St. Joseph. In St. Joseph, across the river from Benton Harbor, Vincent and Blake drilled a well 820 feet deep penetrating the Dundee. The record compiled by A. C. Lane from a meager set of samples is given below. The drift is much deeper in the St. Joseph well than in the Benton Harbor well. The record does not agree very well with that of the Benton Harbor Natural Gas & Oil Co. well and, according to Lane, the latter may be imperfect.

ST. JOSEPH WELL.

(U. S. Geological Survey Well No. 233.)

	Thickness, feet.	Depth, feet.
Surface:		
Sandy drift clay	50	50
Rusty, sandy, with a variety of pebbles	50	100
Bluish drift clay, sandy	80	180
Richmond or Berea?		
Rusty red	5	185
Record missing from 185-500.		
Antrim shale:		
Dark shale	20	520
Traverse not represented by samples but it probably lies between 520 and 750 ft.		
Dundee? (Corniferous) limestone.		
Mixed. Very white and pyritiferous, dark and fiercely eff	70	820

Constantine. A well over 1080 feet deep was drilled many years ago at Constantine, and the record as correlated by A. C. Lane is given below.

CONSTANTINE WELL.

Levi Dodge, owner?

Elevation 803 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand	40	40
Blue clay	15	55
Sand	2	57
Blue clay	43	100
Sand	1	101
Hard pan	35	136
Coldwater shales:		
Soft "slate" or soapstone	150	286
Berea horizon:		
Red shale	16	301
Antrim shale:		
Gray "slate"	91	392
Black shale	311	703
Traverse and Dundee	377	1080 +
Limestone, brine at 790 ft. with H_2S.		

KALAMAZOO COUNTY.

Kalamazoo. In 1887, the Kalamazoo Natural Gas Co. sunk a well 2250 feet for gas. A strong brine was struck in the top of the Dundee at about 1270 feet and brine and a little oil at 1490 feet near the top of the Monroe.

KALAMAZOO WELL.

Kalamazoo Natural Gas Co. Drilled in 1887. Record in part from samples.

Elevation 771 ft. A. T.	Thickness, feet.	Depth, feet.
Surface (approximately, P. B. Beardsley)	130	130
Coldwater Shales:		
Clay and shale (soft); drab color	170	300
Black sandstone (hard)	20	320
Dark blue shales (soft)	300	620
Red clay	110	730
Light blue soft shale	200	930
Berea?		
Twenty ft. of red clay between 900 and 1000 ft	20	950
Antrim shale:		
Dark drab soft shale	120	1070
Black slate, soft and somewhat sandy	130	1200
Traverse (Hamilton) Formation:		
Limestone, blue and hard	60	1260
Blue slate and shale, soft	10	1270
Dundee (Corniferous) limestone:		
Light gray sandstone, hard. Strong brine (probably cherty limestone)	40	1310
Limestone, briskly eff., light buff	180	1490
Monroe Formation:		
Gypsiferous dolomite, anhydrite, with strong brine	25	1515
Very salty, i. e., brine, from 1270-1740 ft.		
Flow of brine also from 1610-1635 ft.		
Salt and oil at 1490 ft.		
Mainly ferruginous dolomite with anhydrite	215	1730
Niagara (Guelph and Lockport):		
White dolomite	145	1875
Red sandy shale	45	1920
White sandstone	50	1970
Red sandstone	30	2000
Rochester:		
Dark shale	80	2080
Clinton:		
Dark gray dolomite, eff. moderately	40	2120
Light to buff dolomite, eff. slowly; small clay and quartz residue, ferruginous	110	2230
Medina:		
Brown sandstone, with a little calcite; rounded quartz and angular felspar, including microcline	20	2250

CHAPTER VIII.

WESTERN MICHIGAN.

MUSKEGON COUNTY.

Muskegon. Along the shore of Lake Michigan from Muskegon north to Manistee and beyond, a large number of deep wells have been drilled since the early 70's for salt, water, and oil and gas. At Muskegon, there are a number of wells, some of which penetrate the Marshall for fresh water, while others reach depths of 1400 to 2400 feet.

The oldest and farthest west of these deep wells is the Whitney or Truesdell, also called the Hacker well. It is located close to the lake at an elevation of about 586 feet. A. T., and according to reports is from 1230 to 1600 feet deep. Copious flows of water were struck at 330 feet, and also at 643 feet, the lower one being mineralized but of agreeable and refreshing taste. Strong brine was struck at the bottom, probably in the Monroe beds, but this did not rise and mingle with the water above.

The Mason well near the old Occidental Hotel, 613 ft. A. T., was begun 1872 and a depth of 2000 feet was reached two years later. In 1875, it was 2400 feet deep and was finally bottomed in the Salina at 2627 feet. An abundance of artesian water and brines was struck, and at 1200 feet oil and gas. At first, the quantity of oil was reported to be 75-100 barrels per day, but the flow proved to be mainly water mixed with a little oil. From the quality of the oil, the horizon then appeared to be that of the Berea grit, but later the much more accurate record of the Central Paper Company well indicates that the oil horizon is in some fine grained grits or sandstones in the base of the Coldwater, but at some distance above the Berea horizon. A strong brine resembling the Dundee was struck at about 2030 feet in rock containing thin beds of sandstone. No rocks typical of the Dundee were recognized and perhaps the formation is absent, since it is known to decrease in thickness toward the western part of the State, and it is absent at Milwaukee on the opposite side of Lake Michigan.

THE "MASON" WELL.

Loc.: Near Old Occidental Hotel. Mason Lumber Co. Drilled in 1875.

Elevation of well 594 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand	60	60
Clay	150	210
Hardpan	15	225
Napoleon or Upper Marshall:		
Sandrock with seams of iron pyrites and some shale	100	325
Lower Marshall and Coldwater:		
Shales and sandrock alternating	300	625
Overflow of water just above 625 ft.; some of the rock dark gray and shale.		
Blue shale, with streaks of some soft material	775	1400
Sandstones and limestones from 625 to 685 ft.		
Strong flow of mineral water at about 685 ft.		
Red rock not far from 900 ft. probably.		
Fine grained grits and sandstones, probably at about 1200 ft. Petroleum and gas. Good lubrication oil. Cf. Central Paper Co. well.		
Antrim shale:		
Solid blue shale	150	1550
Solid red shale	150	1700
Traverse (Hamilton) Formation:		
Limestone, with streaks of shale and soft limerock	300	2000
Salt bearing rock, with streaks of sand (Dundee?), 1 to 4 ft. thick. Cannot say whether salt was struck or not. Brine 100°	50	2050
Dundee not recognized unless it is this sandy horizon.		
Light colored limerock and shale	50	2100
Monroe Formation:		
Dark colored limerock, (dolomite probably and so indicated in a section drawn under Wright's direction)	250	2350
Salina:		
Gypsum and lime streaks, 4 to 6 ft. thick	50	2400
Limerock and gypsum, a little less gypsum than in preceding and more lime	145	2545
Rapid and various changes ending in dark limerock, loose and porous	82	2627

The Ryerson-Hills well, farther east at about 588 feet A. T. is complete in its record only to 1427 feet, but is was drilled to between 2050 and 2200 feet. A flow of brine, probably at about 2050 feet, was struck, yielding about one-third of a barrel per minute when pumped rapidly. Oil was found at about 1200 feet, but this horizon was cased off and the well continued to the deeper brine horizon. In 1900, the well was cleaned out, plugged at 1200 feet, and tested for oil. Only a little was obtained but, after the well was abandoned, the brine which came to the top of the casing had a layer of oil on it, and, according to recent reports, oil and a little gas has been constantly seeping from the well.

RYERSON-HILLS WELL.

