limestone containing salt water. (As this record does not distinguish dolomite and limestone, we cannot fix the boundary between the Monroe and Dundee limestone)	316	836
Salt water at 720 ft.		
Sylvania:		
White sand. Salt water at 836 ft	154	990
Very soft white sandstone 836-1105 ft.		
Limestone. "Struck white sand 990-1095, very soft," (May this be anhydrite?—Lane.)	115	1105
Lower Monroe or Bass Island Series:		
Very gritty hard limestone	20	1125
Dark sandrock, gray	15	1140
Blue hard gritty limestone	35	1175
Very soft light colored lime	40	1215
A little closer	45	1260
Hard close bluish limerock	145	1405
Hard gray sandrock	5	1410
Hard limerock	10	1420
Hard gritty limerock	45	1465
Rotten lime or shale. (The "shale" and "slate" are probably largely anhydrite, or at times dolomitic marl)	78	1543
Salina:		
Solid rock salt	97	1640
Hard shale	10	1650
Nice quality of salt	45	1695
Slate, rotten lime or shale, marly	40	1735
Salt	57	1792
Hard blue lime	18	1810
Shale	10	1820
Salt	80	1900
Soft gray lime	10	1910
Hard lime	95	2005
Salt	15	2020
Slate	95	2115
Salt	35	2150
Slate	15	2165
Salt	20	2185
Slate	15	2200
Salt	100	2300
Slate	15	2315
Salt	160	2475
Hard blue lime	27	2502

Mutual Oil & Gas Company's Well, Royal Oak. In 1913, a test well, for oil was projected by the Mutual Oil & Gas Company of Detroit. Fifty acres of land near Royal Oak were bought and capitalized at $162,000. The land was divided into 5400 parcels 20 feet square, which were to be sold at $30.00 each. A certain portion of the proceeds was to pay for the land, another the promoters for their work in organizing the company and selling the stock, and the third portion for the drilling. In such stock schemes, the charges for purchasing the land and promoting the enterprise are so great that there is relatively little money available for actual drilling.

The test well was to be drilled on land which has one or more surface gas wells. The idea was, that by going deeper, larger quantities of gas would be struck. As the numerous "shale gas" wells in Oakland county are in the belt underlain by the black Sunbury shale, the Berea grit and the Antrim black shale, the gas in the drift is undoubtedly a leakage from these formations. Any well more than a few hundred feet deep will pass completely through these petroliferous formations. Royal Oak well is well down the northeast limb of the low broad anticline between Pontiac and Adrian with its crest near Ann Arbor, and therefore it is apparently in an unfavorable position. The above project was finally abandoned without doing any drilling.

Pontiac. The Pontiac Natural Gas & Oil Company, drilled a well 1505 feet deep at Pontiac, Oakland county. A little gas was found between 1305 and 1310 feet, and also in the limestone at 1497 feet. The Berea sandstone, although exceptionally thick and overlain and underlain by bituminous shales, apparently gave little sign of either oil or gas.

PONTIAC WELL.

Pontiac Natural Gas & Oil Co., G. S. Duncan, contractor. Record by C. E. Wright, from samples and driller's log.

Elevation 934 ft. A. T.	Thickness, feet.	Depth, feet.
Surface	320	320
Coldwater:		
Blue shale	10	330
Blue argillaceous shale	10	340
Calcareous argillaceous sandy shale; light blue; very fine grained	30	370
Sandy argillaceous shale, light blue	70	440
Sandy argillaceous shale	40	480
Reddish argillaceous shale	20	500
Sunbury shale:		
Dark brown argillaceous shale	35	535
Berea sandstone:		
Light drab sandstone; fine grained. Salt water	20	555
Light drab sandstone, fine grained	17	572
Gray sandstone	236	808
Antrim shale:		
Black shale	157	965
Traverse Formation:		
Coarse-grained argillaceous limestone, dark drab	35	990
Fine-grained limestone, light drab; 2 per cent insoluble residue	10	1000
Limestone, light drab and grayish white; 8 per cent insoluble residue	7	1007
Limestone, light gray; 20 per cent insoluble residue	8	1015
Sandy limestone, dark drab; 20 per cent insoluble residue	35	1050
Argillaceous limestone; 10 per cent insoluble clay residue	15	1065
Light blue calcareous clay; 90 per cent insoluble residue	50	1115
Salt water; very strong brine at 1115 ft.		
Dundee limestone (top above 1220 ft.) and Monroe Beds:		
Monroe not separated from Dundee.		
Limestone, light gray, drab to dark drab 1220 to 1350 ft.		
Show of gas at 1300 ft.		
Sandy limestone; light gray, brisk eff.; residue 20 per cent gray sand and some glassy grains at 1350.		
At 1497 ft. in gas-rock for 40 ft. (?), but 1100 ft. water in well.		

South Lyon. At South Lyon (sec. 30, T. 1 N., R. 7 E.), a well was drilled to 1350 or 1400 feet in depth, but only a meager record is available. Rock was struck at about 70 feet, mineral water above 800 feet, and limestone (Traverse and Dundee probably) from 1000 feet to the bottom. Above 1000 feet are sandstones and shales, the latter in places black.

HOLLY MUNICIPAL WELL.

Notes kept by D. M. White of well drilled at Holly, by Kinney and Coleman; 8 inch well.

	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand and gravel	140	140
Soft clay	40	180
Sand and gravel	10	190
Soft clay	40	230
Like we had at 140 to 180 feet.		
Sand and gravel	35	265
Bottom of pipe 265 feet.		
Lower Marshall:		
Light drab shale with shells of sandstone running through it	135	400
Coldwater:		
Light drab shale very much like clay, but does not cave, soft	130	530
Gray sand rock; a little bit of water with salty taste	7	537
Blue shale, some harder than light drab shale	73	610
Dark sand rock, more salty water	10	620
Light drab shale	50	670

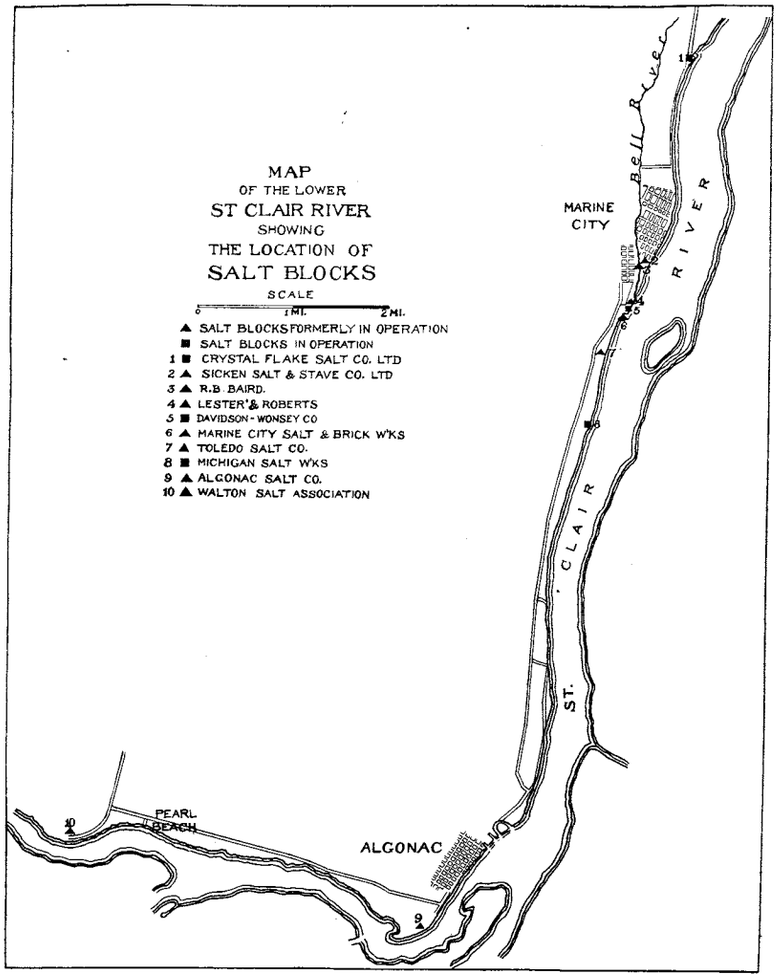


Figure 10. Map showing the location of salt blocks and salt wells along St. Clair river (after C. W. Cook).

MACOMB COUNTY.

Northeastward from Detroit to Port Huron numerous wells have been drilled for salt, oil, or mineral water. (Fig. 10.) Many wells have been drilled at Mt. Clemens for Mineral water and at Marine city and St. Clair for salt. The records of these and other wells indicate not only that the strike of the formations becomes easterly, but that there is a great discordance in the dip of the strata in Macomb and southern St. Clair counties.

Mt. Clemens. The record of the Mt. Clemens No. 3 well shows that the base of the Dundee horizon drops from 145 feet in the Oakwood salt shaft to 400 feet below the surface and the Sylvania from 410 to 965 feet. The dip of the latter is, therefore, about 21 feet per mile and of the former only about 8 or 9 feet.

MT. CLEMENS WELL NO. 3.

Loc.: Claim No. 141. Owner, Mr. Coursin; driller, Mr. Nims. Drilled in 1892. Samples furnished by driller, through T. M. Crocker.

Elevation 617 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Wet dark gray sand with an oily smell and moderately free eff.	35	35
Rock at 123 ft.?		
Record missing	88	123
Antrim shale:		
Burns with an aromatic odor, in shaly flakes; black; smells oily	17	140
Like the above, not so bituminous, tastes of ferrous sulphate	70	210
Traverse (Hamilton) Formation:		
Mixture of black shale and of a limestone like that at 260 ft.; eff. not very brisk; traces of gypsum in solution	8	218
Light buff limestone with traces of shells; very brisk eff	67	285
The same; no gypsum	15	300
Unrecorded	100	400
Dundee (Corniferous) limestone:		
Light buff even grained; very brisk eff; no $CaSO_4$	160	560
Light buff; even grained; very brisk eff., no $CaSO_4$	23	583
Gas at 600 ft. and at intervals for the next 200 ft.		
Upper Monroe:		
As at 560	17	610
As at 560, but slower eff	10	520
Like 560 in color, but with many large pieces of gypsum, and slow eff	30	650
The same, with a certain amount of gypsum	50	700
Brown; slow eff., except a few grains; some gypsum	20	720
Dark buff; slow eff., gypsum	40	760
Dark gray, slow eff., gypsum	25	785
Dark gray; gypsum; eff. faster at 890 ft. than at 900 ft., quartz occasional	105	890
Dark brown; with a trace of gypsum	10	900
Like No. 720 in color; moderate eff.; occasional quartz; trace of gypsum	20	920
Brownish buff; quick eff.; a little quartz, chert and clay	20	940
Like 940, but a shade lighter	25	965
Sylvania sandstone:		
Granular white sandstone, very pure; rounded grains averaging 0.3 mm. in size, and smaller angular grains, averaging 0.15 mm. in diameter, like the sand at 1920 ft. and 1950 ft. at Kalamazoo	35	1000
Unrecorded	60	1060

New Baltimore. The Dundee drops from 400 feet a Mt. Clemens to 690 feet below the surface at New Baltimore. This indicates a dip of about 32 feet per mile to the northeast, or three times as great as that from the Oakwood salt shaft to Mt. Clemens, and probably greater than the average north-northwest dip in Wayne county, although accurate calculations cannot be made for the latter on account of the lack of reliable data.

NEW BALTIMORE WELL.

C. M. Swift, owner. Drillers, J. J. Mason & Co.

Elevation about 588 (?) ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface	120	120
Antrim shale:		
Blue shale	5	125
Black shale	335	460
Compare St. Clair, 400; Marine City, 460; Pontiac, 965; Mt. Clemens, 218.		
Traverse Formation:		
Limestone and calcareous shales	20	480
Limestone	50	530
Compare St. Clair, 630; Pontiac, 1065.		
Blue shale	160	690
Compare St. Clair, 790; Algonac, 513; Marine City, 740 to 635; Pontiac, 1235; Mt. Clemens, 400.		
Dundee (Corniferous) limestone:		
Limestone high grade	130	820
Compare St. Clair, 910; Marine City, 825 to 770; Mt. Clemens, 610.		
Monroe Group, including Salina:		
Dolomites	290	1110
Gypsum bed (anhydrite) 860 to 870 ft.		
Compare St. Clair, 990.		
Gypsum bed 885 to 895 ft.		
Brown dolomite, 920 to 940 ft.		
Compare Marine City, 1060 ft.		
Limestones	165	1275
Compare St. Clair, 1380; Marine City, 1220.		
Brown dolomite and gypsum	85	1360
Blue dolomite, shale and gypsum	35	1395
Compare St. Clair, 1480; Marine City, 1390.		
Buff dolomite	50	1445
Blue and brown dolomite and gypsum	155	1600
Compare St. Clair, 1600; Marine City, 1604.		
Salt	40	1640

Romeo. At Romeo, a well 1575 feet in depth was drilled by M. Porter for the village in a vain search for potable water. The brine, or mineral water struck in the lower part of the well rose about 1000 feet. The record, as furnished by Fred E. Hipp, cannot be satisfactorily correlated. A sandstone from 180 to 240 feet apparently corresponds to the Richmondville, but it may be the Berea since in a well drilled by O. N. Phillips on the D. M. Ferry & Company farm, sec. 23, Avon township, Oakland county, a brine bearing sandstone overlain by 45 feet of black shale was struck at 230 feet. The driller, upon being shown samples of Berea sandstone and Sunbury shale from the Saginaw wells, pronounced them identical in character with the rocks encountered in the Ferry well, and in many other wells drilled by him in Oakland and northwest Wayne county. The sandstone and shale correspond to the Berea and Sunbury respectively, yet it cannot be asserted that the upper sandstone at Romeo corresponds to the Berea horizon, as stray sandstones resembling the Berea are known to occur in the lower part of the Coldwater shales. The correlations as given in the record below are merely tentative.

ROMEO WELL.

Loc.: Near water works? Mat Porter, contractor. Record from F. E. Hipp.

Elevation about 75 feet above R. R. station.	Thickness, feet.	Depth, feet.
Pleistocene or drift:		
Sand and gravel	150	.....
Coldwater shales (probably Antrim and Traverse in lower part):		
Very light rock, floats	30	180
Freestone, i. e., sandstone (Richmondville?)	60	240
"Soapstone," black shale and slate	510	750
Bed of rock salt (?) and well caves badly at 750. Berea horizon?		
"Soapstone," black shale and slate	300	1050
Dundee? (Corniferous) limestone:		
Sandstone or grindstone rock, like the Huron county rock, only it has harder streaks in it. (This may very likely be the cherty Corniferous limestone.—Lane)	250	1300
Monroe?:		
Limestone, light gray	70	1370
Soft rock; rotten limestone; caves badly.		
Plaster beds at 1370 ft.		
End of 4½ in. hole at 1420 ft.		
Gas veins and rock badly caving at 1440 ft.		
End of drill in soft rock at 1575 ft.		

ST. CLAIR COUNTY.

Algonac. Just south of Algonac on St. Clair river, a well 1727 feet in depth penetrates the salt beds of the Salina. This well is either so far east that it is beyond the limits of the Antrim black shale, or the well is over a rock valley where the black shale is cut out by erosion. The Sylvania is not present as a sandstone; apparently it is represented by a sandy dolomite.

New Baltimore is about 10 miles north of west from Algonac and the Dundee drops about 175 feet, or about 17 feet per mile from Algonac to the former place. This is much less than the northeasterly dip from Mt. Clemens to New Baltimore, although the maximum dip should be in general northwesterly toward the central basin.

ALGONAC WELL.

Loc.: South of Algonac on St. Clair river. Albert Miller, owner. Drilled in 1886. Driller's record. (Apparently this is one of the Algonac Salt Co.'s wells. See map.)

Elevation about 584 ft.	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface, clay, etc	208	208
Traverse or Hamilton:		
Soft white shale	85	293
Soft brown lime	20	313
Soapstone, soft, gray and sticky	200	513
Dundee and Monroe, not separated:		
Hard, mixed gray and brown limestone. (The records of this well do not show the distinction between limestone and dolomite)	767	1280
Yellow gypsum (probably anhydrite), 1180-1185 ft.		
Hard, mixed gray and brown limestone	20	1300
Blue shale; medium hard	75	1375
Salina:		
Gray, brown and white hard limestone	125	1500
Rock salt.		
Shale and salt mixed; soft and hard	80	1580
Hard brown and white lime	25	1605
Rock salt	18	1623
Hard gray lime	10	1633
Salt	94	1727
Hard limestone at 1727 ft.		

Marine City. There are a large number of wells at Marine City which penetrate the salt beds. The records of seven of these wells are given in Volume V, but th ee, the Lester and Roberts, the National Salt Company, and the Morley are given below as representative of the others. The record of one of the Michigan Salt Co. wells, located south of the city, is also given. Some oil was struck in the National Salt Company's well in the top of the Salina.

LESTER AND ROBERTS WELL.

Record from samples preserved by J. R. Burr. Driller, Mathew Porter. Record by C. E. Wright.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface	50	50
Clay	150	200
Antrim:		
Hard pan, contains fragments of slate	20	220
Hard pan	10	230
Black bituminous slate, contains FeS_2	70	300
Dark and light drab slate	20	320
Black bituminous slate, contains small pieces of coal	20	340
Dark drab bituminous shale, contains small pieces of coal and FeS_2	10	350
Drab bituminous shale, somewhat calcareous	10	360
Traverse (Hamilton) Formation:		
Argillaceous dolomitic limestone	50	410
Al_2O_3 14.29.		
SiO_2 28.67.		
Light bluish gray to drab colored limestone	40	450
Light gray limestone	20	470
Light gray limestone, contains a little talc and slate	20	490
Light and dark gray limestone; small silicious residue	10	500
Soft argillaceous limestone (soapstone)	50	550
Al_2O_3 9.70.		
SiO_2 21.		

LESTER AND ROBERTS WELL.—Concluded.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Dark drab limestone	10	560
Calcareous argillaceous rock, gritless	75	635
Al_2O_3 17.18.		
SiO_2 41.30.		
Dundee (Corniferous) limestone:		
Light yellowish gray limestone	95	730
Light gray limestone, contains oblong concretions or possibly fossils, 5 mm	40	770
Upper Monroe or Detroit River Series:		
Dolomite, contains yellow specks	30	800
Light brownish drab dolomite; contains in residue a little anhydrite in white specks	30	830
Light gray dolomite; contains in residue a little anhydrite in white specks	25	855
Dolomite, light drab, contains in residue a little anhydrite in white specks	25	880
Hard dolomitic limestone, light gray, massive	25	905
Dolomitic limestone, contains a little anhydrite; also a few fragments of slate	30	935
Dolomitic limestone, contains a few fragments of slate	30	965
Dolomitic limestone, light drab, contains in residue a little anhydrite in specks	15	980
Dolomitic limestone, drab; even texture	10	990
Dolomitic limestone, dark drab	70	1060
Sylvania or Middle Monroe:		
Arenaceous limestone, dissolves briskly but leaves a large cherty sandy residue. Not organic	40	1100
Arenaceous limestone	30	1130
Lower Monroe or Bass Island Series:		
Limestone, light drab	30	1160
Limestone, light gray, contains a little gypsum	30	1190
Limestone, light gray, contains a little gypsum	30	1220
Dolomitic limestone, dark drab	5	1225
Dolomitic limestone, hard, light gray, yellow specks; large silicious residue	20	1245
Dolomitic limestone, very dark drab; large silicious residue	35	1270
Dolomitic limestone, light drab; small silicious residue	23	1293
Gypsum, drab and white	11	1304
Calcareous gypsum, dark drab; large residue, possibly argillaceous	26	1330
Calcareous gypsum, dark drab; very large residue, possibly argillaceous	35	1365
$Si\ O_2$=12.68.		
Calcareous gypsum, dark drab; large residue, possibly argillaceous; contains anhydrite	25	1390
Dolomitic limestone, light and dark drab; large residue slate, anhydrite, gypsum and silica and some organic matter	15	1405
Dolomitic limestone, light drab; large residue slate, anhydrite, gypsum and silica and some organic matter	20	1425
Dolomitic limestone, light and dark drab; large residue slate, anhydrite, gypsum	20	1445
Dolomitic limestone, light drab, residue slate, anhydrite, silica and some organic matter	20	1465
Dolomitic limestone, light drab; large residue of gypsum	20	1485
Gypseous limestone, light drab; large residue of gypsum	20	1505
Gypseous limestone, light drab; large residue of gypsum	33	1538
Calcareous clay. Al_2O_3 22.12	41	1579
Anhydrite. SO_3 59.42	20	1599
Gypsum, (anhydrite) white and dark drab	5	1604
Salina:		
Rock salt	33	1637
Gypseous limestone. $S\ O_3$=14.10	4	1641
(The gypsum is anhydrite.—Lane.)		

NATIONAL SALT COMPANY WELL.