Elevation 588 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	65	65
Clay	135	200
Hardpan	8	208
Hardpan, sandy spots and shale	90	298
Lower Marshall and Coldwater:		
Dark and light shale	200	498
Lime	4	502
Shale	20	522
Lime	1	523
Light shale	20	543
Lime	2	545
Light blue shale	40	585
Lime	2	587
Light blue shale	15	602
Hard lime rock	80	682
White and blue shale and streaks of lime	195	877
Red shale	8	885
Hard lime	3	888
Dark and light shale	222	1110
Lime	5	1115
Loose shale	312	1427
Depth reported 2050 to 2200 feet.		
Record from 1427 feet unknown.		

Close to the lake and near the Ryerson, another well was drilled in 1900. The record, not kept in detail, is said to be very similar to the former. A little oil and salt water were struck at 1227 feet. About the same time, another well 12 feet above the lake was drilled only 44 feet southwest of the Mason well for the Michigan Oil Company. Prof. McLouth kept a careful record with a number of samples. At 1275 feet, a fine grained micaceous sandstone or sandy shale, the oil horizon of the other wells, was struck and this yielded a little oil.

MICHIGAN OIL COMPANY WELL.

Loc.: Forty-four feet southwest of the Mason well.

Elevation 592 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand becoming finer downward	60	60
Calcareous blue clay free from pebbles	163	223
Gravel in clay and sand, till	12	235
Upper Marshall:		
White micaceous sandstone	105	340
Lower Marshall and Coldwater:		
Blue micaceous shale; drilled 65 ft. in 7 hrs	280	620
Harder shale with carbonates of iron and lime; drilled 70 ft. in 10 hours	80	700
Soft blue shale, calcareous	190	890
Brown limestone	24	914
Flagstones, shales with thin laminae of white sandstone and calcareous bands; drilled 40 ft. in 4½ hours; and 6 ft. in 33½ minutes	361	1275
White very fine grained micaceous sandstone or silicious shale, yielding a little oil	18	1293
Sandy shale	27	1320
Shale, somewhat darker at bottom	180	1500

Later the Central Paper Company[1] drilled a well 1650 feet deep on Lot 1, N. E. ¼ sec. 34, T. 10 N., R. 17 W., about 4½ miles from the Ryerson well. This well appears to be at about the same altitude as the Ryerson, and 10 feet lower than the Mason. A careful log was kept and a good set of samples obtained.

As the well is at a considerable distance from the Ryerson, the Mason, and other wells, determinations of the local dips and structures can be made. From Milwaukee, where the edge of the Traverse or Hamilton rocks outcrop at the surface, across Lake Michigan to Muskegon it is approximately 86 miles. At Muskegon, the Traverse appears to be 1700 feet below the surface, therefore the dip from Milwaukee eastward to Muskegon is about 20 feet per mile.

The base of the Antrim black shale occurs in the Central Paper Co. well at 1615 feet and in the Mason at 1700 feet. The latter well is about 10 feet higher in elevation, and, allowing for this, there is a drop in the strata of approximately 75 feet in about four miles. This gives a dip of nearly 20 feet per mile to the eastward, which corresponds with the general dip from Milwaukee to Muskegon.

In the Central Paper Co. well, a bed of red fossiliferous limestone occurs from 845 to 870 feet, and this also occurs from 890 to 904 feet in the well, drilled in 1900 near the old Mason well. In this case, the drop is about 45 feet in four and one-half miles or an average of only 10 feet per mile.

The Central Paper Company, Ryerson-Hills and Mason wells are not in direct line, but they are nearly so and, from the general eastward dip, the strata in the Ryerson should be lower than in the Mason well. On the contrary, the red horizon and other corresponding strata are higher in the Ryerson than in the well drilled in 1900 close to the old Mason well. This indicates a local disturbance in the rock strata, and, according to Lane, the chances for finding a pronounced anticlinal appears to be greater farther north along Muskegon lake, perhaps on the north side in sections 15 and 16. Unfortunately, the oil sand is so fine grained that probably the flow would be limited unless the oil stratum should be struck in a coarse phase.

Beneath this oil horizon, however, are those of the Traverse and perhaps the Dundee. The Traverse is well represented by an alternation of limestones and shales, the latter mainly blue. Possibly, as at Saginaw, some of the limestones may contain oil. As the Dundee is thin, or possibly not present at Muskegon, this formation does not offer great possibilities, but the porous brine bearing stratum at the point, where the Dundee should be expected to occur, may prove to be oil and gas bearing.

[1]Ann. Rept. 1903, p. 274.

CENTRAL PAPER CO. WELL.

Loc.: On Lot 1, N. E. ¼, sec. 34, T. 10 N., R. 17 W., about 4¼ miles from Ryerson-Hills well.

Elevation of well 584 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	50	50
Red calcareous clay.		
Smooth, red calcareous clay	183	233
Lower Marshall sandstone:		
Sandstone, greenish, calcareous, very fine at the bottom; a typical Marshall grit	77	310
Coldwater shale:		
Shale, dark, bluish, more or less calcareous	315	625
Limestone, a clayey and dolomitic water lime, with selenite; like limestones of the Michigan series	35	660
Shales, blue calcareous	185	845
Limestone, red and white, fossiliferous	25	870
Flags, i. e., blue and green silicious shales, with bands of very fine-grained grits, or sandstone; in places more or less calcareous	530	1400
Berea Horizon:		
Shales, red and green	80	1480
Antrim shale:		
Shale, black, bituminous, pyritic, especially at the base	135	1615
Traverse (Hamilton) Formation:		
Shale, blue, calcareous	35	1650

Fruitport. At Fruitport in the southern part of Muskegon county, a deep well was drilled about 1903, but the samples preserved for the Michigan Geological Survey were carried away by mischievous boys and no record was kept by the drillers.

MASON COUNTY.

Ludington. At Ludington, several deep wells (Fig. 15) were drilled to the Salina for salt by the lumber companies in the early days of the salt industry.

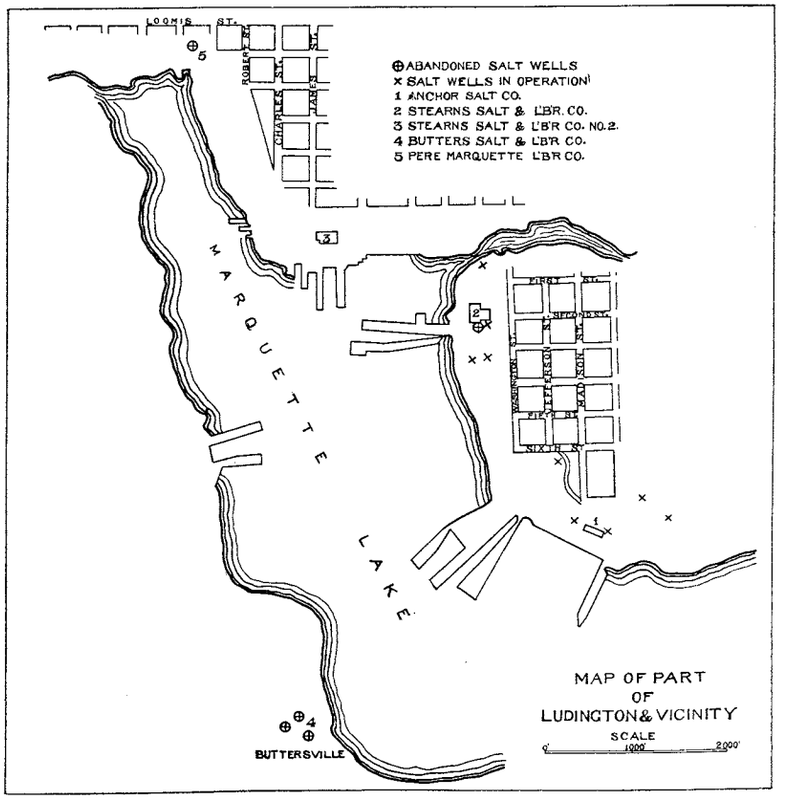


Figure 15. Map of a portion of Marquette Lake, Mason county, showing location of salt blocks (after C. W. Cook.)

The Pere Marquette Lumber Company's well at the north end of Marquette lake, 2220 feet deep, (490 ft. A. T.) and the Butters and Peters well on the southwest side of the lake, 2260 feet deep, penetrated rock salt in the Salina, but apparently no oil or gas was found.

PERE MARQUETTE LUMBER CO. WELL.

Loc.: Near mill at the north end of Marquette lake, Ludington; 1½ miles north of Butters and Peters well. Drilled in 1885. Record in part from samples.

Elevation 590 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	30	30
Marl, shells and pine sticks	5	35
Sand	21	56
Soft clay	4	60
Hard clay	20	80
Hard pan	10	90
Coarse sand and small stones	18	108
Sand and gravel	9	117
Sand	42	159
Sand and gravel	24	183
Sand with clay	17	200
Sand	5	205
Clay	4	209
Clay and gravel	5	214
Clay and sand	27	241
Hard pan	32	273
Clay	11	284
Clay and gravel	8	292
Clay	15	307
Clay and gravel	53	360
Clay	37	397
Clay and sand	15	412
Hard clay	52	464
Hard pan and gravel	12	476
Gravel	16	492
Gravel and sand	6	498
Sand	18	516
Gravel and clay shale	12	528
Coldwater shale:		
Blue shale	35	563
Limestone	15	578
Red shale and marl	8	586
Shale	8	594
Limestone	5	599
Blue shale	601	1200
In Lyon's No. 2 well, a showing of oil at 1175 ft.		
Antrim shale:		
Black slate or hard shale, with pyrite	165	1365
Traverse (Hamilton) Formation:		
Blue shale and limestone	70	1435
Black sandy limestone, with strata of gypsum. The limestone is quite crystalline at a depth of say 1460 ft. There are many specks of pyrites. Brine 30°.	45	1480
Limestone	60	1540
Limestone and gypsum	20	1560
Limestone, hard with grit above, and softer with less grit below. Brine 30°-36°.	240	1800
Blue shale	58	1858
Salt; either salt (?) or soft salt rock. 90° brine	4	1862
Limestone, very sticky. 70°-80° brine. Slow eff. with some sand grains at 1880 feet. Bluish, argillaceous, moderately eff. with a large residue 1920-2005 ft.	100	1962
Dundee? (Corniferous) limestone:		
Very hard limestone. 20° brine. Dolomitic limestone, with a residue of quartz sand and anhydrite.	40	2002
Monroe Formation:		
Dolomite, with soft streaks. 6 in. to 18 in. thick, 50°-56° brine. Brisk eff. 2005-2050 ft. Mainly rounded sand, eff. slowly at 2100 ft. 62°-64° brine. Largely rounded sand. Eff. slow at 2150 ft. Rusty white sand 2125-2220 ft.	138	2140
Hard gray limestone, contains gypsum and is soft in streaks	55	2195
Salina:		
Rock salt. 100° brine	18	2213
Limestone, containing 2 feet of rock salt	7	2220

In the Lyons No. 2 well, a showing of oil was reported at 1175 feet which should be near the base of the Coldwater, possibly in some of the thin stray sandy layers which in the western part of Michigan locally occur in this formation near the Berea horizon.

A few years ago the J. S. Stearns Lumber Company drilled a well 2304 feet in depth to the rock salt of the Salina. An accurate record and set of samples were kept from which it appears that an oily brown limestone occurs at 2085 feet in the upper part of the Traverse, while the middle Traverse is composed of 250 feet of pure limestone. Part of the latter may be the Dundee, but the recognition of this formation is not certain in this well.

J. S. STEARNS SALT & LUMBER CO. WELL.

Loc.: Ludington plant. One mile north of Butters and Peters well and on north side of Marquette Lake. Record by Lane.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand. 10 in. casing to 204 ft.	198	198
Pink clay, calcareous. Water at about 300 ft., T. 53°.	68	266
Gravel	94	360
Pink clay, calcareous	155	515
Gravel. 8 in. casing to rock.	61	576
Coldwater shale:		
Limestone. With 15 ft. of porous granular limestone and salt water 35 ft. below the casing.	74	650
Blue shale	550	1200
Antrim shale:		
Black shale	200	1400
Traverse (Hamilton) Formation:		
Brown limestone	25	1425
Blue shale	35	1460
Brown limestone, oily with H_2S	40	1500
Pure limestone (possibly Dundee?—Lane)	250	1750
Brown sandy dolomite	160	1910
Calcareous shale (Bell or Marcellus)	90	2000
Monroe Formation (Dundee in part?):		
Dolomite	25	2025
Limestone (Anderson or Dundee—Lane)	25	2050
Dolomite	25	2075
Sylvania sandstone?	100	2175
Sandy dolomite and anhydrite	121	2196
Salina:		
Salt	8	2304

The Anchor Salt Co.[2] has drilled five wells to the salt beds. The No. 3 well, 2360 feet in depth, shows three beds respectively 20, 9, and 8 feet thick and the No. 5, four beds 20, 12, 7, and 5 feet thick. The records of No.'s 4 and 5 are given below.

[2]C. W. Cook, Brine and Salt Deposits of Michigan, Pub. 15 Geol. Ser. 12; Mich. Geol. and Biol. Surv., 1913, pp. 157-159.

ANCHOR SALT CO. WELL NO. 4.

Loc.: Ludington, on north side of Marquette lake three-fourths mile northeast of Butters and Peters well. Completed in 1908, J. H. Brogan, driller. Record by P. Hardy.

Elevation between 635 and 650 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene drift:		
Sand and gravel	267	267
Clay	27	294
Hardpan	19	313
Clay	36	349
Sand	89	438
Clay	5	443
Hardpan and sand	25	468
Sand	40	508
Hardpan and gravel	2	510
Sand	4	514
Gravel	4	518
Sand	34	552
Gravel	6.5	558.5
Brown shale	3.5	562
Sand	1	563
Shale	10	573
Sand and gravel	2	575
Coldwater:		
Shale (Hard Illinoian till from 558.5 to 635 ft.? Depth to rock uncertain from record)	60	635
Limestone	14	649
Hard "slate" (shale)	24	673
Limestone	6	679
Red limestone	17	696
Lime	74	770
Sharp lime (sandy or cherty?)	112	882
Lime	18	900
Shale	167	1067
Lime	20	1087
Shale	146	1233
Antrim shale:		
Black shale	29	1262
Brown shale	176	1438
Black shale	58	1496
Traverse (Hamilton) and Dundee?:		
Lime, water at 1536 ft	44	1540
Lime, "Trenton." Water at 1569 ft	37	1577
Brown sandstone	108	1685
Gypsum (anhydrite?) at 1586 and a vein of sand at 1617 ft.		
Sharp sandstone	10	1695
Black sandstone	46	1741
Sharp sand	29	1770
Black sand	8	1778
Brown sand	57	1835
Dark sand	13	1848
Sharp sand	8	1856
Black sand	9	1865
Brown sand	20	1885
Yellow sand	33	1918
Brown sand	34	1952
Black sand	27	1979
Sharp sand	7	1986
Probably the "sand" from 1540 to 1986 is dolomite, cherty or sandy in the "sharp" horizon.		
Streak of shale	3	1989
Limestone	6	1995
Shale	69	2064
Dundee (?) and Monroe:		
Black lime	10	2074
Brown lime	235	2309
Salina:		
Salt	20.5	2329.5
Bottom of salt at 2329.5 ft.		