Loc.: Marine City. Drilled in 1886. Record by C. E. Wright from driller's notes and samples.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Earth	150	150
Gravel	50	200
Antrim shale:		
Dark brown and black shale	200	400
Traverse (Hamilton) formation:		
Light gray limestone, with small amount of sand and gypsum, or anhydrite	75	475
Calcareous clay shale	95	570
Hard light drab shale	15	585
Calcareous clay shale	40	625
Dundee (Corniferous):		
Gypsum, argillaceous limestone	40	665
At 665 ft. struck some calcareous tufa that floated to the surface and when dry was fluffy.		
Light gray gypseous limestone, resembles sand	35	700
Hard grayish white limestone	25	725
Brown and white limestone mixed with small amount of gypsum and sand	25	750
Brine at 750 ft.		
Upper Monroe, or Detroit River Series:		
Brownish gray dolomitic marl with small residue of silica	60	810
Dolomitic drab limestone	10	820
Grayish white calcareous anhydrite	30	850
Drab dolomitic gypsum marl	10	860
Dolomitic gypseous marl	10	870
Dolomitic limestone	10	880
Light gray and drab dolomitic limestone	90	970
Dolomitic limestone, yellowish to buff	30	1000
Sylvania:		
Dark ochreous, sandy limestone, large residue of silica and flint	130	1130
Lower Monroe, or Bass Island Series:		
Buff dolomitic limestone	60	1190
Light gray dolomitic limestone, with residue of gypsum, anhydrite and silica	30	1220
Bluish gray dolomitic limestone with small residue of gypsum and angular grains of black flint	40	1270
Bluish gray dolomitic limestone, with large residue of gypsum, anhydrite and flint	60	1330
Buff sandy dolomitic limestone, with large residue of silica, anhydrite and gypsum	20	1350
Light bluish gray calcareous gypsum, large residue of gypsum and anhydrite	50	1400
Gray mottled with yellow dolomitic limestone	30	1430
Bluish gray dolomitic limestone, large residue of light and dark gypsum and anhydrite	20	1450
Gray dolomitic limestone, with small residue of gypsum, anhydrite and silica	60	1510
Dark drab gypseous limestone, large residue of clayey gypsum	10	1520
Grayish calcareous clay, with large muddy residue	30	1550
Dark drab dolomitic limestone, small residue of gypsum	10	1560
Dark drab dolomitic limestone, large residue of gypsum	10	1570
Salina:		
Rock salt. Oil and salt at 1577 ft	20	1590
Dolomitic limestone, small residue of gypsum and anhydrite	10	1600
Rock salt	30	1630

W. B. MORLEY WELL.

Loc.: One mile north of Marine City. Drilled in 1886. Record from samples.

Elevation about 600 ft.	Thickness, feet.	Depth, feet.
Pleistocene, or drift:		
Clay	150	150
Gravel	5	155
Clay	30	185
Hardpan (clay or shale)	45	230
Antrim shale:		
Brown shale	70	300
Black shale	160	460
Brown calcareous shale	5	465
Traverse (Hamilton) Formation:		
Hard silicious gray limestone	45	510
Light gray calcareous clay shale, large clayey residue	145	655
Light gray calcareous clay	95	740
Dundee (Corniferous) limestone:		
Light gray limestone, small silicious residue	50	790
Hard light gray limestone, small silicious residue. Gas and mineral water at 805 feet.	15	805
Hard light gray limestone, small silicious residue	10	815
Soft light gray argillaceous limestone	10	825
Upper Monroe, or Detroit River Series:		
Buff gypseous limestone, large residue of gypsum and anhydrite	55	880
Soft light gray limestone, small residue	20	900
Soft light gray limestone, small residue of anhydrite	30	930
Hard gray dolomite, small residue of black cherty quartz	65	995
Hard dark gray dolomite, small residue	15	1010
Grayish drab dolomite, medium residue of anhydrite and black grains of shale	55	1065
Sylvania (Middle Monroe):		
Dark buff sandy limestone, large residue of sand, 37 per cent of SiO_2	25	1090
Dark buff calcareous sandstone, 69.34 per cent SiO_2, milk white and glassy	35	1125
Dark buff sandy limestone, 16.4 per cent SiO_2	55	1180
Dark buff sandy limestone, 43.5 per cent SiO_2	27	1207
Lower Monroe, or Bass Island Series:		
Chocolate buff dolomite, medium residue of silica	93	1300
Soft grayish drab dolomite, medium residue of silica	10	1310
Dark drab to yellow gypseous dolomite, large residue of silica, gypsum and anhydrite	30	1340
Light gray and yellow gypseous dolomite, large residue of gypsum and anhydrite	20	1360
Gray calcareous gypsum, large residue of gypsum and some clay	100	1460
Gray dolomite, small residue of silica and gypsum	10	1470

MICHIGAN SALT WORKS WELL NO. 2.

Loc.: At plant south of Marine City. Drilled in 1898. Log furnished by Mr. S. R. McLouth.

	Thickness, feet.	Depth, feet.
Pleistocene drift:		
Clay	150	150
Hardpan	15	165
Clay and gravel	35	200
Antrim shale:		
Black slate	200	400
Traverse (Hamilton) Formation:		
Lime	15	415
Soapstone. Hard to mill. Could cut about 4 ft. per hour with 4 inch stem 43 feet long	50	465
Darker and harder	110	575
Lime. (Dundee?) Average 2 ft. per hour with 5⅛ inch stem, 38 ft. long. Struck sulphur water at 710 and salt water at 725 ft	155	730
Brownish limestone. Soft. Easy on bits	50	780
Dundee and Upper Monroe:		
(?)	15	795
Streaks of gypsum	5	800
Hard streak of lime	25	825
Gypsum	5	830
Hard	20	850
Gypsum	10	860
(?)	10	870
Hard streak of lime	5	875
Soft blue gypsum	25	900
Limestone shelly	70	970
Averaged 15 inches per hour	30	1000
Flint limestone. Good drilling. 18 ft. in 12 hours	40	1040
Same	60	1100
Sylvania:		
Sandy limestone. Very hard	60	1160
Lower Monroe:		
Hard; 8 in per hour from 1160 to 1225 ft	140	1300
Caving rock and gypsum	70	1370
No trace of gypsum from 1370 to 1400 ft	30	1400
Very hard	100	1500
Same	70	1570
Salina:		
Salt, first bed	25	1595
Lime and (?) salt. (The record at this point is not clear, reading "10 ft. lime and 10 ft. of salt to 1605. Lime to 1612 ft.; lime 11 ft.")	10	1605
Lime	7	1612
Lime	11	1623
Salt; top of lower bed at 1623 ft. Lime at 1751 ft.	128	1751

St. Clair. The Diamond Crystal Salt Company have drilled a number of wells to the salt beds and preserved good sets of samples. In one of their first wells, the Dundee was struck at 790 feet, and this indicates a decided dip amounting to about 25 feet per mile north from Marine City. To the north of St. Clair, however, there is a rise again, since at Marysville, the Dundee is struck at 582 feet and at Port Huron 542 feet.

The records of other wells given in Vol. V showed very similar depths for the Dundee and the drop of the Dundee is so great from Marine City on the south and from Port Huron on the north that doubt was thrown on the correlations. The careful record of the Diamond Crystal Salt Co. well apparently substantiates the correctness of the older correlations. Across the river, however, in Courtright, the Dundee is apparently struck at 542 feet, or nearly 250 feet

higher. This rise is so abrupt as to indicate a fault along the river or a pronounced fold to the east in Ontario; otherwise the correlations in the record of the Courtright well must be greatly in error. Present evidence indicates that the correlations in the latter record are incorrect.

DIAMOND CRYSTAL SALT CO. WELL.

Loc.: Near plant. St. Clair. One of the older wells, drilled prior to 1901. Record from samples by A. C. Lane.

	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface	172	172
Antrim shale:		
Blue shale (Erie)	110	310
Black shale (Huron)	220	530
Compare Marysville, 298 ft., Marine City, 360 ft., Oakland, 840 ft., and New Baltimore, 400-460 ft.		
Traverse (Hamilton) Formation:		
Blue argillaceous limestones and dolomites, etc	100	630
Blue shale	160	790
Compare Marysville, 588 ft., Marine City, 630 ft., Oakland, 800 ft., Mich. Salt Co. No. 2, 575 ft. and New Baltimore, 695 ft.		
Dundee (Corniferous) limestone:		
Limestone	120	910
Compare New Baltimore, 820 ft.		
Monroe Formation:		
Dolomites	80	990
Compare Marine City, 800 ft.		
Gypsum and dolomite	40	1030
Compare Marysville, 345 ft., New Baltimore, 860-920 ft.		
Dolomite probably sandy about 1270 ft	1270	.....
Offset through Sylvania sandstone	240	1370
Compare New Baltimore, 1370 ft.		
Dolomite	80	1450
Anhydrite largely	50	1500
Dolomite	40	1540
Dolomite	70	1610
New Baltimore, 1600 ft., Marine City, 1577-1633 ft., and No. 3, 1668 feet.		
Salina:		
Salt and cavity	30	1640
Lime	10	1650
Dolomite and anhydrite	97	1747
Salt	50	1797
Lime (?)	10	1807

DIAMOND CRYSTAL SALT CO. WELLS NOS. 6 AND 7.

Loc.: St. Clair. Composite record[10] of wells Nos. 6 and 7 from driller's log. Started, Feb. 10, 1909. Record furnished by Mr. F. W. Moore.

	Thickness, feet.	Depth, feet.
Pleistocene drift:		
Clay	115	115
Hardpan and gravel	38	153
Antrim shale:		
Blue shale or slate	52	305
Brown shale	195	500
Traverse (Hamilton) Formation:		
Lime	12	512
Blue shale	10	522
Lime	20	542
Blue shale	23	565
Lime	25	590
Soapstone	110	700
Lime	10	710
Soapstone	50	760
Dundee (Corniferous) and Upper Monroe:		
Lime	60	820
Sharp hard lime	10	830
Lime. In part Dundee	290	1120
Hard brown lime	8	1128
Lime	32	1160
Sylvania:		
Hard sandy lime	20	1180
Very hard lime	20	1200
Very sharp lime	145	1345
Lower Monroe:		
Lime	55	1400
Very hard lime	85	1485
Mud vein	5	1490
Red shale	5	1495
Lime	75	1570
Hard brown lime	30	1600
Hard gray lime	20	1620
Salina (First salt at 1630 in No. 5, 1620 in No. 6, and 1623 in No. 7):		
Salt	33	1653
Lime	22	1675
Hard brown lime	10	1685
Lime	20	1705
Very hard lime	38	1743
Salt	20	1763
Lime	5	1768
Salt	10	1778
Shale	76	1854
Salt	30	1884
Lime	8	1892
Salt	10	1902
Lime	10	1912
Salt	8	2020
Lime	5	2025
Salt	105	2130
Lime	5	2135
Salt	30	2165
Brown lime	35	2200

[10]The record of the No. 7 well was not saved until after the first salt bed was reached at 1623 ft., compared with 1620 in No. 6. From the top of the first salt, the record of the No. 7 well is used since it passed through the last salt bed whereas the No. 6 well did not.

ONTARIO.

Wallaceburg. Wallaceburg, Ontario, is about 8 miles south of east from Algonac. At the former place the Dundee was struck at 750 feet, much lower than at Algonac (513 feet) and the dip southeast to Wallaceburg from Algonac appears to be nearly 30 feet per mile.

WALLACEBURG WELL.

Elevation about 585 (?) ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sands and clays	35	35
Boulder clay	85	120
Shale	180	300
Limestones	75	375
Shale and sandstone	74	449
Compare Marine City, 370-480 ft.		
Traverse (Hamilton) Formation:		
Limestone, "top limestone"	106	555
Compare Marine City, 600 ft.		
Shale, "top soapstone"	95	650
Compare Marine City, 640 ft.		
Limestone, "middle limestone"	15	665
Compare Marine City, 730 ft.		
Shale, limestone and clay	85	750
Dundee (Corniferous) limestone (Top of Monroe not separated):		
Light colored limestone	250	1000
Doubtless the lower part is dolomite and belongs to the Upper Monroe.		
Sylvania (Middle Monroe):		
Sandstone	100	1100
Lower Monroe:		
Fine grained dolomites	280	1380
Gypsiferous dolomites	320	1700
(No salt reported, the record may be imperfect.)		
Niagara (Guelph and Lockport):		
Dolomites	120	1820
Limestone	105	1925
Oil at 1865 ft.		
Calcareous and arenaceous shales	110	2035
Medina:		
Gray sandstone, red shale and marls	65	2100

LOCAL STRUCTURE IN MACOMB AND SOUTHERN ST. CLAIR COUNTY.

In the Pontiac well, the top of the Dundee cannot be determined, but using the base of the Antrim as a basis of comparison, the dip from Mt. Clemens to Pontiac is about 20 feet per mile to the west. Northeastward to New Baltimore the dip for the Dundee is over 32 feet to the mile, eastward to Algonac, 8 feet, and south of east to Wallaceburg, Ontario, about 15 feet. These discordant dips indicate the presence of an anticline of considerable extent in the vicinity of Mt. Clemens, but the available data does not indicate the precise position. Its axis apparently pitches in a general northwesterly direction.

At Algonac, the top of the Dundee occurs at 71 feet above sea level, and, using this horizon as a basis of comparison, the dip northwest to New Baltimore is over 17 feet per mile, north to Marine City and St. Clair, 15 and 18 feet respectively, northeast to Fort Lambton,

Ontario, apparently 66 feet, and southeast to Wallaceburg, Ontario, about 30 feet per mile. According to this, another anticline exists near Algonac, but the great discordance in the several dips makes its position and course very uncertain. A further study of the records of wells in Macomb and St. Clair counties and in Ontario tends to show that there are perhaps a series of anticlines and synclines in the region under discussion. A large syncline appears to extend northwest from Chatham, Ontario, through Wallaceburg toward Fort Lambton; a low anticline or terrace at Marine City, and a syncline at St. Clair. Future drilling may show that faulting plays an important part in causing the sudden and discordant dips in Macomb and southern St. Clair counties.

Conclusions. In conclusion, it may be said that the records indicate that there is marked warping and folding, or perhaps faulting, in the rock strata in Macomb and southern St. Clair counties, and that there are pronounced anticlinal structures in the vicinity of Mt. Clemens and Algonac. The drill holes, however, are so located that while they show the presence of anticlines and synclines they do not clearly indicate their position or direction. Such disturbances in general form favorable conditions for the occurrence of oil and gas, and it is not improbable that future drilling, especially to the Niagara and Medina, may show that some of these structures contain oil and gas in commercial amounts as they do a few miles east in Ontario.

CHAPTER V.

THE SAGINAW OIL FIELD.

THE SAGINAW VALLEY DEVELOPMENT COMPANY.

Some years ago Dr. A. C. Lane, then State Geologist of Michigan, wrote an article upon the oil and gas prospects in Saginaw Valley. This article appeared in the Michigan M ner of Saginaw and created considerable interest at the time, especially at Saginaw. Nothing came of it, however, and the article was forgotten until a reprint fell into the hands of some enterprising Saginaw business men in the winter of 1912. They became very much interested in the oil and gas possibilities of Saginaw Valley, as portrayed by Dr. Lane, and soon interested other business men of Saginaw. The Saginaw Valley Development Company was soon organized for the purpose of drilling three test wells, two to the Berea grit, and a third to a depth of 3500 feet or more, unless oil or gas should be struck in commercial quantity before that depth was reached. The officers of the company were Wallis Craig Smith, president; Clark L. Ring, vice-president; and N. N. Rupp, secretary and treasurer. At their request, the officials of the company were given a compilation and interpretation of the data by the Geological Survey which, though meager and inconclusive, was deemed sufficiently favorable to warrant a test of the Saginaw territory.

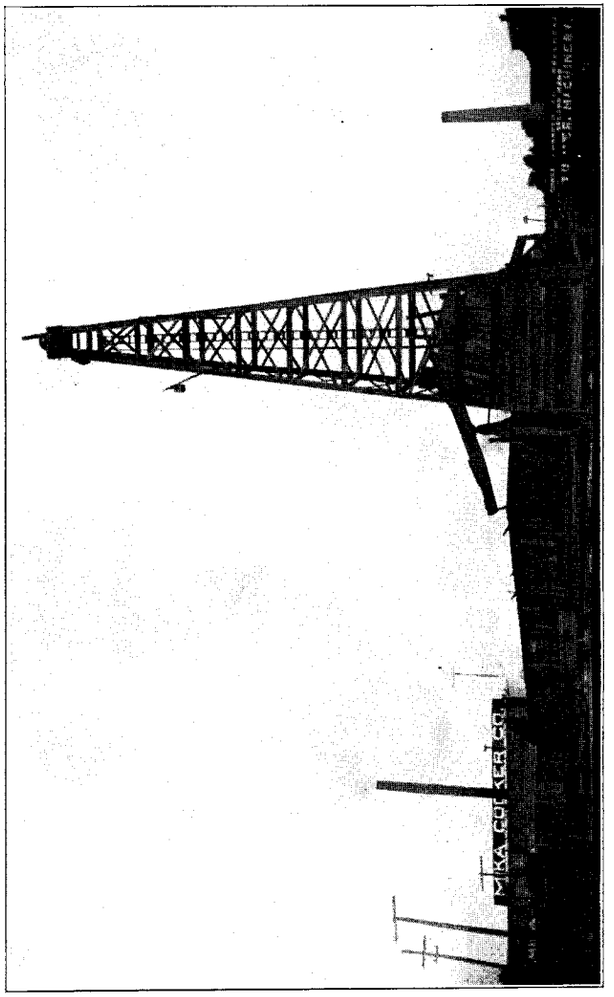
THE SAGINAW ANTICLINE.

Most of the evidence indicating favorable structural conditions for the occurrence of oil and gas in the region was derived from the numerous and comparatively shallow salt (fig. 11) wells along Saginaw river, drawing brine from the Upper Marshall sandstone.

Further evidence was afforded by drill holes at Midland, Caseville, Blackmar, Flint, Owosso, and St. Charles. The two deep wells at Bay City were of great value in giving a general idea of the probable thickness and character of the formations below the Marshall brine horizons.

The center of the Michigan Basin appears to lie in Midland and Isabella counties. Saginaw and Bay City are east of the center, therefore the strata in the vicinity of these places have a general westerly

Michigan Geological and Biological Survey.
Publication 14. Geological Series 11.
Plate 11.



THE GAREY-CASAMER NO. 1 WELL, SAGINAW.

dip which, on the average, is about 20 feet per mile. Since Saginaw is somewhat nearer the central basin corresponding strata at Saginaw should be deeper than at Bay City.

Upon platting the records of the salt wells along Saginaw river the Napoleon, or Upper Marshall sandstone, instead of being deeper at Saginaw is apparently 200 to 300 feet higher than at Bay City. This sandstone rises gradually from a depth of about 1900 feet in Bay City to about 610 feet in the old Wylie well near Bristol street bridge in Saginaw, and then descends to the southwest. Southeast of Saginaw near Blackmar and at Flint, the Marshall and the Berea are apparently much higher than to the east or west of these places. North of Saginaw, the Ralston well, sec. 4, T. 13 N., R. 4 E., and many other drillings for coal indicate a pronounced upward fold in the Coal Measures. The Marshall and the Coldwater also appear to be somewhat higher in the Page Oil & Gas Company's well (sec. 26, T. 14 N., R. 4 E.), than farther east along Saginaw river. At Kawkawlin, the brine horizons are between 700 and 800 feet deep, or considerably shallower than in Bay City to the southeast. Apparently this fold (Fig. 11), should run slightly west of north through Saginaw near Bristol street bridge to a point two or three miles west of Kawkawlin.

Southeast of Saginaw at Balckmar, the Marshall and the Berea occur in wells at 360 and 1545 feet, and at Flint 170 and 1200 feet respectively. As these formations are known to occur at greater depths east and west of these places, it appears that the anticline turns southeast toward Blackmar and Flint, but the evidence is not conclusive as the records of the drill holes at these places are of doubtful accuracy. As the Marshall appears to be only about 360 feet deep at Blackmar, 610 feet at Saginaw, and about 700 feet at Kawkawlin, the structure apparently pitches gently to the north. On the whole, the evidence seems fairly conclusive that a pronounced anticlinal fold exists in the strata down to the Marshall at least, and presumably much deeper, but its exact position and course are not so clearly indicated. Explorations of the Saginaw Valley Development Co. tend to prove the general correctness of this conclusion.

THE EXPLORATIONS.

The company spent some time in obtaining reliable contractors and made careful preparations to do the exploratory work in the most accurate and scientific manner possible. Ten wells were drilled, two to the Traverse, and the other eight to the Dundee. Accurate records were kept and full sets of samples taken for the Michigan Geological Survey, and the resulting information concerning the underlying rock strata in Saginaw Valley nearly to the base of the Dundee may

be considered as the most reliable and complete that has ever been obtained from any one set of deep holes drilled anywhere in Michigan.

Mundy-Fifield Well. The first well drilled by the Saginaw Valley Development Company was located near the S. E. corner of the N. W. ¼ of sec. 27, T. 13 N., R. 5 E., Buena Vista township, Saginaw county, although from the evidence then at hand, this location was four or five miles east of the axis of the supposed anticline. In this well, known as the Mundy-Fifield, the Marshall sandstone was struck at 780 feet, or 40 feet higher than in the South Bay City (North American Chemical Co.) well to the north in sec. 5, T. 13 N., R. 5 E., but fully 170 feet lower than the supposed depth to the Napoleon at the Old Wylie well on Niagara street about 800 feet north of Bristol street bridge.

The Berea was struck at 2070 feet, or 30 feet higher than in the South Bay City well. All of the formations from the Marshall down were found to be higher than corresponding ones in the Bay City wells, but much lower than at Saginaw, as shown by later drillings.