ANCHOR SALT CO. WELL NO. 5.

Log furnished by J. H. Brogan, driller.

Elevation about 595 (?) ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	90	90
Gravel	42	132
Sand	92	224
Gravel and hardpan	176	400
Sand	90	490
Blue clay	44	534
Coldwater:		
Slate (Hard Illinoian till?)	61	595
Blue lime	15	610
Slate and limestone (in part Antrim)	725	1336
Antrim shale:		
Brown shale	147	1482
Traverse (Hamilton) Formation:		
Hard limestone	468	1960
"Cave" (Soft shale? Bell shale? Cf. well No. 4)	70	2030
Dundee (?) and Monroe:		
Hard limestone, Dundee not recognized	233	2263
Salina:		
First salt	20	2283
Hard white lime	14	2297
Second salt	12	2309
Limestone	25	2334
Third salt	7	2341
Limestone	13.9	2354.9
Fourth salt	5	2359.9
Limestone	44.9	2404.8

The No. 3 well with a total depth of 2360 feet showed three beds of salt, respectively 20, 9, and 8 feet in thickness. This well which has about the same elevation as No. 5 is located about 1,000 feet west and 700 feet north of it.

MANISTEE COUNTY.

Manistee. In the Manistee salt district, there are more than 35 deep wells scattered from the shore of Lake Michigan along Manistee lake to Filer City and Stronach, a distance of four or five miles. Below is a list of 29, giving locations and depths as far as obtainable. The records of many of them are very incomplete, only the depth to the salt or the total depth being known.

Number.	Owner.	Location.	Elevation above lake. Feet.	Total depth. Feet.	Depth to top of salt rock. Feet.
1	Canfield & Wheeler No. 1	0.7 mi. N., 0.68 mi. W., sec. 11, T. 21 N., R. 17 W.	12	2,700	1,900
2	Canfield & Wheeler No. 2	0.7 mi. N., 0.68 mi. W., sec. 11, T. 21 N., R. 17 W.	12	1,947	.....
3	Manistee Lumber Co. No. 1	.28 .72 sec. 1	.....	1,926	.....
4	Manistee Lumber Co. No. 2	.28 .72 sec. 1	.....	.....	.....
5	Louis Sands No. 1	.04 .44	.....	.....	.....
6	Louis Sands No. 2	.04 .44	.....	.....	2,012
7	Canfield S. & L. Co	.1 .08, sec. 1	.....	.....	.....
8	Canfield S. & L. Co	.1 .08, sec. 1	.....	.....	.....
9	R. G. Peters No. 1	.92 .28, sec. 7, T. 21 N., R. 16 W.	.....	2,026.5	.....
10	R. G. Peters No. 2	.92 .28, sec. 7, T. 21 N., R. 16 W.	.....	.....	.....
11	R. G. Peters	.92. .28, sec. 7, T. 21 N., R. 16 W.	.....	.....	.....
12	R. G. Peters	.92 .28, sec. 7, T. 21 N., R. 16 W.	.....	.....	.....
13	R. G. Peters	.92 .28, sec. 7, T. 21 N., R. 16 W.	.....	.....	.....
14	Buckley & Douglass	.54 .40, sec. 12, T. 21 N., R. 17 W.	.....	.....	.....
15	Buckley & Douglass	.54 .40, sec. 12, T. 21 N., R. 17 W.	.....	.....	.....
16	Buckley & Douglass	.54 .40, sec. 12, T. 21 N., R. 17 W.	.....	.....	.....
17	Buckley & Douglass	.54 .40, sec. 12, T. 21 N., R. 17 W.	.....	.....	.....
18	Buckley & Douglass	.54 .40, sec. 12, T. 21 N., R. 17 W.	.....	.....	.....
19	Canfield S. & L. Co	.18 .36 sec. 7, T. 21 N., R. 16 W.	30	2,015	1,965
20	Canfield S. & L. Co	.....	.....	1,947	.....
21	State Lumber Co	.18 .21 sec. 12, T. 21 N., R. 17 W.	.....	.....	.....
22	State Lumber Co	.....	.....	.....	.....
23	State Lumber Co	.....	.....	.....	.....
24	Louis Sands	.69 .97 sec. 18, T. 21 N., R. 16 W.	.....	.....	.....
25	Louis Sands	.....	.....	.....	.....
26	Filer & Sons	.96 .86 sec. 19 T.	.....	.....	.....
27	Union Salt & Lumber Co	.72 .68 sec. 20	25	1,982	1,924
28	Union Salt & Lumber Co	.72 .68 sec. 20	.....	or 2,016 to 2,025	.....
29	East Lake or Percy	East Lake	.....	2,045	2,025

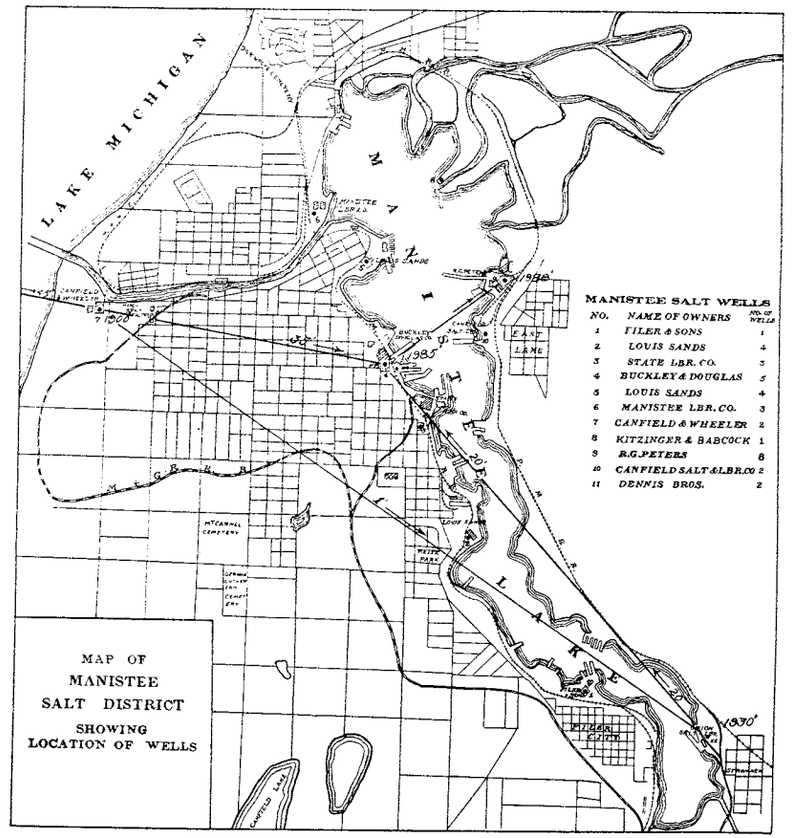


Figure 16. Map of the Manistee salt district showing location of salt wells and the discordant dips of the salt horizon and depths to the same. Arrows indicate direction and numbers, amount of dip per mile.

The Canfield-Wheeler well (592 A. T.) near Lake Michigan (see Fig. 16), originally 1947 feet deep, was afterwards deepened some 500 feet by T. Percy to the white Guelph or Niagara dolomites. These outcrop on the opposite shore of lake Michigan and, according to computations by Lane, the dip across the lake is not less than 39 feet nor more than 50 feet per mile. This dip is intermediate between the 20 foot dip from Milwaukee to Muskegon and the 60 foot one from Neebish Island to Cheboygan. A second well was drilled but only to 1926 feet.

CANFIELD-WHEELER WELL.

Loc.: Near mouth of Manistee River, Manistee. Record by E. D. Wheeler; notes on samples by Lane. (Samples appear to have been mixed.—Lane.)

Elevation 604 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand, with streaks of gravel	93	93
Reddish gray clay	2	95
Sand	107	202
Gray clay	94	296
Dark reddish clay	2	298
Quicksand	3	301
All shades of clay; some sand	54	355
Gravel	3	358
Clay, sand, gravel	36	394
Reddish clay, gravel and some sand	181	575
Dark clay and gravel	5	580
Dark shaly stuff	15	595
Light shaly stuff	7	602
Shale and gravel. Contains pebbles of white limestone, argillaceous marl; large residue of clay	113	715
Richmondville or Berea?:		
Sandrock, with occasional streaks of shale and lime	160	875
Antrim shale:		
Shale and streaks of hard lime. (Traverse in lower part)	200	1075
Light gray limestone and some black shale; medium residue of glassy grains of quartz and black slate at 965 ft. (Base of Antrim?)		
Grayish calcareous sandstone; large residue of small rounded grains of glassy silica at 1020 ft.		
Light gray limestone, medium residue of milky quartz, glassy quartz and black slate at 1040 ft.		
Traverse (Hamilton) Formation:		
Blue shale	380	1455
Bluish gray argillaceous marl; large residue of clay at 1100 ft.		
Light gray and dark brown limestone; medium residue of glassy quartz and black slate at 1145 ft.		
Hard gray and black limestone, with conchoidal fracture; also black and light gray slate at 1290 ft.		
Bluish? argillaceous shale and light gray limestone; also black shale at 1310 ft.		
Limestone as at 1290, and a little blue shale at 1325 ft.		
Light gray marl; very small siliceous residue at 1370 ft.		
Siliceous limestone and marl; residue of glassy quartz and gray and dark gray lumps at 1410 ft.		
Calcareous clay; large residue of clay at 1420 ft.		
Bluish gray calcareous clay; residue of clay 90 per cent at 1432 ft.		
Bluish gray calcareous clay; residue of clay 90 per cent at 1455 ft.		
Sticky grayish brown shale, cased 60 ft. above bottom when hole was 1520 ft. deep; brine 20 per cent	100	1555
This sample came up in the slops (i. e. on the sinker rods) when the hole was down 1510 ft. and is like previous sample.		
Bluish gray argillaceous shale; residue of clay 95 per cent at 1525 and 1530 ft.		
Shaly lime	20	1575
Dundee (Corniferous) limestone:		
Lime rock	29	1604
Reddish limestone, with numerous yellow specks of ochre; small residue of clay and silica at 1620 ft.		
Shale and lime	51	1655
Lime streaks, dark and light	40	1695
Yellow gray silicious limestone; appears quite friable; medium residue silicious and yellow at 1675 ft.		
Monroe Formation:		
White lime; brine 30 per cent from here to 1845 ft. Grayish white calcareous clay at 1200 ft.; large residue	10	1705
Lime and shale, hard	20	1725
Shaly and sticky	15	1740
Light gray argillaceous marl at 1735 ft.; large residue of clay and gypsum.		
Dark buff soft limestone at 1740 ft., as at 1675; medium residue of clay and gypsum.		
Lime cuts free	5	1745

CANFIELD-WHEELER WELL.—Concluded.

Elevation 604 ft. A. T.	Thickness, feet.	Depth, feet.
Calcareous shale	7	1752
Very hard spots and softer, and streaks of lime	28	1780
Very hard streaks, with streaks of softer	23	1803
Porous rock:		
Dark gray or drab dolomite at 1810 and 1825 ft.; very small residue, saline	32	1835
Porous rock:		
Dark drab dolomite, conchoidal fracture; very hard; very small residue at 1835	10	1845
Clay lime rock with hard thin streaks. Brine 80°; light gray soft limestone at 1845 ft., small residue of gypsum and silica	13	1858
Softer; cuts very fast from 1845 to 1858.		
Soft lime rock:		
Dark drab dolomite at 1858, as at 1835 ft.	7	1865
Hard and soft streaks. Brine 92°	10	1875
Massive lime rock. 93° S. 1877 ft. similar to 1858 ft., and a yellowish limestone in small grains; very small residue	25	1900
Supposed to be salt. 96%	4	1904
Samples missing from 1904 to 1912 ft.		
Salina:		
Rock salt	30	1942
Hard lime rock	5	1947

Buckley & Douglass Lumber Co. drilled five or more wells, but only of the No. 5 was a complete record obtained. According to Mr. J. J. Hubbell, the record is as follows.

BUCKLEY & DOUGLASS LUMBER CO. WELL NO. 5.

Elevation about 610 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
First casing 10-inch pipe driven 400 ft	.....	400
Second casing 8-inch pipe to bed rock through sand, clay and gravel	616	616
Antrim shale:		
Hard shale	324	940
4¼ inch casing to 985 ft.		
3 inch casing to 1032 ft.		
A 3 inch pipe for brine inserted 985 ft.		
Traverse and Dundee:		
Limestone	630	1570
Soft shale, 7 inch hole drilled, brass lining to caving rock	110	1680
Monroe Formation:		
Limestone, 6 inch hole, no lining	195	1875
Salina:		
Six inch hole brass lining, caving rock salt and gypsum	20	1895
Limestone, 5 inch hole, no lining	90	1985
Brine cavity	30	2015

The above well is near Manistee Lake about 1¼ miles east of the Canfield-Wheeler, 610 ft. A. T. or about 18 feet higher, but the top of the salt at 1985 feet seems to be fully 70 feet deeper. Too much dependence must not be placed upon comparisons between these two wells as the record of the Canfield is probably not reliable, since the samples do not correspond with the log.

East Lake. The R. G. Peters Salt & Lumber Co. in East Lake is

about three-fourths of a mile northeast of the Buckley and Douglass Lumber Co. The Peters Company drilled a well in 1886 and according to the record of this published in Volume V (Pl. XXXII) the top of the first salt bed occurs at 1988 feet, or practically at the same depth as in the Buckley and Douglass well. In the former, the base of the Antrim appeared to be at 960 feet, in the latter 940 feet. A soft shale from 1570-1680 feet may likewise be correlated with a similar shale in the Buckley-Douglass at 1490-1600 feet. The top of the salt in the Canfield and Wheeler well near Lake Michigan occurs at 1932 feet, hence the salt is about 70 feet deeper in the Buckley and Douglass well. This is equivalent to a dip of about 35 feet per mile slightly south of east. This dip is comparable to the average southeast dip of the Niagara of 39 to 50 feet per mile across Lake Michigan. From the Buckley and Douglass well northeast to the R. G. Peters well the dip is nearly if not quite flat (Fig. 16), assuming that the salt beds are the same in each well. Considerable oil and a great pressure of gas were encountered at 1905 feet in the old R. G. Peters well. Water and oil, according to reports, shot up 150 feet above the derrick, blowing off the top. Some oil was also reported in the Antrim shale at about 960 feet.

R. G. PETERS LUMBER CO. WELL.

Manistee No. 3 of Vol. V. Pl. XXXII.

Loc.: East Lake, Manistee. Drilled in 1885. Driller's record with correlations by C. E. Wright. No samples.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or surface:		
Sand, gravel and clay	614	614
Antrim:		
Black shale, in part bituminous. Some petroleum. Black water at 960 ft.	346	960
Traverse (Hamilton):		
Limerock, hard and salt, light colors	530	1490
Argillaceous shale (Bell shale), caves badly; looks like petrified wormholes; dissolves readily in water	110	1600
Dundee and Monroe:		
Sandy limestone. Dundee cannot be distinguished from Monroe. First showing of oil at 1905	305	1905
Water and oil shot up from the 8 in. casing to 150 ft. above the surface; blew off the top of the derrick.		
Record missing from 1905 to 1988 feet.		
Salt to hard rock below	38	2026
Top of salt at 1988 ft.		