The Berea yielded some brine and a little gas, but no sign of oil. At the depth of 2246 feet the drilling was abandoned, but later in the spring of 1913 it was deepened to the Dundee, no noteworthy quantities of either oil or gas being struck anywhere. The Traverse and the Dundee were struck at 2513 and 3130 feet, or 100 and 140 feet higher respectively than in the South Bay City well, and about 230 feet lower than in the Saginaw wells.

Garey-Casamer No. 1. Another well was drilled near the site of the Wylie Bros. well on what is known as the Garey-Casamer lease. (Pl. II). The Upper Marshall, or Napoleon, was encountered at 610 feet, or 170 feet higher than in the Mundy-Fifield well, and 210 feet higher than in the well in South Bay City. The Berea was encountered at 1833 feet, or 233 feet higher than in the Mundy-Fifield well, and 265 feet higher than at South Bay City. It is to be noted from the foregoing records that the fold becomes more pronounced with depth.

As in the Mundy-Fifield well, the Berea proved to be a small yielder of brine, perhaps 25 barrels per day, and gas. Drilling was continued with the intention of going down to the Dundee, supposed to be 900-1000 feet below. At 2305 feet the Traverse formation was entered and oil of the highest grade was struck at 2317 feet in a sandy or cherty limestone. The so-called "sand" since called the "Saginaw sand," was very thin, probably being not much over two feet thick.

According to statements of officials of the company, the well made two flows of some 40 or 50 barrels of oil altogether. The indications were that a 25 to 30 barrel well had been struck. The well was shot

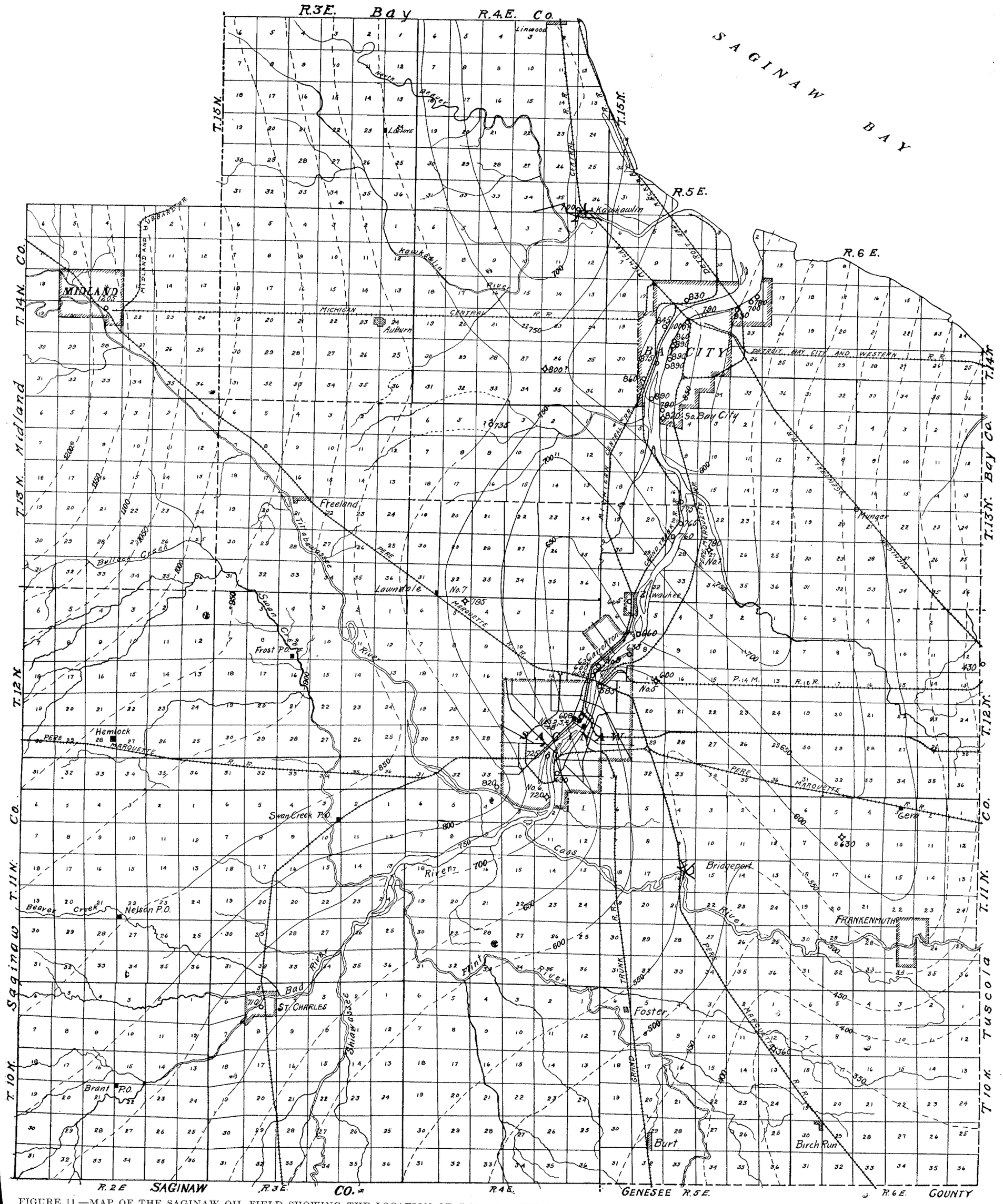


FIGURE 11.—MAP OF THE SAGINAW OIL FIELD SHOWING THE LOCATION OF BORINGS, THE SAGINAW ANTICLINE, AND THE CONTOURS OF DEPTH OF THE MARSHALL SANDSTONE BELOW THE SURFACE IN SAGINAW VALLEY.

with 100 quarts of nitroglycerine. As soon as pumping began, however, it was found that the casing was leaking, and after the first 75 or 80 barrels, the production of oil fell off rapidly until the well yielded only about three or four barrels of oil per day with about 25 barrels of water. After much trouble, the water was finally shut off by the use of rubber packers, but the production was not materially increased. Finally the well was reshot with 20 quarts of nitroglycerine, but the casing was loosened so that water was again troublesome. After continuous pumping for some months without increasing the production, the well was pumped only intermittently with the Jackson-Church and the Cresswell wells in the same vicinity, the production finally decreasing to almost nothing.

Jackson-Church Well. The next well, No. 3, was drilled on the Jackson-Church property near the west end of Bristol St. bridge on Niagara St. and about 600 feet west of south from the Garey-Casamer well. The Marshall, Berea, and the Traverse were struck approximately at the same depth as in the latter well, but no sandy limestone or oil "sand" was found at the top of the Traverse. The "Saginaw sand," as the oil horizon in the Garey-Casamer well is called, appeared to have pinched out, and there was not the slightest show of oil or gas at this horizon.

The well was drilled to the Dundee, which was struck at about 2900 feet. At 2935 feet, there was a show of oil, but the largest was between 2945 and 2955 feet. The drilling was stopped at 3080 feet, after striking brine, which was plugged off and the well shot with 120 quarts of nitro-glycerine. The first pumping is said to have yielded some 50 barrels of high grade oil, and then the production rapidly fell off to about 2 or 3 barrels per day. Later this well, like the Garey-Casamer, was pumped but intermittently.

Cresswell Well. A fourth well was drilled about 1200 feet south of east from the Garey-Casamer No. 1, at the east end of Bristol street bridge on the Cresswell property. The formations were found to be, as in the Jackson-Church and Garey-Casamer wells, at approximately the same depth. In the Cresswell well, a showing of oil was struck in the "Saginaw sand" of the Traverse, another about 100 feet lower, and a third toward the base of the formation. The oils from the second and third horizons were dark and heavy and of much lower grade. None of these showings were deemed worth testing and the well was deepened to 3060 feet, the Dundee being struck at 2886 feet and a showing of oil found above 2942 feet. The oil is high grade, being similar to that found in the Jackson-Church well.

Watson Well. The Watson well, or No. 5, 3068 feet deep, was drilled on the Watson farm near the S. E. corner of S. W. $\frac{1}{4}$ of section 17,

T. 12 N., R. 5 E., Buena Vista township, about a half mile east of the city near the intersection of the highway and the new electric railway from Saginaw to Bay City. There was a small show of gas in the Berea, but no sign of either oil or gas was reported in the Traverse. Oil was struck in the Dundee, but in such small quantity that, after standing six days, there was only a few quarts of oil in the well and about 180 feet of water. The well, which was abandoned without shooting was plugged to protect the Marshall brines from contamination, and also to prevent leakage of gas which escaped in a considerable though not commercially important quantity from the Berea. Strong brine from the Berea constantly flowed over the top of the casing in small stream.

The Upper Marshall, or Napoleon, was struck at 600 feet, or slightly higher than in the Bristol street bridge drillings. The Berea was struck at 1835 feet, or practically at the same depth, and the Dundee at 2928 feet or about 28 feet deeper. Apparently the structure at Saginaw is that of a structural bench or terrace for the upper formations, and an asymmetrical anticline for the lower, the western limb being very much steeper than the eastern which dips but 28 feet from the Jackson-Church to the Watson well, a distance of 2½ miles. From the Watson well east to the C. W. McClure well, 3000 feet in depth, near Gera in section 8, Frankenmuth township, the strata seem to be nearly flat, since corresponding formations were reported to be at practically the same depths and very similar in character as in Saginaw. Farther east, the strata must rise, as at Reese, the Napoleon is less than 500 feet from the surface The broad flat depression in the lower formations to the east of Saginaw evidently pitches toward the north and becomes a pronounced syncline, in the vicinity of Bay City since the Berea drops from a depth of 1850 feet in the Watson well to 2035 feet in the Mundy-Fifield well, and 2100 feet in the South Bay City well, and similarly the Dundee from 2928 feet to 3130 and 3270 feet respectively.

Green Point Well. The Green Point well or well No. 6, also known as the Globe-Blaisdell, is located on the Globe-Blaisdell property nearly opposite the East Saginaw waterworks plant, on the N. W. ¼ of section 2, T. 11 N., R. 4 E. This well is situated about 2¼ miles south southwest from the Garey-Casamer. All of the formations were found to be from 110 to 135 feet deeper than in the Bristol street bridge wells, the Napoleon occurring at 720 feet, the Berea at 1965, the Saginaw "sand" at 2450, and the Dundee at 3012 feet. No signs of oil or gas were noted, but the Dundee, which was penetrated 240 feet, yielded an abundance of brine near the bottom of the well.

Lawndale Well. The Lawndale, or well No. 7, was drilled near Lawndale on the L. Reincke farm in the N. E. corner of section 5, T. 12 N., R. 4 E., about six miles northwest of the Garey-Casamer well, and at about two or three miles west of the axis of the anticline. All of the formations were struck from 185 to 260 feet deeper than in Saginaw, showing a dip of from 40 to 60 feet per mile to the northwest from the Garey-Casamer. The Dundee was penetrated 112 feet without showing a sign of either oil or gas.

The Green Point and the Lawndale, together with the Saginaw Plate Glass Co. wells in West Saginaw, show that the strata from northern and northwestern Saginaw dip rapidly to the southwest and west, proving the correctness of the earlier conclusions that there is an anticlinal arch at Saginaw. Unfortunately, the wells are so located that they do not indicate its precise direction or probable extent. In fact, it is not positively known that it extends continuously northward toward Kawkawlin.

Garey-Casamer No. 2 Well. Since all the wells located at some distance from the anticline gave little or no sign of oil and gas and the wells near or on it yielded both, the company decided to locate the next wells as near the axis of the anticline as possible, but farther to the north. Garey-Casamer No. 2 well was drilled 500 feet north and east from the Garey-Casamer No. 1 to test out the extent of the Saginaw sand in that direction, the sand having pinched out 600 feet to the southwest in the Jackson-Church well. The formations were found to be practically at the same depth as in the other Bristol street bridge drillings, but the Saginaw "sand" in the No. 2 well proved to be hard gray cherty limestone, showing not the slightest sign of oil or gas.

The drilling was continued to the Dundee, which was struck at 2885 feet and yielded a small flow of oil, but after standing several days the well was tested with the bailer and it proved to be less promising than either the Jackson-Church or the Cresswell wells.

Mershon Well. Some of the records of the old salt wells in northeastern Saginaw give the depth to the bottom of the "salt," that is to the red horizon marking the base of the Upper Marshall. After the first few wells had been completed by the Saginaw Development Company and the average thickness of this formation determined, it was possible to calculate the depth at which the top of the Upper Marshall should be struck in northeastern Saginaw. According to calculations, the top of the formation should be struck from about 605 to 615 feet below the surface in this part of Saginaw, or practically the same as in the Bristol street wells. It was also reported that one of the brine wells of Eastman & Co. was only 585 feet deep. This data indicated

that the crest of the supposed anticline was slightly to the east of the Wylie well, and upon this supposition the next, or No. 9, well was located near Saginaw river on the Mershon property about two miles north of the Bristol street wells and about 1000 feet north of the Pere Marquette railroad bridge.

The top of the salt formation was struck at 600 feet, or slightly higher than in the Garey-Casamer wells. The well was drilled to the Dundee, but no noteworthy amount of oil or gas was found at any horizon.

Ring Well. The Ring or No. 10 well was drilled on the C. L. Ring property a few hundred feet north and west of the Garey-Casamer well No. 1 to determine whether or not the "Saginaw sand" extended in that direction. This, the last well to be drilled, was a dry hole and apparently proved that the so-called "Saginaw sand" is very limited in extent and porosity, and that it holds little promise of containing any considerable quantity of oil and gas.

The almost absolute failure of these last wells, together with the great outlay of money already made, caused the company to abandon further exploration and to surrender their large lease holdings. It is to be regretted that more of the drill holes were not spaced along the supposed course of the anticlinal. Five of the ten wells drilled by the Saginaw Valley Development Co. were within a radius of 1200 feet, and three of the remaining five were at considerable distances from the supposed crest of the fold. In short, only about two miles of the anticline, apparently 25 or 30 miles long, has been tested, and this is not sufficient to determine whether the drillings are located in a sag or on a dome, if these secondary structures exist. Since oil and gas occurs in greatest abundance in the vicinity of the domes or cross arches it is possible that, had the explorations been made along the supposed axis of the anticline, oil and gas would have been found in greater quantity.

Gera Well. Chas. W. McClure, a prominent stockholder in the Saginaw Development Company, drilled a well 3000 feet deep near Gera on one of his farms, section 8, Frankenmuth township. According to the driller, the formations were encountered at about the same depths as in Saginaw and the well was "absolutely dry." The Marshall yielded such a strong artesian flow of brine, that drilling operations were stopped for some time.

A comparison of the records (Fig. 12) shows that the formations are remarkably regular in character and thickness. This is so true that, given the top of the Napoleon, the depths at which the Berea, Traverse, and Dundee should be struck can be calculated very closely. The error in calculating the depth of the Dundee in the Jackson-Church

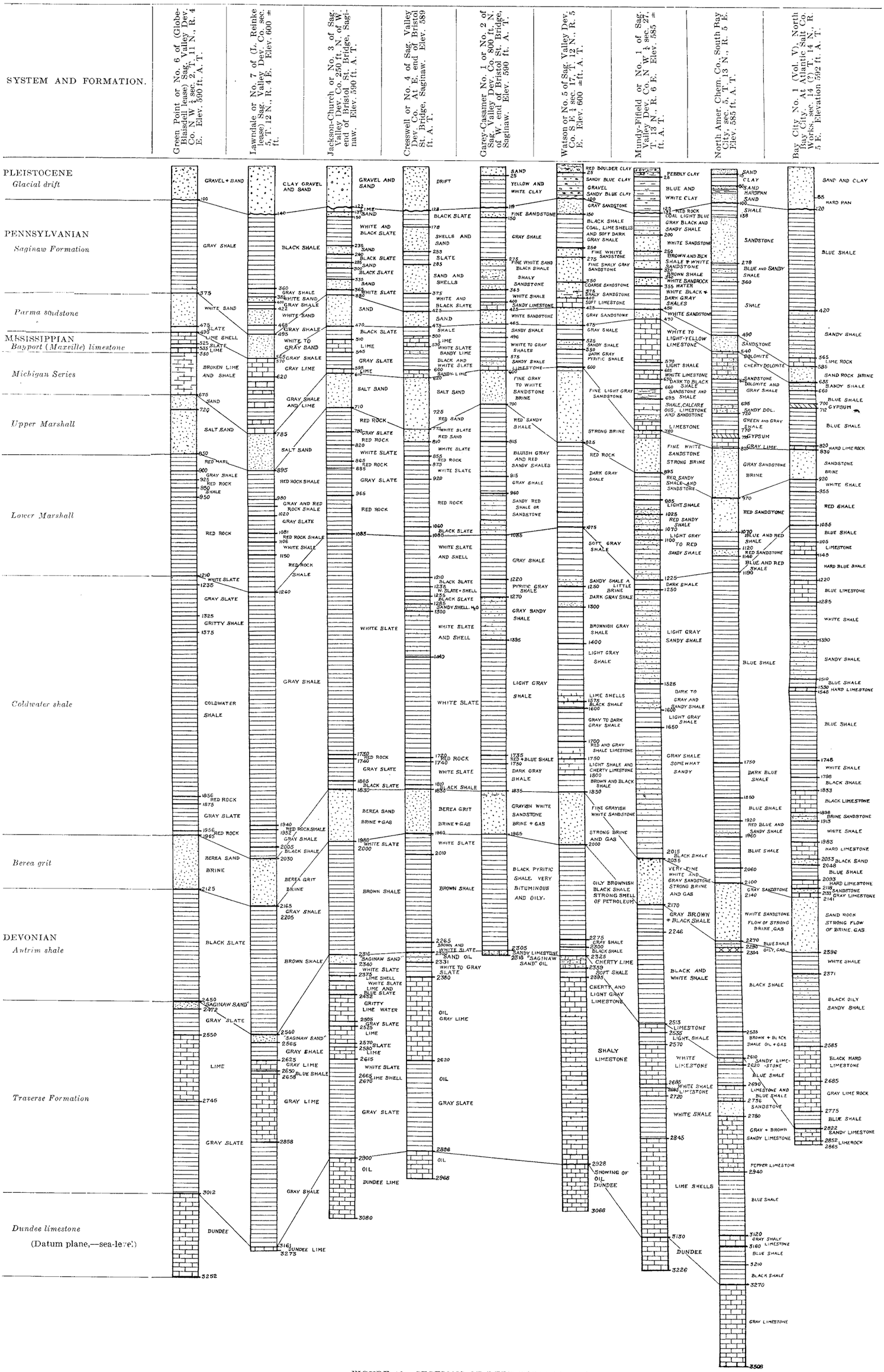


FIGURE 12.—SECTIONS OF DEEP BORINGS IN SAGINAW VALLEY.

and the Green Point wells proved to be less than 10 feet. From a comparison of the records of the Braun (Mt. Pleasant No. 2), Gladwin, Bay City, and Saginaw wells, this uniformity in character and thickness of the formations seems to prevail over most of the central basin. The only formation which changes markedly is the Berea sandstone, which disappears toward the west side of the Basin, or is represented by red or sandy shales. Apparently, the Antrim shale grows thicker as the Berea thins and it has more or less white or blue shale near the top. The thickness of the black shale series from the top of the Sunbury (base of Coldwater) to the base of the Antrim is very uniform in all of the wells in the Central Basin.

THE OIL HORIZONS.

The Berea. From the date assembled before drilling began, it appeared that the Berea was the most promising horizon to test for oil and gas. In the South Bay City well there were strong signs just above this horizon, and in the Blackmar well considerable gas was encountered. A favorable structure seemed to be the only condition lacking for an accumulation of commercial size. It was a keen disappointment when the Berea yielded no oil and only a small quantity of gas which, however, increased considerably with time. In some wells, the gas was not noticed for some time after the brine was cased off. The latter, though apparently very strong, was also deficient in quantity, there rarely being a flow of much more than 25 barrels per day. In the Garey-Casamer No. 2, however, it was over 15 barrels per hour.

For some time, it was a puzzle why this formation did not consistently yield a greater abundance of brine, since it was so thick and well represented. An examination of the samples showed that the Berea is a very fine and close grained gray to white sandstone. In some phases, the sand grains are too fine to be readily distinguished by the naked eye. It is this fine to exceedingly fine grain of the rock which not only limits the flow of brine but also that of gas. A heavy charge of nitroglycerine might possibly increase the flow of gas greatly, but the head of brine probably would overcome it.

The "Saginaw Sand." The so-called "Saginaw sand" in Garey-Casamer No. 1 well appears to be a sandy or cherty limestone. There seems to be some doubt as to the exact nature of the oil horizon, but all of the samples examined by the writer proved to be limestone, commonly cherty or sandy, effervescing very vigorously in cold dilute acid and leaving a comparatively small residue of sand and chert. In any case, the productive "sand" is thin and pinches out wholly to the southwest in the Jackson-Church well, to the northeast in the Gary-

Casamer No. 2, and to the northwest in the Ring well. In the Cresswell, or No. 4 well, this horizon is represented by two "sands"; that is, two cherty limestones separated by a shaly layer. In the Watson well, there is a cherty or pyritous limestone filled with black micaceous particles from 2325 to 2359 feet, but it contained no oil.

The Dundee. The Dundee oil horizon appears to be about 35 feet below the top of the formation and is a light gray to buff and brown granular limestone, effervescing violently with dilute hydro-chloric acid. A fragment shot out of the Jackson-Church well is a gray granular porous limestone, the pores being readily seen by the naked eye. The oil horizon appears to be free from water but there is an abundance of water a short distance below it as shown in the Jackson-Church, the Watson, and the Green Point wells.

EXPLORATION.

Of the eleven deep wells in the Saginaw field, six (Nos. 2, 3, 4, 8, 9 and 10), appear to be on the anticline and four of these six, perhaps significantly, yielded oil and gas in considerable if not commercially important quantities at two different horizons. In the Cresswell well, four oil bearing horizons were struck. The other wells are located from about one-half to three or four miles distant from the apparent crest of the anticline and yielded little or no oil and gas. The Watson, or No. 5, perhaps may be excepted as this well yielded considerable gas at the Berea horizon, but this well apparently is less than half a mile east of the axis of the anticline. Since the wells at some distance from the anticline have been so barren of encouraging results, it seems logical that future prospecting should be along the supposed axis of the structure. Oil may not be found in commercial quantity along its crest, but the chances are presumably greater in its immediate vicinity (especially near cross arches or domes, if they exist), than elsewhere.

In this connection, it must be borne in mind that the evidence pointing to the continuation of the anticline northward from Saginaw is not conclusive. Further drilling may show that the indicated anticline west of Kawkawlin between Bay City and Midland may have no direct connection with the one at Saginaw. The local structures in Saginaw Valley may be very different than is indicated.

Conclusions. In conclusion the following statements concerning the conditions for the occurrence of oil and gas in Saginaw Valley appear to be warranted from the evidence afforded by the wells of the Saginaw Valley Development Company, and wells of earlier date.

(1) A pronounced anticline undoubtedly exists at Saginafw and appears to be continuous northward to a point a few miles west o Kawkawlin. (2) An equally marked syncline underlies the vicinity of Bay City. (3) The structure, as originally worked out by Dr. Lane, appears to be essentially correct, though future drillings may show that the structure at Kawkawlin is not continuous with that at Saginaw. The evidence on this point is not conclusive. (4) The various formations are remarkably uniform in character and structure. (5) There are at least three well represented and accessible oil or gas formations, and five possible oil horizons, three being in the Traverse. (6) All of the oil or gas formations contain oil or gas in small to considerable amounts, and from a geological standpoint, these products should occur in greater quantity at some point or points (the domes or cross arches) along the Saginaw anticlinal. (7) The indicated anticline appears to be 25 or 30 miles in length, and therefore the half dozen drill holes on its crest in the vicinity of Saginaw have tested only a small portion of the supposedly favorable territory.

CHARACTER AND COMPOSITION OF THE OILS.

The "Saginaw" Oil. The oil from the Saginaw "sand" is a very high grade paraffin oil, testing 47° Baume and containing over 62 percent of naphtha and burning oil. In color, it is light green by reflected light and deep red by transmitted light. The following analysis by the Paragon Refining Company of Toledo, Ohio, is indicative of the excellent quality of the oil.

Test of Petroleum from the "Saginaw sand," Garey-Casamer well No. 1:

Gravity of crude	47° Baume.
Naphtha	28.16%
Burning oil	34.5
Intermediate	8.66
Wax distillate	22.8
Tar	3.23
Loss	2.65
Total	100.00%

The black heavy oils found lower down in the Traverse were not tested.

Dundee Oil. The oil from the Dundee is high grade, testing 36° Baume, considerably lower than that from the "Saginaw" sand. The oil is green in color and has a distinct smell of sulphur. Preliminary tests show that it contains a considerable amount of this substance, but no complete analysis is available.

CHAPTER VI.

CENTRAL MICHIGAN.

GEOGRAPHIC AND GEOLOGIC RELATIONS.

The central district of Michigan includes the Saginaw oil field, which has been deemed worthy of a separate discussion in the previous chapter. The central district is not only near the geographic but also the geologic center of the Southern Peninsula. The deepest part of the Michigan Basin is in the region of Isabella and Midland counties. In the immediate vicinity of the center of the Basin the Berea is 2000 feet or more below the surface. The Dundee is nearly 3700 feet below the surface at Mt. Pleasant, therefore the Trenton should be more than 5500 feet (Fig. 1) in depth at this place.

Surface Deposits. Northwest of a line from Midland to Grand Rapids, the drift is very thick, ranging from 250 to 600 feet. From Bay City, southwestward past Midland to Alma and thence northwestward to Manistee there is an old preglacial rock valley which accounts for the great depth of drift at Alma, St. Louis, White Cloud and Mt. Pleasant.

In the southeastern portion of the central basin, the drift is relatively thin, and, from Grand Rapids and Holland southeast to Jackson and beyond, bed rock in many places is at the surface or under a very thin cover of drift. From Jackson to Huron county the drift is generally less than 150 feet thick, and in much of the region rock can be reached from 40 to 100 feet below surface.

EXPLORATIONS.

The great depth to the oil horizons and the thick drift in the northwetsern half of the central district have been most effective in discouraging explorations for oil and gas. Deep drillings, however, have been made at Bay City, Midland, St. Louis, Alma, Gladwin, Mt. Pleasant, Grand Rapids, Charlotte, Delta, Eaton Rapids, Jackson, and near Morrice and Fowlerville, and at Ionia, St. Johns, Ithaca, Owosso, Durand, Perry, Blackmar and Flint.

BAY COUNTY.

Bay City. In North Bay City three or more deep wells have been drilled. One was bored by John Mason in 1885-6 to the depth of 2900 feet. The record indicates that the formations are about the same depth as in South Bay City, but that they are considerably different in character. The Coldwater apparently contains a number of limestone lenses, with a little black shale and sandstone at some distance above its base. The abundance of limestone in the Coldwater is unusual in the eastern part of the State, and possibly these "limestone" beds are only large iron carbonate concretions, which are common in this formation. C. E. Wright quotes John Mason as stating that the well at 2900 feet was in the same rock as the Morley well (Chap. IV) just north of Marine City. This indicates that the well may have been deeper than given in the record, and it is very probable that the record, which is only the driller's, is imperfect.

Brine was struck in the Parma, the Marshall, in the base of the Coldwater, and in the Berea. According to Cooper marked signs of oil or gas were observed at one or more horizons, but no mention of this is made in the record as originally published.

The Hall well (No. 93½ of the Saginaw Board of Trade map), was close to the above well but it only penetrated the Berea. Another well, MacLeans, was on the east side of the river near 28th street.

NORTH BAY CITY WELL.

Loc.: Near Atlantic Mill, North Bay City. Drilled in 1885-6 by John Mason. Record by Lane from notes of C. E. Wright and from record published by Bay City Tribune.

Elevation 592 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand and clay	85	85
Hard pan	35	120
Saginaw Coal Measures:		
Blue shale	300	420
Sandy shale	145	565
Parma:		
Limerock to brine 85°. Carboniferous limestone (?)	20	585
Sand rock; brine 45 ft. to 55 ft	50	635
Grand Rapids Group:		
Sandy shale	25	660
Blue shale	40	700
Gypsum; white; 6 in. casing to 722 ft	12	712
Blue shale	108	820
Hard limerock	10	830
Napoleon or upper Marshall:		
Sandstone; brine to 100°	90	920
Lower Marshall:		
White shale	35	955
Red shale	100	1055
Coldwater:		
Blue shale	50	1105
Limestone	40	1145
Hard blue shale	75	1220
Blue limestone (Calcareous shale?)	65	1285
White shale	105	1390
Sand shale	120	1510
Blue shale	20	1530
Hard limestone (Concretion?)	18	1548
Blue shale	200	1748
White shale	50	1798
Black shale	35	1833
Black limestone	65	1898
Brine bearing sandstone	15	1913
White shale	70	1983
Hard limestone	50	2033
Sunbury or Berea shale:		
Soft black sand	15	2048
Hard blue shale at 2067 ft	45	2093
Black oily shale, 15-20 ft. thick at 2085 ft.		
Very hard limestone; 5 5-8 in. bore to 2120 and 5 1-2 in. below	25	2118
Berea:		
Sandstone	15	2133
Gray limestone	8	2141
Pumped clean sand at 2140 ft.		
Sandrock with salt brine; 100°, overflowing top (2252½ ft. deep, stopped in blue shale.—Wright).	165	2306
Antrim shale:		
White shale	65	2371
Black oily sandy shale	214	2585
Traverse (Hamilton) Formation:		
Black hard limestone	100	2685
Gray limerock	90	2775
Blue shale, quite hard	47	2822
Sandy limestone	30	2852
Limerock	13	2865

In December 1898, the deepest bore hole in Michigan excepting, however, the Braun well drilled in Mt. Pleasant in 1913, was begun at South Bay City by the North American Chemical Co. of Bay city. By February 22, 1899, the well was down to the Berea grit at 2100 feet. Drilling became more difficult and with a four months delay from a broken rope the well was not finished until in January of 1900. Careful notes of the drilling were kept and a complete set of samples

were preserved. From notes and samples, W. F. Cooper, of the Michigan Geological Survey, compiled the log[1] as given below.

NORTH AMERICAN CHEMICAL COMPANY WELL.

Loc.: South Bay City, sec. 5, T. 13 N, R. 5. E. Drilled by Thos. Percy.

Elevation 585 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	15	15
Clay with thin seams of sand	35	50
Sand	10	60
Hardpan	10	70
Sand	30	100
Saginaw Formation:		
Shale	38	138
Quicksand, probably fissure	2	140
Sandstone	138	278
Blue shale	17	295
Sandy shale	10	305
Blue shale	15	320
Sandy shale	5	325
Blue shale	35	360
Shale	60	420
Fire clay	10	430
Blue shale	30	460
Fire clay	10	470
Shale	10	480
Red shale	10	490
Parma Conglomerate:		
Sandstone	50	540
Upper Grand Rapids, Maxville or Bayport:		
Brown dolomite	30	560
Silicious dolomite	60	610
Sandstone	10	620
Lower Grand Rapids or Michigan Series:		
Dolomite	5	625
Gray shale	25	650
Dolomite	10	660
Gray shale	35	695
Sandy dolomite	25	720
Green shale	10	730
Gray shale	10	740
Limestone	10	750
Gray shale	20	770
Limestone	10	780
Gypsum	10	790
Gray limestone	30	820
Upper Marshall or Napoleon Sandstone:		
Gray sandstone, brine	150	970
Analyzed. Usual temperature of brines 60.4° F.		
Lower Marshall:		
Red sandstone	100	1070
Blue shale	30	1100
Red shale	20	1120
Red sandstone	20	1140
Blue shale	45	1185
Red shale	5	1190
Coldwater shale:		
Blue shale	560	1750
At 1304 ft. 65° F; at 1793 ft. 71° F.		
Dark blue shale	100	1850
Blue shale	70	1920
Red shale	20	1940
Blue shale	10	1950
Sandy shale	10	1960
Blue shale	100	2060
Sunbury (Berea) shale:		
Black shale	40	2100
Berea grit:		
Gray sandrock	40	2140
White sandrock, strong brine flowing over surface at 2170 ft. Flow about 20 gal. per hour at 2230 ft	130	2270

[1]Pl. II. Ann. Rept. for 1905, Bay County.

NORTH AMERICAN CHEMICAL COMPANY WELL.—Concluded.

Elevation 585 ft. A. T.	Thickness, feet.	Depth, feet.
Antrim shale:		
Blue shale	20	2290
Black shale, oily, gas	14	2304
Rock salt (from precipitation?)	6	2310
Black shale, calcareous at 2380 and 2490 ft. (concretions?)	225	2535
Brown shale	15	2550
Black shale	60	2610
Oil and gas at 2580.		
Traverse Formation:		
Sandy limestone	10	2620
Sandstone	10	2630
Blue shale	60	2690
Limestone	10	2700
Blue shale	27	2727
Limestone	9	2736
Sandstone. Brine with indications of gas (between 2734-2740 ft.)	44	2780
Sandy limestone	30	2810
Brown sandy limestone	50	2860
Gray sandy limestone. Brine	45	2905
At 2934 ft. 90.1°-90.2° F.		
Pepper sandy limestone	35	2940
Blue shale	180	3120
Gray shaly limestone	40	3160
Blue shale	50	3210
Marcellus shale:		
Black shale	60	3270
Dundee limestone:		
Gray limestone (yellow limestone—Cooper.)	238	3508
At 3455 ft. 97° F.		

The information furnished by this record was valuable in indicating the character, depth and thickness of the formations, and number and depth of the water bearing strata, and the possible oil and gas horizons which might be expected to be encountered in drilling in the vicinity of Saginaw.

In the South Bay City well, water or brine was struck in abundance in the Coal Measures, the Parma, and the Upper Marshall. A strong brine was found in the Berea, in the Traverse, and very probably a highly mineralized brine was struck in the lower portion of the Dundee, although the latter is not noted in the record.

Strong signs of oil and gas were noted just above the Berea grit, but in none of the lower horizons except the Upper Traverse were noteworthy signs reported. The well penetrated the Dundee limestone 238 feet and the bottom of the well is probably close to the top of the Monroe dolomites since the Dundee is not known to be more than about 250 feet thick in Michigan.

Kawkawlin. At Kawkawlin, northwest of Bay City, salt wells show that the Napoleon brine horizon occurs between 700 and 800 feet, or 150 to 200 feet higher than in Bay City. Since westward the same horizon is struck at Midland at 1205 feet a very strong fold must lie between Midland and Bay City. As noted on previous pages, the Saginaw anticline is conceived as running slightly west of north from Saginaw through a point two or three miles west of Kawkawlin. The

connection between the anticlinal fold at Kawkawlin and Saginaw seems probable since the Coal Measures also show a strong upfold in the Ralston well near the old Bay Mine No. 2. The Marshall and the Coldwater in the Page Oil and Gas Company (see Chap V) well also appears to be higher than they are farther east along Saginaw river.

FRANKLIN WELL.

Loc.: Kawkawlin, Bay County.

Elevation 596 ft. A. T.	Thickness, feet.	Depth, feet.
Drift	100	100
Saginaw Formation:		
Shale and sandrock with coal seams	300	400
Grand Rapids Group:		
Gypsum at 400 ft., limestone and gypsiferous shales	100	500
No record	200	700
Napoleon:		
Sandstone with a strong brine	100	800
Lower Marshall:		
Red shales	233	1133

The thicknesses as given in the above record are evidently approximations as they are in round numbers.

SAGINAW COUNTY.

Blackmar. In the early 70's, a well reported to be 1764 feet in depth was drilled at Blackmar, Taymouth township, Saginaw county. Considerable gas and a strong brine appears to have been struck below 1545 feet. As a coarse sandstone corresponding to the Napoleon was struck at 360 feet, the sandstone below should be the Berea. As mentioned in the discussion of the Saginaw oil field, this depth appears to be much less than to the east or west of Blackmar, hence it is supposed that south of Saginaw the anticline veers to the east and runs through Blackmar towards Flint.

The depth of the well is given as 1764 feet but the record only adds up to 1677 feet.

BLACKMAR WELL.

Loc.: Blackmar, Taymouth Twp., Saginaw County. Mr. Blackmar, owner.

Elevation about 613 ft. A. T.	Thickness, feet.	Depth, feet.
Drift	90	90
Shale	270	360
Coarse sandrock, brine 63° salinometer test	90	450
Blue shales	45	495
Red shales	200	695
Gray sandy shales	850	1545
Sandstone with a strong brine at 1675? (1545?) ft	110	1655
Gray shale	20	1675
Limestone	2	1677

GENESEE COUNTY.

Flint. At Flint there are many shallow borings, chiefly for coal. These indicate that the Maxville limestone is absent, probably eroded. In a deep well drilled many years ago a coarse sandstone was struck at 170 feet which yielded a "strong stream of sweet water." This, according to Lane, resembles the Marshall, and another sandstone at about 1200 feet containing a strong brine would therefore correspond to the Berea. The recent drillings for coal in the vicinity of Flint, however, indicate that the Marshall is more than 170 feet below the surface, hence the sandstone yielding the flow of fresh water is probably a sandstone belonging to the Coal Measures.

FLINT WELL.

Reported by Dr. Clark.

Elevation 715 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Drift	68	68
Sandstone	67	135
Shales and sandstone with seams of coal	35	170
Marshall:		
Sandstone, with a strong stream of fresh water at 260 feet	108	278
Alternations of shale and sandstone; in the lower part strong brine (from Berea?)	922	1200

MIDLAND COUNTY.

Midland. At Midland, there are seven wells to the Marshall, which is struck at about 1200 feet or 580 feet deeper than at Saginaw. This represents a dip from South Bay City to Midland of about 20 feet per mile, and 30 feet per mile from Saginaw. The No. 1 was drilled for Larkin & Patrick in 1879. Others were drilled later for brominiferous brines by H. H. Dow and the Midland Chemical Company. The wells in the northwestern part of the city reach rock sooner than those in the southeastern part. The drift is much thicker than at Saginaw and Bay City but not nearly so thick as at Mt. Pleasant, Alma or Gladwin. Brine was struck in the Coal Measures, the Parma, and the Napoleon, the brine increasing in strength with depth. The record given below is representative of the character of the formations.

MIDLAND WELL.

Elevation 608 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface deposits	285	285
Coal Measures:		
Micaceous white sandstone, fresh water	33	318
Black soft shale	27	345
Sandstone, brine at 420 ft	65	420
Hard shale	35	455
Sandstone	70	525
Hard shale	50	575
Hard sandstone	7	582
Black shale	118	700
Calcareous ($FeCO_2$) shale	45	745
Black shale	65	810
Parma:		
White sandstone	110	920
Grand Rapids:		
Argillaceous limestone	50	970
Plaster bed, fairly pure anhydrite	80	1050
Calcareous shale	80	1130
Limestone	75	1205
Napoleon or Upper Marshall:		
White sandstone somewhat ferruginous	100	1305

In the No. 13 well of the Dow Chemical Co. red shale occurs at 1390 feet or above. (C. W. Cook, Pub. 15, Geol. Series 12, 1913.)

GRATIOT COUNTY.

Alma. At Alma, one of the deepest wells in central Michigan was drilled in 1895 for the Alma Sanitarium. It reached a total depth of 2865 feet and was bottomed in the Upper Traverse limestones where mineral water with a temperature of 98° F, was struck. A little gas also seems to have been found in the top of the Traverse.

The drift was very thick, bed rock being struck at 500 feet. This is much deeper than at St. Louis and Mt. Pleasant. The Napoleon is about 375 feet higher than at Mt. Pleasant, thus indicating an abnormal dip of the formation from Alma to the north-northwest.

ALMA WELL.

Loc.: Alma Sanitarium, 1889. Sec. 34, T. 14 N., R. 3 W. Reported by Prof. C. A. Davis, from samples.

Elevation about 755 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Clay and gravel with quicksand and water at 60 ft. and 3 ft. water-bearing gravel at 157 ft	475	475
Sand and gravel	25	500
Woodville?:		
Feldspathic sandstone (335-590 at St. Louis)	50	550
Coal Measures:		
Pyritiferous black shale, coal horizon	25	575
Blue shale	40	615
White shale	22	637
Pebbly sandstone	38	675
Shale sometimes black, coal reported	35	710
Parma sandstone:		
Pyritic sandstone, brine	80	790
Grand Rapids:		
Blue and black sandy shales	70	860
Blue and white gypsum	35	895
Bituminous, dolomitic red or blue argillaceous limestones (cement rock)	120	1015
Upper Marshall or Napoleon:		
Clean white sandstone, brine	85	1100
Lower Marshall:		
Red sandy shale	200	1300
Blue shale	20	1320
Red shales	180	1500
Coldwater:		
Blue shales	75	1575
Brownish fine grained grit, no water	30	1605
Black shales	35	1640
Light yellowish fine sand	40	1680
Dark shale colored limestone or shale	60	1740
Dark blue shale	510	2250
Berea shale:		
Black shale	50	2300
Berea absent?:		
Antrim (Ohio shale):		
Blue shale	60	2360
Black shale	260	2620
Black shale with harder streaks (limestone shells?) Sandy from 2630-2670 ft	130	2750
Traverse Formation:		
Dolomitic limestone	30	2780
Blue shale	20	2800
Sandy limestone, dolomitic	61	2861
Mineral water at 2825 ft. Temp. 98° F.; gas.		

St. Louis. There are two or three deep wells at St. Louis which penetrate the Upper Marshall. The latter is reached at about 1330 feet and yields abundant brine. No definite records are available.

Ithaca. The Ithaca well, though not deep, has a carefully compiled record as published by a local newspaper. The drilling did not reach the Marshall and the 2 feet of light shale at the bottom of the well is probably the top of the Grand Rapids Group.

ITHACA WELL.

Record by the Gratiot Journal.

	Thickness, feet.	Depth, feet.
Pleistocene or surface:		
Surface clay	10	10
Blue clay, stony	70	80
Hardpan	38	118
Gravel	1	119
Hardpan	30	149
Gravel. Considerable water	2	151
Hardpan	40	191
Gravel	4	195
Blue clay	6	201
Hardpan	10	211
Gravel	2	213
Red clay	60	273
Hardpan	4	277
White clay	25	302
Blue clay	8	310
Hardpan: Very hard	10	320
Gravel	5	325
Hardpan	5	330
Woodville (?) sandstone:		
Gray sandstone. Very hard. Bottom of 8-inch casing	2	332
Gray sandstone	4	336
Saginaw Coal Measures:		
Fireclay	3	339
Red sandstone	4	343
Red shale	2	345
Blue shale	4	349
Bottom of 7-inch casing, with two 16 foot lengths, standing up into 8-inch pipe, 15 ft. bagged and swedged out on top. Bottom of this casing is 349 ft. by measurement.		
Blue shale	6	355
Limerock	2	357
Sandstone	5	362
Blue shale	5	367
Dark lime	1	368
White shale	15	383
Black shale	16	399
Light shale	15	414
Blue shale	20	434
Dark lime	6	440
Light shale	22	462
Dark lime	8	470
Sandrock	8	478
Dark lime	2	480
Sandrock	2	482
Light shale	8	490
Sandrock	25	515
Light shale	10	525
Parma:		
Light sandstone	86	611
Grand Rapids Group(?):		
Light shale	2	613

ISABELLA COUNTY.