In 1908, another well was drilled by the R. G. Peters Salt & Lumber Co. to the salt bed and a set of samples and a log were preserved, from which the appended record has been compiled. According to Mr. R. A. Nickerson, general manager of the company, a considerable flow of oil was struck at 1925 feet, which was immediately cased off

and the well continued to the salt bed, which was struck about 1980 feet.

R. G. PETERS SALT & LUMBER CO. WELL NO. 7.

Loc.: N. W. ¼, N. W. ¼, sec. 7, T. 21 N., R. 16 W., East Lake. Record from samples and notes, furnished by R. A. Nickerson, General Manager. Samples examined by Lane.

Elevation 600 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or surface	593	593
Antrim:		
Soft blue shale	4	597
Bluish gray calcareous shale, gas at 730 ft	203	800
Hard black micaceous shale	187	987
Traverse (Hamilton) Formation:		
Fine gray cherty limestone, vigorous eff. Some blue shale	347	1325
Very hard geodiferous dolomite with pearl spar in geods at 987 feet, gas at 1100 feet.		
Black shale and gray limestone with selenite (gypsum) crystals; vig. eff.	75	1400
Gray limestone (Vig. eff.) and a little black shale; selenite. Harder than at 978	25	1425
Mainly light gray limestone (Vig. eff.) with a little black shale. Selenite	25	1450
Gray to dark gray and black shale	37	1487
Dark gray shale and light gray argillaceous limestone. Top of cave rock; mod. eff. and very pyritic; selenite	13	1500
Soft gray calcareous shale	50	1550
Crumbly soft shale (Bell) resembling blue clay; some eff	45	1595
Dundee (Corniferous) limestone:		
Hard gray to buff fine grained limestone; cherty (sand) and pyritic; violently eff	10	1605
Reddish fine grained brown limestone sandy and cherty; very pyritic and ferruginous; mod. eff	15	1620
Monroe Formation:		
Gray dolomitic limestone; pyritic and gypsiferous; some bituminous matter	18	1638
Reddish anhydrite and dolomite, sand and selenite	7	1645
Anhydrite and dolomite, light buff in part	7	1652
Ferruginous (altered from pyrite) buff dolomite, anhydrite, selenite. Gas at 1654 feet	4	1656
Buff dolomite, anhydrite, selenite; some chert from 1638 to 1658 ft. Some bituminous matter	5	1661
Pyritic buff dolomite with anhydrite and selenite; softer than above	19	1680
Very red (ferric oxide from pyrite) anhydrite and dolomite; very fine grained	20	1700
Mainly red (ferric oxide from pyrite) anhydrite, and some dolomite	80	1780
Dolomite and anhydrite with selenite	30	1810
Brown dolomite and anhydrite, selenite, and a little dark shale	10	1820
Mainly anhydrite, pyritous	10	1830
Mainly pure anhydrite with a little black shale	20	1850
Hard gray vesicular dolomite with selenite crystals	12	1862
Cherty dolomite and anhydrite; "cave rock"	8	1870
Brown dolomite with much anhydrite and selenite	10	1880
Vesicular grayish brown dolomite with selenite; ferruginous	15	1895
Vesicular gray dolomite with much selenite in cavities	10	1905
Mainly red (from altered pyrite) anhydrite and dolomite, gas rapidly increasing from 1911 to 1916. Quite a flow of oil from 1916 to 1925 feet	25	1930
Mainly very red anhydrite and dolomite	10	1940
Vesicular gray dolomite; selenite crystals; very salty	20	1960
Dark gray porous limestone (dolomite)	20	1980
Salt	20	2000

In the Louis Sands Salt & Lumber Co. wells, in Manistee, gas has been reported in sufficient quantity to be utilized in a small way.

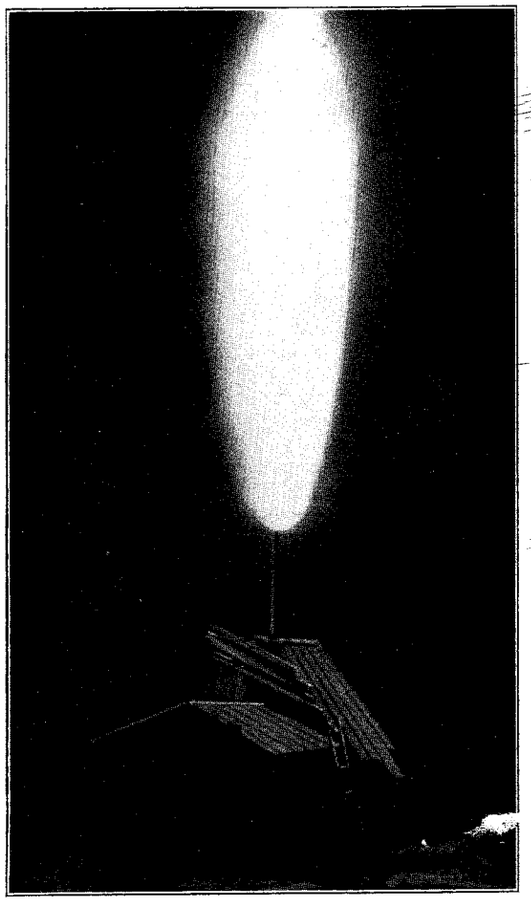
Stronach. The Stronach Lumber Co. wells at Stronach (604 ft. A. T.) are a little over 3½ miles southeast of the Canfield-Wheeler and 2½ miles from the Buckley and Douglass wells. The salt bed, 1930 to 1964 feet is about as high as in the Canfield and about 30

feet higher than in the Buckley and Douglass or in the Peters at East Lake. The Bell (Marcellus) shale from 1450-1625 feet likewise is higher and signs of oil and gas were encountered directly beneath this shale. The Antrim black shale, however, is at about the same depth, i. e. 970 feet. Gas was struck in the top of the black shales at about 600 feet and oil and gas about 30 feet below the top of the Dundee, which is cherty, porous and perhaps brecciated as it caves in some of the drillings. In the Union Lumber Co. wells (605 ft. A. T.), the top of the salt, reported at 1949 feet, is apparently a little deeper. The bottom was supposed to be at 1982 feet, but the bottom of the brine cavity deepened to 2015 and 2025 feet. This indicates that the bottom of the salt was not reached in the drillings.

The average dip of the formations, as previously noted, is between 39 and 50 feet per mile to the southeast. From this one would expect that corresponding strata at Stronach and Filer City should be from 150 to 200 feet deeper than near Lake Michigan in the Canfield-Wheeler well. On the contrary they are nearly as high at Stronach and Filer City as in the latter well, and are even higher than in the Buckley and Douglass and Louis Sands wells, which, although not in direct line, are between the Canfield and Wheeler and the Stronach wells. This indicates that there is an upward fold or anticline near Stronach which may contain oil and gas in commercial quantity. As there are no deep wells southeast of Stronach, one cannot tell whether the [illegible] lies at Stronach or farther to the south and east.

Onekama. From the records of wells at Ludington and Manistee, it is to be observed that the drift is very thick, ranging from 500 to over 700 feet in thickness. It contains several thick beds of water bearing sand or gravel, and clay, some of which are probably persistent over large areas. As the black bituminous Antrim shale underlies these thick deposits in northern Manistee county, gas is commonly found with water in surface wells in small to very considerable quantities.