Mt. Pleasant. In 1903, the city of Mt. Pleasant and the Midland Chemical Company drilled a well over 1550 feet deep penetrating to the lower Marshall, which was struck at about 1400 feet. This well indicates that the corresponding formations are from 200 to 600 feet deeper at Mt. Pleasant than at Alma, Midland, Bay City and Saginaw.

In 1913 W. F. Braun, an oil operator from the Pennsylvania and the Oklahoma fields drilled the deepest well in Michigan on the Riley farm near Mt. Pleasant in sec. 27, T. 14 N. R. 4 E. The record down to the top of the Traverse at 3082 feet is by Mr. Braun, but from that point his record has been supplemented by that obtained from an examination of a complete set of samples, which Mr. Braun kindly preserved and sent to the Michigan Geological Survey.

A comparison of the Alma and the old Mt. Pleasant well records with the new one shows that the rock formations are very similar even in many minor details. The depths to the Berea and the Dundee, however, are greater than calculated. In neither the Alma nor the Braun well is the Berea present in its typical phase as a sandstone. The "limestone and black sand" from 2568 feet to 2598 feet yielding oil at 2590 feet with a specific gravity of 47° Baume, may possibly represent this horizon. Some gas accompanied the oil. Another show of oil occurred in the Antrim black shales at 2632 feet.

In July the well reached the top of the Dundee at 3667 feet, but this formation yielded such a strong flow of water at 3675 feet that the well had to be abandoned at 3680 feet. Generally the upper portion of the Dundee does not yield much water.

Deep drillings at Bay City, Saginaw, Gladwin, Alma and Mt. Pleasant indicate a remarkable uniformity in the character and thickness of the formations down to and including the Dundee, therefore if the formations below the Dundee are as regular in thickness, the Niagara should be found at about 5100 feet and the Trenton at 6200 feet or more. Such depths are so great that the cost of testing the oil possibilities of either one of these formations is out of proportion to the chances for success.

MT. PLEASANT WELL.

(Mt. Pleasant Village and Midland Chemical Company.)

Loc.: 0.65 miles N., 2 miles west of S. E. Cor. of sec. 10, T. 14 N., R. 4 W. Record from samples and notes of A. Borden.

Elevation about 707 (?) ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or drift:		
Gravel, glacial overwash	80	80
Blue till	20	100
Quicksand	20	120
Blue till	160	280
Porous bed with water, coarse gravel on top, fine sand below	74	354
Red clay	26	380
Ground moraine, till with broken coal measures	55	435
Saginaw Coal Measures:		
Black shale with streaks of coal (410,435, 560 ft.), sandstone, limestone or carbonate of iron and fire clay, mostly less than five ft. thick	185	620
Fine white sandrock with mineral water	90	710
Gravelly sandrock, with a strong flow of water not so salt	80	790
Shale and red limestone	30	820
White limestone	30	850
Parma:		
White sandstone with very salt water	120	970
Maxville:		
White limestone, fiercely effervescing	55	1025
Shale	5	1030
Sandstone	20	1050
Michigan Series:		
Dolomite and shale	75	1125
Anhydrite and dolomite	100	1225
Anhydrite, nearly pure (gypsum)	45	1270
Dolomite, shale and anhydrite (gypsum)	103	1373
Sandstone	8	1381
Shale	5	1386
Sandstone	4	1390
Shale	15	1405
Napoleon:		
Sandstone, dark, with heavy brine	145 +	1550 +
Lower Marshall, 1550 + ft.:		
Red rock; well originally 1463 ft. deep, afterwards deepened to be between 1550 ft. and 1585 ft., ending in red rock.		

W. F. BRAUN WELL.

Loc.: On Riley farm, Mt. Pleasant, Mich., W. ½, N. W. ¼ of sec. 27, T. 14 N., R. 4 W. Driller's record to 3082 ft. Record supplemented by samples below this point.

Elevation given as 800 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand loam	2	2
Quicksand and water	16	18
Clay	32	50
Sand and water	8	58
Clay	2	60
Sandy clay	15	75
Quicksand vein, good water	1	76
Sandy clay	13	89
Quicksand	1	90
Sandy clay	10	100
Quicksand	10	110
Gravel	15	125
Gravel and quicksand	47	172
Blue fire clay	45	217
Gravel	5	222
Blue "fire clay"	60	282
Red "sand rock" (boulder?)	10	292
"Fire clay," blue	10	302
Red sand rock (boulder?)	27	329
"Fire clay," pinkish color	41	370
Quicksand and water	5	380
Red "fire clay"	10	390
Gravelly sand	10	400
Saginaw Coal Measures:		
Limestone	5	405
Red sand rock, hard	40	445
Fresh soft water	5	450
Sand rock red	3	453
Black slate (shale)	10	463
Gray sand rock	10	473
Black fire clay	4	477
Gray sand rock	31	508
Black shale	25	533
Gray shaly limestone	10	543
Black shale	124	667
Pure white sand, fresh water	55	722
Red shale	30	752
White soapstone	24	776
Gray limestone	26	802
White shales	9	811
Parma:		
Pure gray salt sand, much brine	124	935
Maxville or Bay Port:		
Limestone gray, very hard	45	980
Mixed limestone, pebbly and sandy	35	1018
Michigan Series:		
Salt blue (shale?)	3	1021
Mixed limestone	6	1027
Blue shale	11	1038
Mixed rock, blue shale and limestone	32	1070
Mixed rock gypsum and clay	35	1105
Gray limestone	10	1115
Blue shale	35	1150
Black shale	10	1160
Gray limestone	10	1170
White limestone	24	1194
Blue shale	6	1200
White limestone	15	1215
Blue shale	25	1240
Gray limestone, very hard	25	1265
Mixed limestone of rock and shale	35	1300
Gray limestone	10	1310
Blue shale	10	1320
Limestone, very hard	10	1330
Blue shale	10	1340
Fine gray sand (top of the Upper Marshall?)	60	1400
Gray limestone	38	1438

W. F. BRAUN WELL.—Continued.

Elevation given as 800 ft. A. T.	Thickness, feet.	Depth, feet.
Upper Marshall or Napoleon:		
Salt sand, gas, sand top; much salt water, 1535 ft. of 8¼ in casing	69	1507
Lower Marshall:		
Red sand rock	75	1582
Coldwater:		
Blue shale	716	2298
Gray shell (carbonate nodule?)	2	2300
Blue shale	15	2315
Gray shell (carbonate nodule?)	3	2318
Blue shale	232	2550
Sunbury shale:		
Brown shale	18	2568
Limestone	4	2572
Brown shale	6	2578
Berea (?) horizon:		
Black sand and shale, showing oil and gas; oil of Sp. gravity of 47°, at 2590 ft	20	2598
Antrim shale:		
White shale	18	2616
Brown shale	40	2656
Black shale	20	2676
Black sand and shale small show of oil; hole reduced to 6½ inches	6	2682
Black shale	233	2915
Black sand, mixed with black shale; mineral ore showing silver (?) and iron ore	13	2928
Black shale	54	2982
Black sand, mixed with black shale, showing mineral ore, silver (?) and iron	13	2995
Black shale, mixed with limestone	15	3010
Black shale	72	3082
Traverse (Hamilton) Formation:		
Salt and pepper limestone; mod. eff. Very little chert. Some particles of black shale from above at 3082.		
Light grayish buff limestone	2	3084
Buff gray limestone, mod. eff. Slightly cherty	2	3086
Grayish buff limestone, pyritic, a little chert; briskly eff	2	3088
Gray limestone, briskly eff	5	3093
Dark buff gray limestone, mod. eff	6	3099
White and dark gray limestone, pyritic; vigorously eff. Some dark gray shale; *calcite* crystals	6	3105
White crystalline limestone and very calcareous shale; some pyrite; vigorously eff	6	3111
Very calcareous blue shale	17	3128
Light gray to dark gray limestone; brisk eff.; calcite fragments	15	3143
Light gray limestone and dark gray shale; brisk eff	7	3150
White to light gray limestone; brisk eff	7	3157
Yellowish gray limestone; violent eff	13	3170
Very cherty white limestone	18	3188
Very cherty fossiliferous (coral, acervularia?) limestone; blue and black shale; violent eff	6	3194
Very cherty fossiliferous (coral) light gray limestone; violent eff.; some blue shale	6	3200
Very cherty light gray limestone, pyritic with some blue shale	6	3206
Very fine white cherty limestone; violent eff	4	3208
Cherty white crystalline limestone; violent eff	2	3210
Yellowish white and very cherty limestone; violent eff	2	3212
White to light gray cherty limestone; violent eff	6	3218
Very cherty white fossiliferous limestone; violent eff	12	3230
Fine grained cherty white limestone; violent eff	4	3234
Buff gray limestone; violent eff.; some dark shale	6	3240
White to light gray cherty limestone; very hard; violent eff	5	3245
Same	15	3260
Light gray limestone; violent eff	16	3276
White limestone; violent eff	20	3296
Light gray with some black limestone and dark gray shale; violent eff	4	3300
Light and dark limestone ("salt and pepper"); violent eff.; some gray shale	6	3306
Dark gray limestone	6	3312

W. F. BRAUN WELL.—Concluded.

Elevation about 800 ft. A. T.	Thickness, feet.	Depth, feet.
Traverse (Hamilton) formation:		
Gray limestone, violent eff	25	3337
Salt and pepper limestone	13	3350
Buff white limestone mixed with some shale	25	3375
Buff gray limestone	9	3384
Light limestone and dark to black shaly limestone	4	3388
Gray limestone mixed with some light limestone	12	3400
White and gray limestone; violent eff	15	3415
Buff gray limestone mixed with some dark; violent eff	12	3427
Hard white to light gray limestone; violent eff	3	3430
White limestone mixed with gray	42	3472
Salt and pepper limestone	8	3480
Gray shale mixed with limestone at 3480.		
Calcareous gray shale	24	3504
Very calcareous light gray shale	2	3506
Calcareous bluish gray shale	10	3516
Dark bluish gray shale mixed with light gray limestone	6	3522
Dark bluish gray shale	11	3533
Calcareous gray shale and limestone	25	3558
Calcareous and fossiliferous gray shale	22	3580
Very dark gray, cherty and fossiliferous limestone and dark calcareous shale	8	3588
Cherty limestone mixed with shale	10	3598
Bluish shaly limestone; some chert; very hard	22	3620
Dark buff gray limestone and black shale; mod. eff	47	3667
Dundee limestone:		
Very hard buff to dark gray limestone; cherty and very pyritous; mod. eff.	8	3675
Very hard, dark buff pyritous limestone; mod. eff	5	3680

So strong a flow of water was struck at 3675 ft. that drilling was stopped at 3680 ft. Temperature at bottom 104° F. Temperature gradient apparently one degree in about 67 ft.

GLADWIN COUNTY.

Gladwin. A very deep well was dril'ed in 1913 at Gladwin for oil by Chas. G. McClure of Saginaw. According to the records of wells in the vicinity of Gladwin rock is from 200 to 400 feet, below the surface but, in the McClure well, the drift was found to be 600 feet in depth and great difficulty was encountered in getting the drive pipe down to rock. Much quicksand and water was found in the drift.

The elevation of this well is not known, but it appears to be about 780 feet above sea level, or nearly 200 feet higher than the Saginaw wells. Mr. McClure, having drilled one well near Gera in Saginaw county and striking the Dundee between 2900 and 3000 feet, inferred that this formation should be struck at about the same depth at Gladwin. The Gera well is on the flat, eastern limb of the Saginaw anticline, and therefore the Dundee is 100 to 150 feet higher than it would be if the normal dip prevailed.

Since Gladwin is 200 feet higher and is not on an anticline, the depth to the Dundee should be several hundred feet greater than in the Gera well, and apparently this is the case. In May, the well reached the depth of 3043 feet, having penetrated the Traverse formation less than 100 feet and operations were temporarily suspended as the normal capacity of the drilling outfit had been exceeded. According to reports another drilling rig was brought in, but on account of the small hole, or other difficulties, the well was abandoned without reaching

the Dundee oil horizon. Since the Traverse in the central part of the Basin is everywhere about 600 feet thick, the Dundee at Gladwin should be struck between 3550 and 3600 feet.

The record was made by the writer from a hasty examination of a set of samples in Mr. McClure's office. The exact thickness of the various strata could not be determined from the data accompanying the samples, hence the record is more or less indefinite.

Assuming that the elevation of the Gladwin well is about 50 feet higher than the Braun well, the dip of the Napoleon from Gladwin to Mt. Pleasant is only about 5 or 6 feet per mile.

McCLURE WELL.

Loc.: Near Gladwin. Chas. G. McClure, owner; drilled in 1913.

Elevation about (?) 790 ft. A. T.	Depth, feet.
Surface	600
Sand with water at 380 ft.	
Saginaw Coal Measures:	
Dark gray shale	600
Parma:	
Sandstone	650
Grand Rapids Group:	
Calcareous green shale	790
Dark gray shale with considerable gypsum	945
White sandstone with brine	950
Light gray limestone and shale	1020
Shaly limestone with gypsum	1030
Dark limy shale	1190
Gray shale with pyrite, gypsum and brine	1230
Napoleon at	1250
White sandstone, with some limestone fragments, pyrite and brine	1300
Lower Marshall:	
Red sandy shale	1350
Coldwater shales:	
Dark gray shales (1425 ft. to)	1675
Gray shales	2150
Richmondville? sandstone:	
Extremely fine grained light gray sandstone, somewhat calcareous, full of small black specks	2170
This sandstone resembles very closely some of the Berea found at Saginaw, but it appears to be too high for the Berea and may be one of the stray sandstones often found in the Coldwater shales at some distance above its base.	
Light gray shales (2205 ft. to)	2275
Dark gray shales but not bituminous at	2350
Antrim:	
Very black and bituminous shale at	2495
Light gray shale	2465
Brownish black bituminous shale (2525 ft. to)	2825
Light gray and brownish shale, mixed	2880
Both black and brown shale, more or less calcareous.	
Very pyritic black shale with some white chert fragments	2900
Very pyritic black shale with some white chert fragments	2940
Traverse (Hamilton) Formation:	
Top probably at about	2970
Light gray limestone with some black particles of shale, probably from the black shale above	2975?
A sample was missing between 2940 and 3025 ft. and this bottle without a label appears to be the missing sample which probably was taken not far from 2975 ft. The top of the Traverse, therefore, should be between 2940 and 2975 ft. and from the amount of black particles in the sample, the top may be nearer 2975 ft.	
Gray limestone fiercely effervescent	3025
Some particles of black shale in this sample, probably from above. These were also calcareous.	
Light gray limestone, fiercely effervescent, cherty and granular. The limestone breaks up into very fine particles	3035
Light gray limestone, fiercely effervescent, cherty and granular. The limestone breaks up into very fine particles	3040
Cherty light buff limestone, moderately effervescent	3043
Well afterwards deepened but amount unknown.	

MECOSTA COUNTY.

Big Rapids. Near Big Rapids a well was drilled to the depth of 1400 feet by A. L. Clark a number of years ago. This well, known as the Red Cross well, entered rock at 600 (?) feet and struck water at 600, 800, 850 and 1300 feet. The brine at 1300 feet is very strong, and is probably from the Marshall. No record of the well is available.

KENT COUNTY.

Grand Rapids. The Grand Rapids Artesian Well Co. sunk a well for water to the depth of 2220 feet. An abundance of fresh water was found in the Upper Marshall sandstone, but it did not flow. Weak brines were struck in the Lower Marshall, mineral water in the Coldwater, a stronger brine from a sandstone in the lower part of the Coldwater, and gas and brine in the top of the Dundee. The black shales of the Antrim yielded a strong smell of gas and oil.

GRAND RAPIDS WELL.

Grand Rapids Artesian Well Co. Record by C. E. Wright.

Elevation between 605 and 639 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or Surface:		
Drift	10	10
Grand Rapids Group:		
Black clay slate	47	57
Plaster rock (gypsum) mixed with clay slate	71	128
Marshall Sandstone:		
Sandstone, dark and light colored	17	145
Sandstone, light gray. Fresh water, increases with depth	95	240
Lower Marshall:		
Hard black coarse sandstone. Increase of fresh water	19	259
Blue clay slate	12	271
Ash-colored sandstone, mixed with clay seams and layers of soapstone; fine texture. Small quantity of weak brine, 20°	129	400
Coldwater shale:		
Sandy shale at top and clay-rock boulders and sheets below	20	420
Light blue to ash-colored shale, with very little change in color except for short places which are little darker. Quite uniform as to hardness. Except these (?), the lower 250 ft. has more hard streaks, and boulders that would make slate pencils	735	1155
Dark hard water-lime from 702 to 712 ft. There is a streak of ten feet from 712 to 722 ft. of calcareous water-lime, dark and hard at top and softer below; but it is all hard rock.		
Dark red clay, soft	20	1175
Sandstone, (Richmondville?) brine 26°, small amount	30	1205
Light to greenish blue shale, mixed with clay rock. Streaks and boulders and streaks of gas-scented material	295	1500
Antrim shale:		
Black slate rock; scent of gas at top and stronger in depth and very strong at bottom	208	1708
Black slate or hard rock; strong odor of gas and oil	67	1775
Traverse (Hamilton) Formation:		
Drab limestone; color changes nearly every foot	52	1827
Drab magnesian limestone	28	1855
Very dark water-lime	10	1865
Each screw changes color	20	1885
Limestone; light gray and medium hard in upper portion and dark drab and hard below	115	2200
Gas, marl, limestone and brine	20	2220

IONIA COUNTY.

Ionia. A comparatively shallow well was drilled near the old sandstone quarries at Ionia many years ago. While it penetrated no oil horizon, the record is inserted as there are so few drillings in this part of the State giving any reliable information concerning the underlying rocks.

IONIA WELL.

Loc.: In vicinity of old sandstone quarries. Record by Mr Blanchard.

	Thickness, feet.	Depth, feet.
Saginaw Coal Measures:		
Sand rock	95	95
80 to 110 ft. in thickness.		
Shales and fire clay	4	99
Coal from 20 in. to 4 ft. at 99 ft.		
Fire clay	2	104
Sand rock, fine grained	40	144
Coal seam, thickness unknown		
Sandrock and shales alternating	306	450
"Copious stream of sweet water at 300 ft." Record not accurate in some places.		

BARRY COUNTY.

Assyria. In 1899 a well was drilled near Assyria (sec. 14, T. 1 N., R. 7 W., about 870 A. T.) but no record is obtainable. According to the driller, John Brogan, the bottom of the Antrim black shale was struck at 1875 feet. In 1903, another well was drilled at Assyria from which a good set of samples was preserved for the Survey by G. D. Connor and J. J. Callender. The latter located the well with an "instrument," but no oil was found, although the well passed through the Dundee. Apparently the well was deepened in the spring of 1904 from 2040 to over 2300 feet, but no record was obtained of the lower part of the drilling.

ASSYRIA WELL.

Loc.: Sec. 9, Assyria Twp.

Elevation 917 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or Surface:		
Soil	2	2
Sand and gravel	38	40
Clay and gravel	15	55
Quicksand with water	7	62
Sandy clay	34	96
Fine sand, clay and gravel	34	130
Clay and gravel	32	162
Michigan Series:		
Limestone, light colored dolomite	1	163
Bluish shale and gypsum	77	240
Napoleon or Marshall:		
Clean white sandstone with water. Came within 100 ft. of top of well	70	310
Dark sandstone	10	320
Lower Marshall:		
Soft blue shale with "heavy black sand"	110	430
Calcareous shale and fine gray sandstone	20	450
Bluish shale, fine and sandy	50	500
Coldwater shale:		
Dark gray shale, very fine grained	575	1075
Typical Coldwater.		
First showing of oil at 560 ft. and water at 900 ft. Brown shale at 1075 ft. is iron carbonate.		
Dark green shale, calcareous	325	1400
Berea horizon:		
Red shale. Typical Bedford	50	1450
Antrim shale:		
Black and bituminous shale	18	1468
Dark blue shale	57	1525
Very black and bituminous shale, smell of gas	175	1700
Very black in part. Smell of gas or ammonia	55	1755
Pyritic and not as calcareous as above.		
Gray shale, hard and calcareous	15	1770
Very black and pyritic shale	40	1810
Traverse (Hamilton) Formation:		
Brown limestone fiercely effervescent	50	1860
Dark and shaly looking.		
Very black shale, very pyritic and quite calcareous. No water below 1875 ft	15	1875
Dundee (Corniferous) limestone:		
Buff limestone, fiercely effervescent	65	1940
Cherty limestone, brownish fiercely eff	35	1975
Pure white limestone, little or no chert, fiercely eff. Brine at 2000 ft., 93° salinometer test	35	2010
Dark brownish tending to drab limestone, fierce eff	15	2025
Light brown limestone; fiercely eff	5	2030
Dark gray limestone, some chert	10	2040
Very fiercely eff. limestone with much brown chert, a little pyrite and some clay at 2040 ft.		
Water at 2300 ft. Filled hole 600 ft. before cased off. No record of the lower part of drilling.		
Total depth	.....	2300 +

EATON COUNTY.

Charlotte. A well 2209 feet in depth was drilled at Charlotte many years ago by E. Shepard and F. W. Higby. The calcareous nature of the Coldwater shales is to be noted as this appears to be rather characteristic of the Coldwater in the western part of the State. The Berea horizon is represented by gritty red shales. This formation exists as a sandstone only on the eastern side of the Basin, being generally represented by red shales in the western half of the State. Brine was reported in the Dundee, but doubtless water was also struck in the Parma and the Marshall sandstones.

CHARLOTTE WELL.

E. Shepard and F. W. Higby. Driller's? record and notes on samples examined by A. C. Lane.

Elevation 906 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Rock	72	72
Woodville or Parma:		
"Fine sandrock." Mainly quartz sand, with a very little calcite and larger bits of dark bluish gray shale; water	88	160
Saginaw Coal Measures. (Perhaps in part Grand Rapids):		
"Fine shale." Quite dark bluish, with black specks (fossiliferous?), very finely divided quartz, much clayey matter and but a trace of calcite	210	370
Grand Rapids Group:		
"Fine sand rock." A somewhat sandy, medium gray shale; no reaction for gypsum; a trace of calcareous matter. There are some fragments very fine grained, but quite gritty	200	570
Upper Marshall or Napoleon:		
"Soft sand." Fine grained; quite calcareous; greenish gray sandstone, showing under the lens distinctly the rounded grains of colorless quartz. One larger piece shows distinctly the grayish or greenish white sandstone, with the rounded quartz sand and occasional specks of mica	110	680
Coldwater shale (Some of the top is probably Lower Marshall):		
"Shale and sand." Argillaceous limestone, with a little quartz and green earth; greenish gray	320	1000
Much like the preceding 320 ft.		
Calcareous shale, eff. briskly	150	1150
"Soft sand?" Much of the matter greenish gray argillaceous, as in previous samples, but there are also fragments of siderite or dolomite, often brownish. These may represent nodules of kidney iron ore	310	1460
"Sand and slate." Somewhat sandy limestone; contains some brown and white mica. (Richmondville?)	40	1500
"Soft slate." Calcareous shale with traces of quartz	160	1660
Berea (?):		
"Hard sand." Gritty calcareous shale. In the whole preceding section there is no distinct break	20	1680
"Red rock." Calcareous red shale; gritty; ferruginous	20	1700
Antrim shale:		
"Shale." Black shale, with occasional harder reddish fragments, barely calcareous	200	1900
"Shale." Brownish black bituminous shale, non-calcareous; burns with an aromatic smoke	30	1930
Traverse (Hamilton) Formation:		
"Shale." Shows frequent pyrite; black bituminous and gray grains, slightly calcareous	20	1950
"Shale." Gray calcareous shale with bits of calcite from fossils	30	1980
"Shale and lime." Highly fossiliferous shale full of bits of brachiopods(?) and of black matter	5	1985
Dundee (Corniferous) limestone:		
"Top of limestone." Gray limestone, briskly eff	15	2000
"Limestone." Brine at 2050 ft.; eff. briskly, with a cherty residue and a little quartz. All these limestones down to 2121 ft. are yellowish or buff ferruginous with magnetite	50	2050
Brine:		
Sp. g. 1. 198.		
Salin .97°.		
"Limestone." Eff. briskly	35	2085
"Limestone." Acid water in it. Eff. briskly: residue of cherty dolomite, quartz, magnetite and pyrite	15	2100
"Limestone;" hard water under it. Eff. briskly; residue of chert, quartz, green grains, with iron rust, magnetite and pyrite	2	2102
"Limestone;" like previous sample, residue larger	3	2105
"Limestone;" damp, reacts faintly from sulphates (gypsum), like previous sample	16	2121
"Limestone." Buff to gray, with little fragments of iron ore in thin seams (hematite; magnetic), but little quartz and no chert	29	2150
"Limestone." Buff to gray; slight residue of chert and quartz	59	2209
Driller's (?) record in quotation marks.		

Grand Ledge.—A comparatively shallow well was drilled at Grand Ledge a few years ago, but only a meagre record is available.

TABER WELL.

Record by W. D. Southworth.

Elevation about 860 ft. A. T.	Thickness, feet.	Depth, feet.
Coal Measures:		
Sandstone	75	75
Coal	2½	77½
Sandrock. Fresh water at 110 ft. in sandrock and large vein at 287 ft.	222½	300
Michigan Series:		
Chalk rock	3	303
Shale. Mineral water at 385 feet	209	512

Eaton Rapids. In 1910 and 1911, two wells were sunk for oil in Eaton county, one at Smithville near Eaton Rapids, and the other about one mile south of Delta on the J. Hitchcock farm. The Eaton Rapids well reached a depth of at least 2005 feet for samples from 1510 to 2005 feet were preserved for the Survey. The samples above 1510 feet were never received. The well appears to have reached the Berea horizon, but no marked signs of gas and oil were observed at any horizon, according to reports. The well was not finished owing to legal troubles or other difficulties.

EATON RAPIDS OIL WELL.

Loc.: Smithville, Hamlin township, Eaton county. A. E. Smith, owner, Jno. Flanagan and J. A. Gardner, drillers. Samples by A. E. Smith.

Elevation about 900? ft. A. T.	Thickness, feet.	Depth, feet.
Samples missing to	.....	1510
Coldwater:		
Light gray shale	30	1540
Light gray shale, slightly gritty	30	1570
Light gray shale, non-calcareous	30	1600
Light gray shale	150	1750
Light gray shale, gritty	90	1840
Gray shale with red streaks	60	1900
Red and white shale (oxidized after exposure to air?)	80	1980
Berea at about 1975 ft.?:		
Antrim (Sunbury?):		
Pyritic black shale	10	1990
Sandstone (Berea?) conglomeratic, chert, feldspar, epidote?, magnetite, green and white quartz, limonite fragment, dark sandstone, fragments of black shale, calcite	5	1995
Black shale and limestone	10	2005

Delta. The Delta well, about 2330 feet in depth, was started in 1911 and work was not finally abandoned until the fall of 1912. The location of the well was made by the use of an "instrument" but little or no trace of oil was found, although the drill apparently penetrated the Dundee about 30 feet.

The well appears to have been started without any knowledge concerning the character, thickness and depth of the formations, or of the water and probable oil horizons; as a consequence, much time and money were wasted in casing off the numerous water bearing strata down to the Coldwater shales. According to reports, the casing was pulled and the hole reamed out 8 or 9 times before the last water horizon above the Coldwater was passed. The depth to the oil horizon appears to have been greatly underestimated, so that the drilling outfit brought in was inadequate for penetrating to the depth necessary to reach the Dundee oil horizon. Indeed, the drilling had to stop when supposedly within only a few feet of the coveted goal. Samples were taken and a log was kept by Mr. Ricker, owner of the well, but no record and only a partial set of samples reached the Survey. The following is the log compiled from verbal statements of one of the drillers and Mr. Ricker and from an examination of the partial set of samples.

DELTA WELL.

Loc.: One mile south of Delta on Carrier Creek, sec. 10, Delta township, Eaton county. E. Hitchcock farm.

Elevation about 830 ft. A. T.	Thickness, feet.	Depth, feet.
Surface	40	40
No record. (Much white sandstone, some shale, with big flow of fresh water above 428 ft.)	.....	.....
Grand Rapids:		
Dolomitic sandstone similar to 875 ft. at	.....	544
No record. (Much sandstone and some shale)	196	740
Calcareous white sandstone	10	750
Dolomite and sandstone	10	760
Light gray shale, soft	5	765
Upper Marshall:		
Fine white sandstone	15	780
Much water (artesian) down to Coldwater.		
Fine grayish white dolomitic sandstone	50	830
Lower Marshall:		
Red sand and gray shale	5	835
Fine gray dolomitic sand	5	840
Very fine dolomitic sand	5	845
Very fine dolomitic sand, very sandy	10	855
Dolomitic gray limestone, slow eff. in cold HCl	10	865
White and very fine white sandy dolomite	25	890
Coldwater shale:		
Gray calcareous shale	10	900
Samples missing, probably blue and gray shales	300	1200
Gray shale, fossiliferous at	.....	1200
Samples missing, probably blue shale	575	1775
Mineral water from sandstone lens in the Coldwater, 10-15 bbls. per day.		
Gray dolomite	2	1777
Gray shale	73	1850
Extremely fine grained gray sandstone (Berea?), ferruginous with fine black specks similar to Saginaw Berea. Richmondville?	45	1895
Light gray calcareous shale	5	1900
Argillaceous dolomitic limestone, cherty	5	1905
Berea?:		
Red shale, calcareous	5	1910
Antrim shale:		
Dark gray shale	5	1915
Black and very bituminous shale at	.....	1950
Dundee limestone:		
Cherty shell at 2304 ft.:		
Buff or brown limestone, fiercely eff. Some chert, pyrite, and limonite fragments. (From pyrite?). Dundee very hard. According to Mr. Ricker the shell at 2304 ft. required 36 hours to penetrate. The artesian flow above 425 ft. was very strong and the water fresh, though there was a slight smell of "sulphur"	.....	2330

Comparing the top of the Antrim black shale in the Charlotte and Delta wells, the dip is about 16 feet per mile to the north which is comparable to the dip of 17 feet per mile northeast from Kalamazoo to Charlotte. The striking fact is, however, that the black shale in the Eaton Rapids and Delta wells are practically at the same level, indicating little or no dip directly northward from the first place, therefore a structural bench, or possibly an anticline may exist between Eaton Rapids and Delta. More reliable data, however, is necessary before a positive statement is warranted.

INGHAM COUNTY.

Lansing. There are several drillings at Lansing from 350 to 1400 feet deep. The Hoffman well 700 feet and the old Lansing Magnetic 1400 feet in depth flow, but the water in both wells comes from the upper strata. Dr. Lane suggests that the latter well may have reached the Berea, but this is hardly possible for the Berea in the Eaton Rapids and Delta wells appears to be fully 1900 feet or more below the surface. Unfortunately no record of the rock strata penetrated in the old Magnetic well was kept. The record of the well at the State Industrial School is given below.

INDUSTRIAL SCHOOL WELL.

Loc.: At the School in the eastern part of Lansing.

Elevation about 840 ft. A. T.	Thickness, feet.	Depth, feet.
Clay and gravel	36	36
Sand and gravel	5	41
Sandy hardpan	4	45
Lake sand and gravel	39	84
Clay, sand and gravel	16	100
Lake sand and gravel	1	101
Coal Measures:		
Soft sand rock	3	104
Hard fire clay	4	108
Soft white sand rock	13	121
Soft sandy fire clay	15	136
Hard sand rock	119	255
101 to 255 is sandstone. "first water"—Winchell.		
Hard fire clay alternating with beds of sand rock, variable in color from whitish to blue	64	319
Cherty lime	1	320
Gray lime	4	324
Sandy fire clay mixed with seams of hard rock	51	375
Soft sand rock	37	412
Hard gray limestone	2	414
Soft white sand rock	15	429
Blue limestone	1	430
White fire clay	1	431
Sand rock	4	435
Fire clay with iron pyrites	50	485
Soft sand rock	5	490
Blue limestone	16½	506½

Mason. The E. Strope well at Mason is about 650 feet deep and flows a weak stream. The upper rocks down to 200 feet are mainly sandstone increasing in porosity with depth and yielding abundant water.

JACKSON COUNTY.

Jackson. At Jackson, three wells, respectively 2455, 2174, and 2100 feet in depth, have been drilled. The No. 1, or Worthington & Cooley Manufacturing Company well probably reached nearly to the bottom of the Monroe formation. An abundance of water was struck in the Marshall (including Parma?) with an "extra" flow at 218 feet, near the middle of the Coldwater, in the top of the Dundee, and at several lower horizons. According to the record, about 270 feet of "black shale" forms the base of the Coldwater, but only the last 28 feet is described as bituminous. The Berea is present, but it is very shaly. There is about 50 feet of blue sandstone at 660 feet in the Coldwater which, in Volume V, Dr. Lane correlated with the Marshall. The Antrim is characteristically black, the Traverse thin but typical with its calcareous shales or "soapstones," and the Dundee shows the exceptional thickness of over 250 feet.

JACKSON WELL.

Loc.: Worthington & Cooley Mfg. Co. R. M. Decker & Co., drillers. Record from driller's log and samples.

Elevation 928 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or Surface:		
Quicksand and clay	22	22
Saginaw Coal Measures:		
Shelly sandstone	14	36
Black shale	10	46
Fine gravel (conglomerate)	5	51
Black shale (fireclay?)	32	83
Limestone	5	88
Grand Rapids Group?	.....	?
Marshall (Plus Parma at top?) sandstone:		
Mainly calcareous gray sandstone with minor amounts of argillaceous sandstone. Part of the bottom may be limestone or shale as shown in the other Jackson wells	285	373
Extra flow of water at 210 ft.		
Black shale	7	380
Blue sand	5	385
Dark shale and calcareous drab sandstone	30	415
Dark gray shale and blue sand (light gray to dark drab shale)	15	430
Dark gray shale and sandstone	15	445
Coldwater shale:		
Dark shales slightly calcareous at some horizons	215	660
Blue sandstone slightly calcareous	50	710
One foot of brown limestone at 665 ft.		
Dark gray clay shale	420	1130
Sandstone at 725 ft.		
One foot of limestone at 770 ft.		
Water commenced to flow at 1050 (?) ft. after nearly ceasing just before this depth.		
"Black" shale	208	1338
Some show of limestone at 1255 ft.		
Dark drab shale with 10 per cent brownish red at 1338 ft.		
Reddish brown shale	34	1372
Bituminous black shale (called coal)	3	1375
Dark gray and black (Sunbury) shale	25	1400
Berea Grit.		
Sandy shales	65	1465
Antrim Shale:		
Dark gray shale	10	1475
Bituminous black shale	135	1610
Very black shale at 1555 ft. with some smell of petroleum; also at 1570 feet.		
Blue shale	14	1624
Black shale	36	1660
Petroleum smell at 1655 ft.		
Brownish black calcareous shale	45	1705
Thin hard flinty shell at 1705 ft. Samples show bituminous black shale.		
Traverse (Hamilton) Formation:		
Dark gray calcareous shale	55	1760
Dundee (Corniferous) limestone:		
Limestone changeable in color; cherty or sandy. Brine at 1765 ft	82	1842
Very hard white shell at 1842 ft.		
Sandy limestone; "could run only 2 feet before sharpening; bitter water".	6	1848
Limestone calcareous and argillaceous; mainly gray in color, some yellow	19	1867
Calcareous blue shale	17	1884
Limestone gray, yellow or buff in color, often cherty or shaly	131	2015
Monroe Formation:		
Dolomite with anhydrite and gypsum with an abundance of marls of various colors. The marls are very salty, sometimes quite sandy and often with 10 to 20 per cent of gypsum or anhydrite	385	2400
Sandy dolomite	45	2445
Marls with chert, anhydrite with more or less salt and quite ferruginous; some gas	10	2455

The Woodworth well was drilled in the northern part of the city in 1883 and only a driller's (Fred Saeger) record is available.

JACKSON NO. 2 WELL.

Loc.: Woodworth's farm, north side of city. Driller's (?) (Fred Saeger) record, 1883.

	Thickness, feet.	Depth, feet.
Surface:		
Clay	6	6
Gravel	14	20
Saginaw Formation:		
Brown limestone (Grand Rapids Group?)	30	50
Fine clay	90	140
Marshall Formation:		
Sandrock	160	300
Coldwater shale:		
White shale	815	1115
Sandy shale, brackish. Brine	6	1121
White shale	289	1410
Berea?:		
Red shale	8	1418
Antrim shale:		
White shale	11	1429
Brown limestone	1	1430
Black shale	15	1445
White shale	52	1497
Sandy shale	15	1512
White shale	15	1527
Brown limestone	3	1530
Brown shale, contains gas	71	1601
Brown shale	99	1710
Black shale	20	1730
White lime	12	1742
Black shale	25	1767
Traverse Formation:		
White shale	40	1807
Sandy shale	10	1817
Dundee (Corniferous) limestone:		
Brown lime	228	2045
Monroe Formation:		
White shale (i. e. anhydrite—L)	9	2054
Sandrock	15	2069
White shale	10	2079
Sandrock	12	2091
White shale	15	2106
Gray lime	2	2108
White shale	15	2123
Porous sandstone, salt rock	5	2128
White shale	15	2143
Gas rock	20	2163
White shale	10	2173

The Jackson No. 3 well was drilled near Francis and Milwaukee streets and was begun in 1863. Only a very incomplete record is available.

JACKSON WELL NO. 3.

Loc.: Francis and Milwaukee Sts. Driller's record. 1863.

	Thickness, feet.	Depth, feet.
Surface:		
Drift	5	5
Saginaw Coal Measures:		
Sandstone	60	65
Fire clay. Pronounced first class by gas-retort men	23	88
Marshall:		
Sandstone	203	291
Coldwater:		
Limestone	97	388
Slate	340	728
Saline from 685 ft. on increasingly.		
Salt water at 1040 ft. 20 per cent salt.		
Oil in traces at 1395 ft.		
Argillaceous slate at 1443 ft.		
Reached 1800 ft. on February 12, 1864.		
Reached 2000 ft. on June 4th, 1864.		
Bottom 2100 ft.		

CALHOUN COUNTY.

Goguac Lake. The Marshall sandstone underlies the surface in Calhoun county throughout a belt extending from the northwest to the southeast. None of the wells for water at Albion, Marshall, and Battle Creek are over 500 feet in depth, as water is generally struck in abundance in the sandstone at shallow depths. A few of the test wells however, penetrate the Coldwater shale 200 or 300 feet. In the Goguac lake well near Battle Creek, traces of oil were found in these shales.

GOGUAC LAKE WELL NO. 6.

Loc.: At Goguac Lake near Battle Creek. Drilled in 1902 for Battle Creek Water Works by Sim Coleman. Size of pipe 8 inches. Record by W. F. Cooper.

Elevation 903 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Lake sand and cement gravel	15	15
Fine lake sand	55	70
Dark sand and gravel with strong taste and smell of "sulphur"	10	80
Quicksand with some lake sand	118	198
Soft blue clay, with some coarse gravel with some streaks of light gray sand rock	10	208
Coldwater shale:	198	407
Blue shale		
At 287 ft. found indications of oil in dump from sand pump. Estimated one gill of oil to 10 gallons of dump.—Cooper.		
Hard gray sand rock	3	410
Soft blue shale	20	430

LIVINGSTON, SHIAWASSEE AND CLINTON COUNTIES.

Local Geology. A comparison of the wells from Genesee and from southeastern Saginaw county, southwest to Eaton and Barry counties

across the southeastern part of the Central Basin indicates that the strata in northwestern Livingston and southern Shiawassee counties are higher than to the northeast or southwest, contrary to what should be expected. Unfortunately, the wells in these two counties are too shallow to reach horizons which can be definitely recognized, or their records are of such doubtful character, that the evidence indicating the presence of an anticline is inconclusive.

On the eastern side of the Basin, the Berea sandstone appears to have been struck at 1545 feet at Blackmar (610 ft. A. T.), 1500 feet at Columbiaville, and 1200 feet at Flint (723 ft. A. T.) West of the meridian of Jackson the Berea is apparently absent, but its horizon is usually represented by red shales, generally very sandy. At Jackson this red horizon occurs at 1410 feet, at Eaton Rapids (900± ft. A. T.) 1980 or 1995 feet, at Charlotte (906 ft. A. T.), 1680 feet, at Assyria (917 ft. A. T.) 1400 feet, and at Delta (830± ft. A. T.) 1905 feet. The sandstone horizon at the bottom of the old mineral well at Lansing could not have penetrated this horizon at 1400 feet as shown by the Eaton Rapids and Delta wells.

Near Morrice close to the Looking Glass river (850 ft. A. T.) on sec. 25, T. 6 N., R. 2 E., C. W. Gale drilled a deep well in the 60's. The record obtained is one from memory, and it appears that the well was drilled to the depth of about 1135 feet and much black shale and also "blue clay" were struck. A strong brine was struck at the bottom which according to reports flowed and did not smell of sulphur. A little oil used to occur on the surface of the river.

Little dependence should be placed on such a record as drillers are careless in their observations and statements, and too often they pay little attention to the character of the horizons above the one which they desire to reach. The great amount of blue clay and black shale reported in the well, however, is similar to the Coldwater and the Antrim. It is also to be noted that in the Jackson No. 1 well, according to C. E. Wright, the upper part of the Coldwater is drab "slate" and the lower 270 feet including the Sunbury shale, "black slate," but in the other wells at Jackson, however, there are only white shales according to the drillers' records. The Durand and Howell wells and the Jason and Shumway well (1000 ft. A. T.) northwest of Fowlerville on the Grill farm, sec. 17, T. 4 N., R. 3 E., likewise show the same abundance of black or brown shales. According to Lane, the brown shales of the Jason and Shumway well may correspond to the Coldwater, the coarse brine bearing sandstone between 600 and 800 feet to the Berea, and the black shales beneath the latter to the Antrim. Lane argues that if this sandstone is the Marshall then there is an abnormal amount of black shale associated with it, for, as a rule,

black shales are rarely found in association with this formation, but are nearly always associated with the Berea.