In the vicinity of Portage Lake, Manistee county, considerable gas mixed with water has been struck in many artesian wells throughout an area of four or five miles long. In 1901, a well in sec. 22, Onekama township, was drilled close to the fish hatchery on the north side of the lake. A strong flow of gas under high pressure was struck which, according to reports, rapidly decreased in pressure and volume. According to Mr. W. W. Davis, a well driller and contractor, who has drilled a great many of the artesian wells in the Portage Lake district in the past twenty years, the well caved below the bottom of the casing, which did not reach to the gas horizon, and thus the flow of gas was shut off. Other wells yielding much gas with water have been struck since then. In 1913, Mr. Davis made a test well near the fish



THE ONEKAMA GAS WELL, MANISTEE COUNTY.

hatchery for Mr. H. Ward Leonard of Manistee. The well is located on the Northern Transportation Co. land about 25 feet from the old gas well. On January 27, 1913, gas with a pressure of about 185 pounds and free from water was struck at a depth of 437 feet in a sand or gravel bed. The casing is 2 inches in diameter and, in pulling out the well rods, the last 185 feet were blown free from the well and scattered around in the tree tops. The well was "blown" almost every day for several weeks from about 15 minutes to an hour and a half to prevent clogging. After it has blown for some time the pressure, measured by a registered steam gauge, gradually sinks to about 145 pounds but upon closing the valve the pressure is almost instantly back to 185 pounds or more. When the gas was lighted (Pl. III) the flame shot up 25 to 30 feet above the top of the casing.

The analysis of the gas, as furnished by Mr. Leonard, was made in 1913 at the Grand Rapids gas plant and indicates that the gas is of good quality and is free from sulphur.

ANALYSIS OF ONEKAMA GAS.

Carbon dioxide	0.2
Oxygen	1.1
Carbon monoxide	0.1
Nitrogen	11.7
Methane	86.0
Total	100.0
Heating power B. T. U (cu. ft.)	1070.0
Candle power	3.0

There is much water in the overlying sand and gravels but it is shut off from the gas sand, which appears to be just below a compact conglomeratic mass of shale fragments. The following is the log as given by Mr. W. W. Davis, the driller.

LEONARD GAS WELL.

Loc.: Sec. 22, Onekama Twp., Manistee county. Owner, H. W. Leonard, Manistee; driller, W. W. Davis; 1912–13.

	Thickness, feet.	Depth, feet.
Red clay, gravel and sand	57	57
Blue clay	10	67
Sand	152	219
Layer of blue clay and sand	71	290
Red clay	120	410
Shale fragments with black water (sulphur water?)	20	430
Gas bearing sand	7	437
Gas free from water and hydrogen sulphide gas. Flow of gas estimated at 4200 cu. ft. per min.		

The list of wells located around Portage Lake given below, with notes concerning the occurrence of gas was also furnished by Mr. Davis.

	Depth, feet.	Remarks.
Clark Well, Section 33	470	Gas but no flowing water.
Sands & Smith Well, Section 33	537	Gas and water.
August Lipkowski Well, Section 34	418	Gas and water.
H. Ward Leonard Well, Section 32	535	Gas and water.
Dunham Well, Section 26. Enough gas for one jet	510	Trace of gas but no water.
Showalter Well, Section 25	318	Trace of gas and good flow of water.
Dunham Well No. 2, Section 33	425	No gas.
N. & M. Transportation Co. Well	450	Gas and water.
Prosser Well, Section 35	399	Very little gas.

From the abundance of gas in the sand and gravel beds in the region, it is probable that the body of gas described above is of considerable size and commercial importance, though as yet it has not been utilized.

CHAPTER IX.

NORTHERN LOWER MICHIGAN.

SURFACE DEPOSITS AND EXPLORATIONS.

The northern part of the Southern Peninsula has few and widely scattered deep drillings and these are chiefly near the lake shore at Frankfort, Petoskey, Charlevoix, Cheboygan, Onaway, Alpena, Grand Lake, Harrisville, Killmaster, Oscoda, Tawas City, Prescott and Standish. The only ones in the interior are the Hanson wells at Grayling and the Cadillac well, now being drilled.

As noted on previous pages, there is a broad belt extending from Newaygo, Mason and Manistee counties northeastward into Otsego, Montmorency, and Alcona counties, in which the surface materials are very thick, ranging from 400 to more than 1000 feet, the average being probably about 600 feet. This has been, and will continue to be a most effective obstacle in discouraging explorations for oil and gas.

BEDROCK GEOLOGY.

The rock strata of this part of the State compose the northern segment of the Michigan Basin, consequently in passing around the lake shore from Frankfort, Benzie county, to Harrisville, Alcona county, the strata dip successively southeast, south, and southwest toward the center of the Basin. The formations beneath the drift form belts more or less concentric with the lake shore, and in passing form the lake margin to the central basin the edges of the Devonian formations —the Dundee, Traverse, Antrim, Berea, Coldwater, Marshall, the Grand Rapids Group, and the Saginaw Coal Measures are crossed in order.

Relations of surface signs to the oil and gas formations. Three of the oil horizons outcrop at the surface or lie beneath the drift cover in this part of the State. Locally as in southeastern Alcona county there are springs which, from the amount of gas given off, appear to be in a state of ebullition and one of these near Killmaster (center of sec. 26, T. 26 N., R. 8 E.) gave off so much gas that it led to the Killmaster drillings (see Fig. 18). Similar springs occur near Atlanta, Montmorency county. Gas is struck in wells also, as in Benzie county and around Portage Lake, Manistee county.

In the vicinity of Alpena there is a large area in which the Traverse formation and the Dundee limestone outcrop, or are under a light cover of surface materials. The Traverse has been carefully studied in northern Michigan by Grabau, and the outcrops around Little Traverse Bay and Alpena have received very careful study from limestone, cement, and chemical companies, which have extensively developed the deposits of the high grade limestones of the Traverse and the Dundee formations.

While no prominent anticlinal folds are known to exist in Alpena county, discordant and abnormal dips, noted by Winchell and Rominger, occur in several localities. The general dip is to the southwest, yet the rocks north and east of Alpena dip northeast toward Lake Huron. The Dundee limestone is much fractured and faulted locally and extreme brecciation is characteristic of the Monroe Beds throughout the northern and southeastern part of the State.

During the past few years Mr. Henry R. Hindshaw, former assistant State geologist of New York, has made an extensive study of the limestone deposits of possible commercial value in Alpena and Presque Isle counties. He observed the abnormal dips, local fractures, and the brecciation of the Dundee limestone, which near Rogers City, is so great that drilling with a core drill is very difficult.

In the Salina, in Alpena and Presque Isle counties, the salt beds aggregate 300 to 800 feet in thickness. According to the upward rise of this formation toward the northeast and east, it should form the bottom of the Lake Huron basin. Thin salt beds occur at Manistee and Ludington, and here too are to be observed abnormal local dips and a "vesicular" dolomite above the salt which caves in drillings and is very probably brecciated. The brecciation in the Dundee and the Monroe in the Frankfort well appears to be undoubted.

In limestone areas, much of the drainage is underground. In the limestone belt of northern Michigan there are relatively few streams as most of the surface waters drain into the numerous sinks. The Dundee, especially near its base, and the Monroe beds are very heavily water bearing, being filled with crevices, fissures, caverns, and underground water channels. The water channel struck in the Detroit salt shaft was more than five feet across. In many instances drill tools suddenly drop four or five feet into cavities. Again, in drillings, beds of dolomitic sand are struck in the Monroe which flow into the drill holes like thin mud. Such sands and oozes may be the residuum of other beds carried away by solution.

Mr. Hinshaw related these facts—the abnormal dips, the brecciation of the Dundee and the Monroe beds, the large underground water circulation, the oozes, the relation of the margin of the Salina formation to the basins of lakes Huron and Michigan, and conceived the idea that these lake depressions are due in part to the ablation, or solution of the salt in the Salina and that the brecciation was caused by the slumping incident to the removal of the salt beds below. While the validity of all of the evidence has not been investigated, the theory as advanced contains elements of plausibility and is worth consideration.