According to the village clerk, in the municipal well for water at Perry, Shiawassee county, drilled in 1914, blue shale extends from about 200 to 600 feet with about 30 feet of water "gravel" (conglomerate?) below 250 feet. The well was continued to 725 feet where brine was encountered. The Perry well is only about 7 miles northwest of the Jason-Shumway well and the brine horizon at 725 feet may correspond to that at 600 feet in the latter since the elevation of the two wells is about the same and the rock strata dip to the northwest. The preponderance of "blue rock" in the Perry well tends to throw doubt on the reports of so much black shale in the Jason-Shumway well. Quite possibly dark shale has been reported as black shale by the drillers. The 270 feet of "black shale" above the Berea in the Jackson No. 1, however, is comparable in amount to that in the Shumway well above the coarse brine bearing sandstone supposed to be the Berea, this sandstone may be the Richmondville or a stray sandstone in the Coldwater above the true Berea horizon.

If this sandstone in the Morrice and the Jason-Shumway wells is the Berea, then there is a very pronounced arching of the strata in the vicinity of Fowlerville. (Fig. 2). If such is the case, it is difficult to explain the absence of the Marshall and a large part of the Upper Coldwater. Lane advances the idea that this uplift and arching preceded the deposition of the Coal Measures but not that of the Grand Rapids Series, in which case, the Grand Rapids Series, and locally the Marshall, and Upper Coldwater were either not deposited or were eroded away. This would bring the Parma sandstone directly above the Coldwater or above the Marshall. In the latter case, the Marshall and the Parma could not be distinguished, as they are very similar in appearance.

There is further evidence in support of Dr. Lane's hypothesis of a pre-Coal Measure uplift and folding. From the studies of Dr. Sherzer in southeastern Michigan, the formations, down to the Traverse at least, are about 200 feet higher at Ann Arbor than they are on either side at Adrian and Pontiac. This fold, which is nearly 70 miles in breadth apparently pitches northwest in the direction of Livingston county, and perhaps is directly related to the supposed fold in the latter county, which, if it exists, probably runs northwest from Fowlerville through Laingsburg or its vicinity.

It must be admitted that the evidence, while highly suggestive, is not sufficient to draw a positive conclusion. A carefully made drilling to the Dundee in northwestern Livingston county, or in southeastern Shiawassee county would doubtless prove whether or not there is a pronounced anticline as indicated by the evidence.

LIVINGSTON COUNTY.

Fowlerville. The Jason-Shumway well, northwest of Fowlerville, though full of strong pure brine and plugged, constantly leaked gas which came from the sandstone mentioned in the previous paragraphs. The abundance of black or brown shale is not unfavorable for the occurrence of oil and gas.

JASON-SHUMWAY WELL.

Loc.: Sec. 17, T. 4 N., R. 3 E., Grill Farm.

Elevation of well 900 ft. A. T.	Thickness, feet.	Depth, feet.
Surface to rock (8-in. drive pipe)	95	95
Slate (at 120 ft. oily at the house)	35	130
Shale (gas at 155 ft.)	63	193
Gray sand (dry well from 200-600 ft.)	25	218
Brown shale (gas at 380 and 600 ft.)	382	600
8-in. hole for 587 ft., cased at that depth with 5 7-8 in. casing.		
Coarse gritty sand with salt water (Berea?)	200	800
As analyzed, filled the well, and slowly oozed out in spite of a plug, with bubbles of fuel gas, and a temp. of 65%.		
Black shale	20	820
Brown shale	150	970

Fowlerville.—In the northwesten part of Livingston county about 4 miles southeast of Fowlerville, oil was struck apparently in dark sandstone lens in blue shale at the depth of only about 157 feet. The oil horizon is in the Coal Measures, which underlie the northwestern half of Livingston county. The well, if pumped, might have yielded half a barrel of oil per day.

FOWLERVILLE OIL WELL.

Loc.: Two miles south and 2 3-4 miles east of Fowlerville in N. E. ¼ of sec. 6, T. 3 N., R. 4 E. Henry White farm. 1903.

	Thickness, feet.	Depth, feet.
Pleistocene:		
Clay	30	30
Sand	8	38
Gravel	2	40
Sand	6	46
Blue clay	28	74
Sand	30	104
Gravel	2	106
Sand and gravel	22	128
Coal Measures:		
Sandrock	8	136
Blue shale with oil and gas, the flow being estimated at about one-half barrel per day	30	166
Dark sandstone at 157 ft.		

SHIAWASSEE COUNTY.

Owosso. Four miles northeast of Owosso, C. W. Collyer in 1863, as it appears, drilled a well 1000 feet deep. The Marshall was struck at 556 feet, but, below 601 feet, white and blue shales with red horizons predominated. The Grand Rapids Group appears to be little represented, probably eroded or not deposited as it is absent farther east.

OWOSSO WELL.

Loc.: Four miles northeast of town. C. W. Collyer, 1863.

Elevation 745 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Gravel, sand, etc	94	94
Jackson Coal Series:		
Gravel and clay	6	100
Clay, mixed with sand and gravel	26	126
Shale	20	145
Coal	4	150
Shale	100	250
Parma sandstone:		
Sandrock	47	297
Sandrock, very hard	4	301
Sandrock	103	404
Sandrock of white quartz pebbles; resembles split peas	31	435
Sandstone	38	473
Grand Rapids Series:		
Limerock (dissolves in acid)	3	476
Blue shale	29	505
Blue shale	28	533
Brown lime-rock	3	536
Soapstone. Brine at 541 ft	20	556
Upper Marshall:		
Sandstone	45	601
Brine at 557, 572 and 601 ft.		
Coldwater and Lower Marshall:		
White shale and sand, brine at 616 and 633 ft	115	716
Blue shale	23	739
White shale (gray)	50	789
Blue shale	31	820
Brown shale and white lime-rock	9	829
Blue shale	15	844
Blue limestone	7	851
Red shale	3	854
Blue shale	32	886
Red shale	3	889
Blue shale	64	953
Red shale	10	963
Blue shale	37	1000

Durand. The rock strata in the Durand well are so variable in character, that it is hard to correlate them with the rock strata at Owosso. Lane thinks that, if the anticline mentioned on previous pages is present in Livingston county, the structure extends southeast to Durand, and the Marshall is not represented.

DURAND WELL.

Record from blue print furnished by Grand Trunk R. R.

Elevation about 790 (?) A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface clays	12	12
Quicksand	7	19
Gravel	4	23
Hardpan	18	41
Gravel	2	43
Hardpan	19	62
Gravel	1	63
Hardpan	15	78
Blue clay	10	88
Hardpan	10	98
Gravel	2	100
Hardpan	9	109
Saginaw Coal Measures:		
Brown shale	65	174
Parma:		
8 in. casing to 176 ft.		
Water bearing gravel	4	178
If this is really under shale it must be a conglomerate.		
Hardpan and stones	60	238
Iron casing 208 ft.		
Grand Rapids (?) or Lower Marshall:		
6 in. casing to 267 ft. 89 ft. farther.		
Black shale	103	341
Well plugged at 332 ft.		
Blue shale	2	343
Black shale	12	355
Limestone	1	356
White shale	67	423
Green shale	10	433
White shale	54	487
Blue shale	20	507
Limestone	1	508
Blue shale	92	600
Limestone	5	605
White shale	14	619
Blue shale	24	643
Salt bearing sandstone	5	648
Well yields 4 gallons of brine per minute.		

CLINTON COUNTY.

St. Johns. Near the Water Works at St. Johns are three deep wells ranging from 574 to 780 feet in depth. The record of the No. 3, obtained as this report went to press, shows that the Marshall sandstone occurs at 700 feet below the surface.

ST. JOHNS WATERWORKS WELL.

Loc.: At plant.

Elevation about 765 + ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Clay with thin layers of quicksand	40	40
(This indicates the depth of the moraine at St. Johns. There is a heavy water bed at 28 ft., but the supply is too near the surface to be considered safe.)		
Coarse gravel	112	152
Saginaw Coal Measures:		
Red sandstone, bearing some water	20	172
Blue shale	202	374
Black shale with alternating hard and soft layers	1	375
White, water bearing sand rock (Parma?)	150	525
Gray, water bearing sand rock	10	535
Michigan Series?		
Black shale	15	550
Blue shale	24	574

ST. JOHNS WATER WORKS WELL.

Loc.: At water and lighting plant. Record No. 2.

Elevation 753 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Blue clay	19	19
Pipe clay	12	31
Clay and hardpan	61	92
Stony and hardpan	19	111
Granite boulder	2½	113
Soft clay	10	123
Gravel and hardpan	13	136
Hardpan	5	141
Coal Measures:		
Red sandrock	5	146
Sandrock	20	166
Gray sandrock	17	183
Yellow sandrock	17	200
To shale rock	14	214
Shale rock	3	217
Slate rock	26	243
Blue sandrock	21	264
Yellow sandrock	23	287
Yellow hard and lighter	51	338
Parma sandstone:		
Sandrock	6	344
Hard blue sandrock	44	388
Water rock	23	411
Blue sand, harder	45	456
Maxville or Bay Port:		
Slate	12	468
White sand	10	478
Water rock sand	17	495
Blue packed sand	22	517
White water rock	10	527
Blue sand	13	540
Michigan Series:		
Hard strata	10′ 4″	541′ 4″
Blue sand to white	18′	559′ 4″
	3′	652′ 4″
Hard blue sandrock	27′	589′ 4″
Blue shale and sandrock (Very hard).	19′	608′ 4″

WATERWORKS WELL NO. 3.

Loc.: Three hundred ft. north of Electric Light and Water Works, St. Johns; 10 inch well 301 ft. in depth, drilled in 1908; deepened in 1914 to 780 ft.; 6 inch hole. A. R. Purcell, Jackson, contractor; Chance Emley, driller. Record of 10 inch hole from records of Water Works Dept., remainder of record by R. A. Smith from samples and information furnished by Archie Bishop, Supt. Electric Light and Water Works.

Elevation 753 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Clay	10	10
Clay and gravel	20	30
Water sand	20	50
Fine sand and clay	20	70
Fine sand and blue clay	10	80
Blue clay	10	90
Clay and sand	22	112
Coarse water gravel	31	143
Red clay	8	151
Saginaw Coal Measures:		
Red sand rock	6	157
White sand rock	4	161
Soapstone (probably "fire clay" or calcareous shale)	10	171
Blue shale	3	174
Red sandstone	9	183
White sandstone	5	188
Red sandstone	12	200
Blue shale	15	215
White sandstone	12	227
Soapstone	10	237
Red sand rock	10	247
White sand rock	8	255
Blue shale	10	265
Soapstone; end of 10 inch hole	36	301
Parma sandstone:		
Sandstone (Sandstone struck just below the bottom of the 10 inch hole, as reported by A. Bishop, Supt.)	24	325
Fine white sandstone	100	425
White sandstone; coarse and pyritic; water	25	450
Maxville, or Bay Port limestone. Upper Grand Rapids:		
Gray limestone; vig. eff. Sample marked 150 to 520 and next sample 500 to 540	70 or 50	520 or 500
Grayish white sandstone, pyritic	20 or 40	540
Michigan Series or Lower Grand Rapids:		
Gray limestone with much sandstone; the latter apparently from the sandstone directly above	10	550
Snow white gypsum and some shale	30	580
Dark gray shale and white gypsum	120	700
Napoleon or Upper Marshall:		
White sandstone and strong brine	60	760
Gray sandstone and shale	20	780
Well bottomed in white sandstone at 780 feet. Water rises to within 34 feet of surface. Can lower the head but six feet.		

CHAPTER VII.

THE SOUTHWESTERN DISTRICT.

A large number of deep wells have been drilled for oil and water at various places in the southwestern part of the State as at Kalamazoo, Assyria, Dowagiac, Berrien Springs, Bridgman, Benton Harbor, Niles, White Pigeon, Constantine, and Allegan.

ALLEGAN COUNTY.

Though oil and gas were struck in many of the wells, only at Allegan has oil been found in possibly commercial quantities. Nearly a dozen wells 1300-1400 feet in depth have been drilled in and about the city in the last twenty or twenty-five years.

Allegan. About fifteen years ago the Allegan Gas, Oil & Mining Company drilled a number of wells at Allegan. According to Mr. J. G. Ellinger, president of the Company, their No. 1 well, which was located on the river flats near the Pere Marquette depot produced about 5 barrels per day natural, and this was not appreciably increased by shooting The well was 1275 feet in depth, oil occurring in the sandy shales at 1245 feet and in a sandy limestone at the top of the Dundee at 1256 feet. For six weeks their No. 2 yielded about 3 barrels of oil per day of 24 hours and nearly enough gas to fire the boiler.

The sand was struck at 1328 feet practically at the same level as in the No. 1, as shown on the contour map (fig. 13). Both of these wells were abandoned as not being worth operating. The No. 3 (?) well was absolutely dry although the "sand," according to the drillers, looked very promising. This well, 1411 feet deep, was located on the higher ground in the eastern part of the city.

In 1912, the Northern Oil and Gas Company drilled two wells, the first on "high ground" near the southwest corner of the N. E. $\frac{1}{4}$ of section 32, Allegan township, and the second in section 28 on the river flats, 1800 feet north of the No. 1 well of the Allegan Gas, Oil & Mining Company. The No. 1 well was drilled to the depth of 1387 feet, the Dundee limestone, the "oil sand," being struck at 1318 feet, but very little oil was found even after shooting. There is an upper thin "sand" separated from a lower but much thicker one. In this well, the surface deposits were found to be exceptionally thick, rock being struck at 355 feet. Great quantities of water and hard "lime

shells," probably chert beds and siderite nodules, were encountered. The cherty "lime" just beneath the drift is about 75 feet thick and, near its base, it yielded a heavy flow of water upon which the bailer "running at top speed" could make no impression. It took several months to complete the well.

In the No. 2 well, 1340 feet in depth, the surface deposits were found to be only 87 feet deep, and little or no water was struck in the bed rock except in the lower part of the Dundee below the oil horizon. No casing outside of the drive pipe would have been needed. Owing to the soft character of the rocks and the absence of water troubles the well was completed in 13 days.

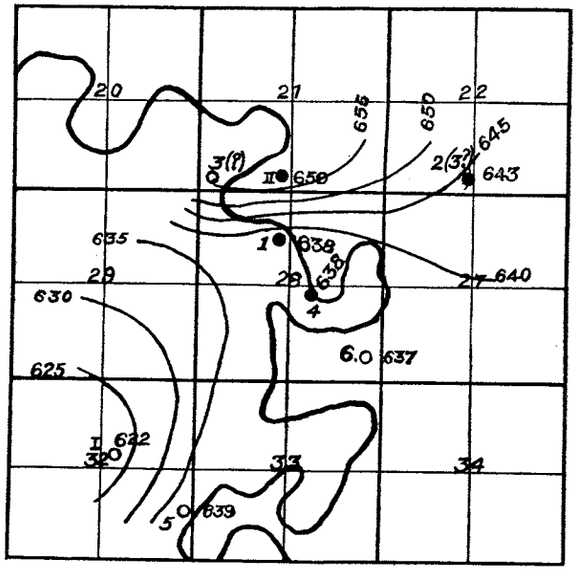


Figure. 13. Contour map showing the depth of the Dundee limestone below sea level in the vicinity of Allegan and the location of borings.
Roman numerals refer to the wells of the Northern Oil and Gas Company; Arabic to the older explorations.

Oil was struck at 1287 feet apparently in commercial quantity. The two oil "sands" separated by a few feet of gritty limestone consist of light buff to gray limestones of the Dundee. The well was shot December 6, 1912, with 120 quarts of nitro-glycerine, 60 quarts in each sand. Upon pumping, the well yielded about two barrels of oil per day and a little water.

The oil is dark reddish brown, smells of "sulphur" and tested about 36° Baume according to Mr. Mercer, president of the company. Little or no gas accompanied the oil.

Three of the wells drilled in Allegan yielded from 2 to 5 barrels of oil per well. If a group of such wells were drilled and operated from a central pumping plant as at Port Huron and in Ontario, probably, under the present high prices of oil, a fair return could be obtained upon the investment. As the oil horizons are twice as deep at Port Huron, the cost of drilling and operating the wells would be much greater.

Character of the Formations and Local Structures. All of the drillings show consistently that the blue-gray shales of the Coldwater, with here and there a red horizon, predominate down to about 1150 feet where the black shales of the Antrim begin. The Antrim is composed of gray shales in the upper portion and dark or black shales near the base. This formation is very thick but the Traverse is thin, the former being probably over 400 feet in thickness. The Dundee appears to be a cherty or sandy limestone very changeable in color with a shaly phase just below the top.

Through the kindness of Mr. C. F. Mercer, president of the Northern Oil & Gas Co., and Mr. Perry Fox, driller, the locations and altitudes of several of the former drillings were furnished together with all of the information available concerning the depth of the Dundee. In platting the wells according to sea level base, it is observed that there are irregularities in the general dip, and the most prominent structure is the apparent terrace or structural bench in sections 27 and 28 with the abrupt northward dip into the southern part of sections 21 and 22, Allegan township. The highest elevation of the Dundee occurs in the No. 2 well in section 32, yet this well yielded little oil or gas. The oil was found on the lower part of the terrace and on the steeper slopes to the north. It must be said, however, that some of the data may not be accurate. According to Mr. Mercer the Allegan Oil, Gas and Mining Co. well, Plate VI, Volume V, is located on the Kalamazoo river flats near the Pere Marquette depot, therefore could not have the altitude of 708 feet as given in Volume V. Owing to the doubtful location and elevation of some of these wells too much stress should not be placed on the structures as indicated by the records.

The following are the records of one of the older drillings and of the two wells drilled by the Northern Oil & Gas Co. The logs of the latter were made partly from memory and partly from notes by Mr. C. F. Mercer, president of the company, and Perry Fox, driller. The thickness of the various strata of rock are approximations. The depth to the Dundee, however, is accurate as it was carefully determined by steel tape measurements.

ALLEGAN GAS, OIL & MINING COMPANY WELL.

Loc.: In Allegan on bluffs above river flats? (near P. M. depot?). J. E. Ellinger, President. Record by driller. Notes on samples by Lane.

Elevation 708? ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Sand and clay	120	120
Gravel and flowing water at 120 ft.		
Unreported	135	255
Slate and sandstone at 255 ft.; end of drive pipe. Sample impure gray banded sandstone at 255 ft.		
Coldwater shale:		
Sandstone. Brine at 292 ft. cased with 3 5-8 in pipe to 331 ft. Sample 260 pyritiferous bituminous coal, 275 siderite, 295 pyrite nodules and bluish shale, 331 brownish drab siderite, full of grains of calcite and pyrite with traces of fossils	76	331
Blue shale	249	580
Sample greenish bluish non-fossiliferous shales.		
Red rock	15	595
Sample red and green mixed shale, calcareous red shale, residue of red clay, very little grit.		
Blue shale	15	610
Sample red freely eff. shale.		
Red rock (Berea?)	5	615
Sample no eff. but burns from green to red with HCl.		
Antrim shale:		
Gray shale, fine drilling (in part Coldwater?). Sample no eff., greenish and bluish gray shales	375	990
Black shale	105	1095
Sample burns on heating—bituminous shale.		
Traverse (Hamilton) Formation:		
Hard rock, salt water between 1120 and 1200 ft	80	1175
Sample siderite. This may be merely a large nodule.		
Black rock or slate	20	1195
Sample bituminous black shale.		
Lime rock (top of Traverse?)	10	1205
Sample mixture of dolomite and black shale.		
Blue shale. Oil at 1245, crust very hard, turned drill	55	1260
Sample greenish or bluish gray shale, slowly eff.		
Dundee (Corniferous) limestone:		
Sandy limestone, oil at 1264	15	1275
Light yellow limestone rapidly eff., containing white chert and fragments of dark gray pyritiferous seams, also brachiopod fragments? Either Leptocelia acutiplicata or Spirifer gregaria	125	1400

NORTHERN OIL & GAS COMPANY WELL NO. 1.

Loc.: S. E. cor. N. E. ¼, sec. 32, Allegan Twp., H. F. Thomas farm. C. F. Mercer, president. Perry Fox, driller. Drilled in 1912.

Elevation 696 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand	320	320
Blue clay, sticky	20	340
Gravel, water	15	355
Coldwater shale:		
Flinty lime	10	365
End of drive pipe at 365 ft.		
Slate streaked in color	10	375
Black gritty lime or sand	15	390
Big flow of fresh water.		
Blue slate, no grit, soft	260	650
Cased 450 ft., 8¼" casing.		
Red slate, hard	10	660
Little salt water under red slate. (Berea?).		
Blue shale, clean drilling, in part. Antrim?	500	1160
Berea? absent?		
Antrim shale:		
Light brown shale, changing to darker. Part of the shales grouped with the Coldwater are doubtless Antrim	110	1270
Traverse (Hamilton) Formation:		
Light blue shale, hard	10	1280
Gray lime, hard	3	1283
Blue slate	25	1318
Dundee (Corniferous) limestone:		
Light bluff lime. Oil	1	1319
Changed color most every screw.		
Total depth	68	1387
About water enough to drill with. Not accurate as to changes. Depth to top of Dundee measured by steel line.		

NORTHERN OIL & GAS COMPANY WELL NO. 2.

Loc.: S. E. cor. of S. W. ¼, Sec. 21, Allegan Twp. 1800 ft. north of old No. 1 (near P. M. depot) of Allegan Gas, Oil & Mining Co. and on river flats. Drilled in 1913. Record reported by Perry Fox, driller, and C. F. Mercer, president. Record from memory and rough notes. Top of Dundee accurate; measured by steel tape.

Elevation of well about 628 feet A. T.	Thickness, feet.	Depth, feet.
Surface:		
Ten in. drive pipe through drift	87	87
Coldwater:		
Soft blue clay or slate	200	287
Lime hard, black and dry	20	307
Lime shell	70	377
Slate, blue, soft	248	625
Yellow colored slate	5	630
Blue slate and red rock	10	640
Blue shale, hard (Largely Antrim)	510	1150
Berea absent?		
Antrim shale:		
Brown shale with streaks of black lime	70	1220
Part of shales above doubtless Antrim.		
Traverse (Hamilton) Formation:		
White or blue shale	15	1235
White lime shells	10	1245
Slate blue, hard	42	1287
Dundee (Corniferous) limestone:		
Lime called Dundee changeable, no grit	24	1311
Oil at 1287-1290 ft.		
Gritty lime	5	1316
Looked good for oil	10	1326
About 1 bbl. water an hour 1290-1295 ft.		
Total depth	.....	1340
Pumped at an average of 2 bbl. oil per 24 hours.		
Shot with 120 quarts of nitroglycerine, 60 qts. above and 60 qts. below gritty lime.		

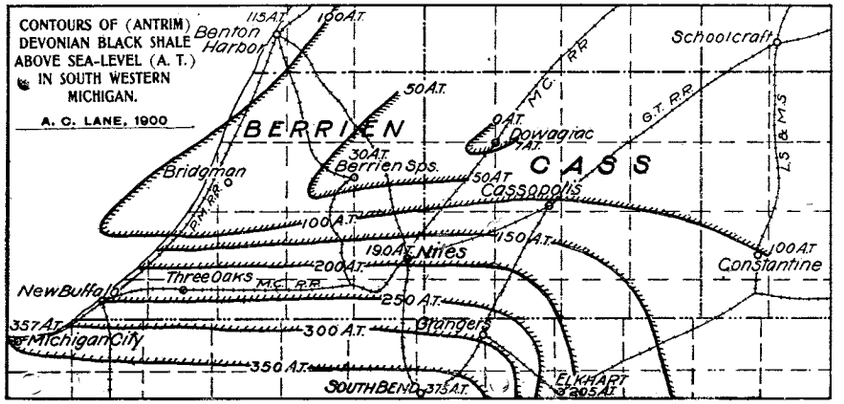


Figure 14. Contour map showing the indicated anticline east of Niles and the elevation above sea level of the base of the Antrim black shale in southwestern Michigan.

BERRIEN, CASS, ST. JOSEPH AND KALAMAZOO COUNTIES.

Local structures. From a comparison of the records of the wells in Berrien, Cass, and St. Joseph counties, and in western Indiana, it appears that in Berrien county a well defined trough or syncline extends northeast in the vicinity of Bridgman, Berrien Springs, and Dowagiac, and a less well defined anticline northeast from near South Bend and Grangers in Indiana into Cass county 10 or 12 miles east of Niles. At Benton Harbor the base of the Antrim black shale is about 115 feet A. T., at Berrien Springs 30 feet A. T., at Niles 190 feet A. T., at Dowagiac 0 feet A. T., at White Pigeon 227 feet A. T., and at Constantine 137 feet A. T. From this data it will be observed that from Benton Harbor to Berrien Springs there is a drop to the southeast of 85 feet in about 15 miles, and a rise of 160 feet from the latter place to Niles, a distance of 12 miles. The southern limb of this trough or syncline is much steeper than the northern. Southward the rise is pronounced from Berrien Springs to South Bend where the Antrim is nearly 350 feet higher, but south of South Bend the strata descends again, giving rise to the anticline (Fig. 14) mentioned above.

The territory in the vicinity of the Berrien Springs syncline may be classed as unfavorable for the occurrence of oil and gas, while the region from South Bend and Grangers, Indiana, northeast into Cass county may be worthy of exploration. This anticline seems to be related to the Kankakee uplift and therefore may have a much greater northeastward extension toward Jackson than indicated by present drillings.

Oil horizons. The Dundee oil horizon is comparatively shallow in

the vicinity of the anticline, probably being nowhere more than 1000 feet below the surface. At Niles, 10 or 12 miles west of the axis of the anticline, it is only 580 feet below surface.

The next probable oil horizon beneath the Dundee, excepting perhaps the Niaraga, is the Trenton limestone, which is not only deeply buried, but wholly unknown. It is in this part of the State that drillers from Ohio have confused the Traverse or Dundee limestone with the Trenton. In the southwestern part of the State the drift is underlain by the blue shales of the Coldwater and the Antrim black shales. After penetrating these shales and striking a limestone beneath some black or brown shale, drillers are deceived and believe that they have struck the Trenton. The black shale is the Antrim, and the limestone that of the Traverse or Dundee. It is doubtful that the Trenton has been penetrated in southwestern Michigan.

CASS COUNTY.

Dowagiac. The only boring which may have reached the Trenton is the Dowagiac well, which is known to be 1760 feet deep, and which apparently penetrated the Lorraine shales.

DOWAGIAC WELL.

Loc.: Round Oak Gas & Fuel Co., Dowagiac. Drilled 1887 by Wm. M. Farr. Record by C. E. Wright from driller's notes and from samples.

	Thickness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Fine and coarse sand	34	34
Gravel	4	38
Blue clay	18	56
Sand and some gravel	49	103
Blue clay	8	111
Coarse gravel	4	115
Blue clay, very tough	48	159
Coarse and fine sand and gravel	41	200
Coldwater shale:		
Blue argillaceous shale, slow eff	82	282
Red argillaceous shale (Land surface belonging to the Antrim?—Lane)	12	294
Antrim shale:		
Argillaceous shale, light blue with streaks of hard blue sandstone. Slow eff. 90% residue	49	343
Argillaceous limestone, very hard	5	348
Argillaceous shale, slow eff. 95% residue	177	525
Sandy shale; dark bluish drab, hard and soft; slow eff. 90% residue	50	575
Argillaceous shale, dark drab and brown, quite soft; slow eff. 95% residue of clay	65	640 –
Argillaceous shale; dark brown, hard and soft; slow eff. 90% residue of clay	10	650
Argillaceous shale, dark brown, medium hard	35	685
Brown argillaceous shale, burning with aromatic smell	90	765
Traverse (Hamilton) Formation:		
Dark drab argillaceous limestone; brisk eff. 10-15% residue of clay	40	805
Dark drab coarse grained limestone; brisk eff. 2% angular grains of silica	68	873 +
Dundee (Corniferous) limestone:		
Light gray fine grained (coarse at 950 ft.) limestone; brisk eff. 4-5% angular grains of quartz and silica, 1% at 920 ft	78	950
Dark drab fine grained limestonc; brisk eff. 4%-5% of brown residue of silica and carbon	25	975
Light drab fine grained limestone; brisk eff. 5% of dark brown residue of silica and carbon	5	980
Brownish drab limestone; brisk eff. 5% siliceous residue	10	990
Monroe Formation:		
Dark gray and drab dolomite 25 to 30% residue of gypsum, anhydrite and silica	30	1020
Drab dolomite, fine grained; brisk eff. 10% residue of gypsum, anhydrite and silica	18	1038
Drab dolomite, fine grained; brisk eff. 12 to 25% residue of gypsum, anhydrite and silica	47	1085
Light gray dolomite, fine grained; brisk eff. 12% residue of gypsum, anhydrite and cherty silica at 1080 ft.		
Light gray sandy limestone (Sylvania?) 4 to 12% rounded grains of glassy sand, quartz and flint	15	1100
Niagara; Guelph and Lockport:		
Light gray limestone, dolomitic in part; 1 to 7% of chert, quartz, anhydrite, pyroxene	175	1275
Light gray argillaceous limestone 15 to 30% clay	45	1320
Gray limestone, dolomitic in part; brisk eff. 1 to 2% of rounded glassy grains of sand and angular ones of chert	120	1440
Creamy gray fine grained marley limestone; very brisk eff. 8% of silica and clay	40	1480
Creamy gray fine grained limestone, dolomitic in part	60	1540
Grayish white to gray fine grained limestone, brisk eff. 2 to 5% rounded grains of glassy sand and angular ones of flint, anhydrite, and clay	70	1610
Gray dolomitic fine grained limestone; brisk eff. 5% of silica and clay	35	1645
Creamy white marly limestone; 1 to 8% of rounded grains of sand, clay and anhydrite	35	1680
Rochester:		
Bluish drab clay shale; brisk eff. 95% clay	20	1700
Dark drab argillaceous limestone (Clinton?)	20	1720
Lorraine and Utica:		
Blue black calcareous argillaceous shale; slow eff. 95% clay	8	1728
Carbonaceous limestone brownish red to yellowish gray; brisk eff. 10 to 20% rounded glassy grains of sand, white chert and anthracite	32	1760

BERRIEN COUNTY.

Niles. At Niles, at least six wells have been drilled for oil and gas or water. One from 500 to 700 feet deep, drilled in 1865 close to the bridge, yielded some gas. Another, drilled about 1885 on Second street 20 rods from the railroad, yielded a large flow of water for some time after the drilling was completed. One of the drillers, also reported striking oil, claiming that, owing to outside influence, he had concealed the fact from the public. A third well was drilled about the same time near the C. C. C. & St. L. R. R. to about 1100 feet. No. 4 was located about one or two miles south of the city on a river terrace. A strong brine which rose nearly to the surface was struck at 546 feet and another in limestone, probably the Monroe, at about 850 feet. These were cased off, but fresh water was struck below 880 feet (Niagara?) and this rose as high as the first. Trenton rock was reported at 1000 feet, but the top of this formation must be several hundred feet deeper. Some gas was constantly given off, making the water "milky" or foamy. The well was abandoned apparently at 1438 feet, but it is claimed that the well was drilled to 1600 feet. Though this well is higher than those in the city, corresponding strata appeared to be struck at the same depth but this is what should be expected as the general dip of the strata should be northeasterly. The No. 5 (Vol. V) well, drilled in 1899, was located across the river 200 feet from No. 4 and only two or three feet above the water. It was about 518 feet deep, and yielded brine at 504 feet. By the use of a packer, the water was shut off and some gas was obtained. In 1903, a sixth well 592 feet deep was drilled by the Niles Oil & Gas Company about a mile west of Niles on the old Baumann farm. A little oil with brine was struck in the Dundee at the bottom of the well.

Nearly all of the oil and gas in the above wells apparently came from the Dundee or "bastard" Trenton which also yielded an abundance of brine some distance below the top and especially in its lower portion. In the No. 3 and No. 4, a little oil was struck in the top of the Niagara. A good log of the No. 6, or Niles Oil & Gas Company well was kept by Mr. F. W. Cook of the Niles Daily Star and a copy furnished the Survey. The log below shows the general character of the rocks down to the Dundee. This record tends to substantiate the general correctness of the hearsay records of the earlier wells.

NILES OIL & GAS COMPANY.

(Niles Well No. 6.)

Elevation 660 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Yellow impure sand (all the samples of the superficial deposits down to 265 ft. are more or less calcareous)	91	91
Fine gravel (Torpedo sand) with water	12	103
Till (or boulder clay, sand and gravel mixed)	79	182
Till	19	201
Clayey till	6	207
Clay, grit free, calcareous brown	10	217
Coarse sand	48	265
Antrim shale:		
Black shale, bituminous, very slightly calcareous (not so black as below)	20	285
Black shale, bituminous	136	421
Traverse (Hamilton) Formation:		
Blue calcareous shale	141	562
Light colored limestone (nearly pure $CaCo_3$)	18	580
Dundee (Corniferous) limestone:		
Slightly darker, and more magnesia? (with oil and salt water)	12	592 +

Berrien Springs. About 1900 a well 700 feet in depth (650+ ft. A. T.) was drilled at Berrien Springs about 60 rods north of St. Joseph river. The Hon. Roscoe D. Dix furnished an accurate record of the well as given below. As noted previously, the base of the Antrim black shale is respectively 160 feet lower than at Niles to the southeast and 85 feet lower than at Benton Harbor to the northwest, therefore Berrien Springs is near the bottom of the syncline. No oil was reported, but signs of brine were observed in the base of the Dundee, when drilling ceased.

BERRIEN SPRINGS WELL.

Elevation 650 + ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Gravel	40	40
Blue clay	70	110
Antrim:		
Soapstone	440	550
Reached 550 noon June 5. Compare Benton Harbor at 280 ft. Niles at 415 ft.		
Black shale with pyrite, bituminous	70	620
Compare Benton Harbor at 475 ft., Niles at 460 ft. Dowagiac at 675 ft.		
Traverse:		
Limerock with indications of salt water at bottom	80	700
Stopped at 670 ft., June 15. Compare Dowagiac at 874 ft.		

Some distance north of Berrien Springs a well was drilled to the depth of 1260 to 1300 feet, but no record was obtained. A good record would be valuable in showing whether or not there is a sudden northward rise of the strata. In 1903, the Umholtz Oil Company bored a well 620 to 625 feet in depth on the Umholtz farm about 8

miles north of Niles and 4 miles from Buchanan. Some oil and gas was struck at 618 feet just beneath black shale.

From a comparison of the wells in this part of the State, the Berea horizon shows considerable irregularity in character. This horizon appears to be nearly as reliable in yielding signs of gas in Michigan as the Dundee of oil. It is possible that gas in commercial amounts might be struck in this formation in the vicinity of favorable structures.

Bridgman. Some thirty years ago an oil well was drilled at Bridgman in Berrien county. A pocket of gas was struck which burned for some time. In 1904, a second well was drilled by the Bridgman Oil & Gas Company about 40 rods south of the depot. No record was kept of the drillings, but one of the workmen gave from memory the record below.

BRIDGMAN OIL AND GAS CO.'S WELL.

Loc.: Forty rods south of depot, on ground about 3 ft. lower than railroad track, e. i., 636 ft. A. T.—May, 1904.

Elevation about 636 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	3	3
Clay, sticky	100	103
Sand, fresh water	5	108
Clay, blue	50	158
Sand, some fresh water	5	153
Clay, blue	40	203
Sand, fresh water	20	223
Gravel, cement	5	228
Clay, blue, waxy	30	258
Coldwater shale:		
Clay (really shale), big break	50	308
Antrim shale:		
Brown shale, gas near top, scum on water after striking gas	200	508
Dundee (Corniferous) limestone:		
So called Trenton, "bastard"	5	513
Samples 520 to 700, limestone with echinoderm fragments, quick eff.		
Salt sand	25	538
Brown sand, salt water rising nearly to the top	25	563
Trenton, porous, drilled nice	200	763
Salt water at bottom of this 200 ft., with traces of gas above.		
Monroe Formation:		
Sample at 768 a gypsiferous dolomite. Water stands 600 ft. deep in the well	5	768

Benton Harbor. At Benton Harbor a well was drilled for oil and gas by the Benton Harbor Natural Gas and Oil Co., but little or no signs of either were found.

BENTON HARBOR NATURAL GAS AND OIL CO.

Record by C. E Wright from samples. Samples from Fred Jordan.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Undifferentiated	130	130
Antrim shale:		
Bluish gray argillaceous shale	5	135
Red shale	15	150
Chocolate brown shale, eff. in cold Hcl; 70 per cent residue. Under microscope, fine fringy argillaceous mass and small granules; does not depolarize the light.		
Light blue shale; quite hard; eff. slightly; large residue, finely granular, apparently isotropic	20	170
Blue shale or "slate"; no sample	110	280
Black shale or "slate"	195	475
Traverse (Hamilton) Formation:		
Argillaceous limestone; dark bluish drab; contains iron pyrites; brisk eff. 50 per cent residue of a fringy clay mass	165	640
Calcareous argillaceous shale; dark drab; medium hard; brisk eff.; 70 per cent residue of clay	25	665
Dundee (Corniferous) limestone:		
Arenaceous limestone; dark drab; brisk eff.; 20 per cent residue of rounded glassy grains of sand	35	700
Limestone, grayish white mixed with dark drab; brisk eff.; 10 per cent residue, mainly isotropic	11	711
Porous limestone; light gray; brisk eff.; 2 per cent residue of a finely granular mass	9	720
Grayish limestone; brisk eff. in cold acid, 10 per cent residue of round glassy grains of sand (and bits of green shale; no anhydrite	5	725
Similar?	10	735
Similar?	5	741
Dark drab to light drab limestone; brisk eff.; 5 to 10 per cent residue of rounded grains of sand	9	750
Water with strong brine at 750 ft.		
Similar?	5	755
Similar?	9	764
Light gray limestone; brisk eff.; 2 to 8 per cent residue of rounded glassy grains of sand	14	778
Brisk eff	10	788
Monroe (and Niagara?) Formation:		
Limestone; drab; brisk eff.; 20 per cent residue of sand and gypsum	27	815
Marly gypsum; very light gray; 80 per cent residue of anhydrite and a few grains of silica	17	832
Dolomitic limestone; drab; resembles sand; slight eff. in cold acid; 10 per cent residue of rounded glassy grains of sand, anhydrite and gypsum	108	940
Dolomite; slow eff. in cold acid; 3 to 20 per cent residue of grains of grayish sand	305	1205

In 1904, the Salzman Mineral Bath Co. drilled a well at Benton Harbor near the corner of 5th and Park Streets.

SALZMAN MINERAL BATH CO. WELL.

(U. S. Geological Survey Well No. 183.)

Loc.: Cor. 5th and Park Sts., Benton Harbor. Drilled in 1904.

Elevation 600 (?) ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Fine grained, light	130	130
A sand, fine grained, and considerable variety in the grains, showing it must be a glacial sand	5	135
Antrim shale:		
A light bluish shale	215	400
Light, rather gritty silicious shale. I suspect that this is from the top of the strata	180	580
Black shale. This is a typical Antrim or Ohio shale. If we may believe samples 4 and 5 the amount that is black is not as much as usual	60	640
Traverse (Hamilton) Formation:		
Dark, with crinoidal limestone mixed; may represent the Traverse	43	683
Record missing, probably limestone passing into shale 683-690 ft.		
Largely clay; perhaps the lower part of the Traverse	60	750

ST. JOSEPH COUNTY.

White Pigeon. In 1903, the White Pigeon Oil & Shale Gas Co. drilled an 800 foot well near the northwest corner of the N. E. ¼ of sec. 22, T. 8 S., R. 12 W. The oil "sand" at 756 feet is a yellowish, cherty, fiercely effervescent limestone 75 feet below the top of the Dundee. At about 710 feet water was encountered which rose 400 feet. The well was shot "wet," i. e. without casing off the brine, at about 763 feet but without effect.

WHITE PIGEON WELL.

Loc.: Near the N. W. cor. of the N. E. ¼ of sec. 22, T. 8 S., R. 12 W. Record by A. C. Lane, from driller's log and from samples.

	Thickness, feet.	Depth, feet.
Pleistocene:		
Quicksand, fine silt	120	120
Gravel, ¼ inch pebbles (limestone, chert quartzites, dark traps)	20	140
130 ft. of 10 in. casing shutting off fresh water.		
Clay, blue calcareous	42	182
Compare surface to 93 or 136 ft. in the Constantine wells.		
Coldwater shale:		
Shale, blue non-calcareous	31	213
Quicksand	28	241
Calcareous and from the varied character of its grains, evidently a glacial sand, which must come in from some vertical fissure traversed by the drill, and yet is peculiar as being in very nearly the horizon of the Berea grit which yielded a strong brine and gas from 283 to 383 ft. in one of the Constantine wells, while in the other it seems to have been represented by 15 ft. of red shale, from 286 to 301 ft., while in this well it is not to be recognized at all. This variety in record is probably due to an unconformity at the base of the Carboniferous, and the red shale which appears in various records in this corner of the State may be due to the weathering and oxidation of black and green shales beneath an old land surface.		
Shale, dark blue, probably in part Antrim, belonging with the next division	224	465
Antrim shale:		
Black shale	108	573
This apparently corresponds to the base of the dark shales at Elkhart between 375 and 350 ft. down, and in the first Constantine well record the red calcareous shale immediately underlying is counted in, and 211 ft. of shales given between 492 and 703 ft. Corresponding horizons are found about 82 ft. deeper at Constantine.		
Traverse (Hamilton) Formation:		
Red calcareous shale	32	605
Very calcareous, gritty with a few large grains of sand and some crinoid buttons.		
Soft blue limestone	78	683
This formation was apparently not separated off in the Constantine records, but its base and top of the Dundee is probably nearly marked by the brine and sulphuretted hydrogen which occur at 790 ft. and correspond to the horizon of the "salt sand" from 696-711 ft. here. The red, gritty shale at the top may also mark a time between the Traverse and Antrim as here developed, when there was a land surface here. The paleontogist Schuchert assumes that there was a neck of land here at about such a time, and the more recent Niles and Dowagiac wells show a greater thickness of blue calcareous shale with no red shale mentioned, while from Coldwater and Elkhart no Traverse is reported. The Niles well in Volume V gives 415 to 500 ft. of very similar strata.		
Dundee (Corniferous) limestone:		
Sample missing. Said to be similar to those below	13	696
Limestone, very white, clear, fiercely eff. in acid, leaving a little quartz sand residue	15	711
"Salt sand," here a brine was struck which filled up the hole about 400 ft., no casing done when the well was shot.		
Five samples, all yellowish, fiercely eff. limestone with a little quartz and microcline sand and more chert	45	756
At bottom, "oil sand."		
Limestone; record says "blue shale," but sample is a coarsely chipping, fiercely eff., somewhat darker limestone, struck together with gypsum, possibly from the brine	7	763