It is obvious that if the salt in the outer edges of the formation should be removed by solution, there would be slumping in the beds above, which might very possibly cause brecciation in rocks like dolomites and limestones. The slumping would also explain the abnormal dips, observed near the lake shores.

According to Mr. Hindshaw's theory, marked disturbances in the rock strata are liable to be found along the margin of the southern Peninsula, excepting in those regions where salt was never deposited. Such disturbances are favorable to the accumulation of oil and gas, but the brecciated rock must be capped by some soft and plastic stratum such as shale, which would not readily fracture or these products would escape.

LITTLE TRAVERSE BAY ANTICLINE.

Along the south shore of Little Traverse Bay, the limestones and shales of the Traverse formation outcrop in low bluffs. In the vicinity of Khagashewing Point (Fig. 2) there are numbers of low folds which pitch southward. While the folds are small, together they make up a structure sufficiently large to contain oil and gas in commercial quantity. A Mr. W. N. Norton, representing an eastern oil company, made a survey of the Charlevoix region and made preparation to drill a number of test wells in 1913, but for some reason the project was suddenly abandoned.

BENZIE COUNTY.

Frankfort. At Frankfort two wells respectively 1800 and 2200 feet in depth were drilled many years ago, but only a meager record of either was obtained. The first one, 1800 feet in depth, was abandoned on account of the great flow of water from the brecciated Dundee limestone at the bottom. The second is 500 feet to the southwest, and, at 1800 feet, a sulphate brine testing 20 per cent salinometer was encountered. This brine appears to come from a horizon corresponding to the Manistee and Stronach salt horizon. The well was continued to 2200 feet and the brine decreased in strength toward the bottom, where an enormous flow of water was struck, probably in the Niagara.

FRANKFORT WELL NO. 1.

A. G. Butler, owner? Reported by C. E. Wright and Mr Percy. Vol. V. Pl. XVIII.

Elevation of mouth of well 600 ft. A. T.	Thickness, feet.	Depth, feet.
Surface	527	527
Traverse (Hamilton) Formation:		
Hard limestone	543	1070
Shale, soft caving stuff	160	1230
Dundee (Corniferous) limestone:		
Black to gray brecciated limestone with hard flinty blocks	150	1380
Bottom at		1800
Much water towards bottom, 8000 barrels per day.		

EMMET COUNTY.

Petoskey. At Petoskey, a well was drilled nearly if not quite to the bottom of the Dundee limestone. Judging from the depth of the drift the well is in an old glacial rock valley for within a short distance on either side rock is only 5 feet below the surface.

PETOSKEY WELL.

Loc.: Thirty-three feet north of Chi. & West. Mich. R. R. station near end of Lake Street and 180 feet from Bear river. Drilled in 1888. Reported by H. P. Parmelee, Charlevoix; C. S. Hampton, G. S. Richmond, Petoskey.

Elevation of well 600 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Gravel, etc	30	30
Traverse (Hamilton) Formation:		
Limestone strata, highly fossiliferous throughout the entire depth. The fauna is nearly the same as that found in the surface bed. Color light gray, a few strata quite dark and much harder	250	280
Ten to 15 ft. of blue shale, no fossils. Beneath this was a flow of quite pure water, somewhat charged with H_2S	15	295
A nearly solid bed of Acervularia limestone, without a trace of mollusca or other corals. Color light, often creamy white	60	355
A thin layer of gray lime rock of incoherent structure at 355.		
Bell shale (Marcellus):		
Dark shale	80	435
Dundee (Corniferous) limestone:		
About 120 ft. of crystalline limestone of same color, texture and composition throughout	120	555

Bay View. At Bay View, a well about 500 feet deep was drilled in 1895. This record and others show that the Traverse on the western side of the State is predominantly limestone, shale being very subordinate in quantity in contrast to the Alpena region. The only thick bed is the blue basal or Bell shale in which the drilling stopped, but thin shale beds have been struck in some of the shallow wells along the south shore of Little Traverse Bay.

A very hard layer was struck at 450 feet in which only 18 inches a day could be drilled. Water in great quantity was struck in the limestone below this shell. Nearly all of the limestone is hard as an average of only 10-12 feet per day could be made.

BAY VIEW WELL.

Loc.: One hundred and twenty paces northwest from the door of G. R. & I. R. R. station and 40 feet from the shore of the bay. Reported by H. P. Parmelee, Charlevoix, and A. J. Richards. Completed July, 1895.

Elevation of well 585 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Shingle	4	4
Traverse:		
Cream limestone	260	264
Medium gray limestone	198	462
Dark limestone	11½	473½
Twenty-five feet of cellular blue shale	25	498½
Flow, 200 bbls. an hour.		

CHARLEVOIX COUNTY.

Charlevoix. In Charlevoix, three wells were drilled within 50 feet of each other. Only of No. 3 were samples obtained. The drift was found to be 230 feet in thickness, yet rock is at the surface to the east and west of the city. This indicates the presence of deep rock valley. Apparently the well was bottomed in the blue Bell shales at the base of the Traverse.

CHARLEVOIX WELL.

Elevation 600 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand	6	6
Gravel	9	15
Fine sand	155	170
Gravel	6	176
Sand; quicksand at 214 ft	54	230
Traverse:		
Fine grained earthy limestone, eff. with dilute HCl. No fossils found in the samples	10	240
Gray limestone, eff. freely with dilute HCl. No fossils in samples	10	250
Earthy or chalky, brownish, porous, much oxidized clayey limestone with a strong clay odor, being in fact in large part clay, but with sufficient lime to give it coherence, and cause free eff. with dilute HCl	10	260
Dark gray argillaceous and somewhat shaly limestone, eff. freely in dilute HCl	10	270
Finely stratified shale, eff. feebly with strong HCl. Compact in texture	10	280
Fossiliferous whitish limestone, containing *Atrypa reticularis* and other fossils. Eff. freely with dilute HCl	10	290
White crystalline limestone containing considerable crystalline calcite. It carries fragments of *Acervularia davidsoni*. Some portions of the samples are compact and argillaceous	10	300
White chalky limestone, non-argillaceous, fossiliferous; eff. freely with dilute HCl	15	315
Brownish, earthy and argillaceous limestone, with a strong clay odor; Bryozoa and other fossils have been observed. Eff. freely with dilute HCl	7	322
Gray calcareous clay of very uniform texture, partially oxidized. Eff. freely in dilute HCl, but is nevertheless a good clay	8	330
Gray, compact calcareous clay rock, but of massive character, and eff. freely in dilute HCl	5	335
Fragments of *Acervularia davidsoni* with the calices free from matrix, and evidently embedded in clay. No clay is, however, retained	10	345
Gray calcareous shale, mixed with pure white limestone, the latter containing Favosites and Acervularia	5	350
Gray argillaceous limestone and some white limestone, with fragments of Spirifer and Acervularia	5	355
Gray limestone. *Acervularia davidsoni* is abundant. Favosites and *Atrypa reticularis* also occur	5	360
Gray, compact, semi-argillaceous limestone; fossils not observed, except crinoid stems. Much shale is mixed with the limestone	7	367
Fragments of *Acervularia davidsoni* and Favosites	3	370
Compact, gray, argillaceous limestone; no fossils observed. It is almost a clay	5	375
Fine grained, compact, argillaceous rock	12	387
Limestone and black shale	3	390
Gray argillaceous limestone with whiter limestone containing *Acervularia*	10	400
Chalky clay. Crumbles and soils fingers. Cream colored	2	402
Bluish gray clay, slightly calcareous; eff. feebly with HCl	8	410
Compact, brown to gray limestone, weathering earthy	5	415
Cream colored calcareous clay, identical with the rock at 400 ft	5	420
Limestone similar to that at 410 ft. No fossils	10	430
Cream colored earthy clay, somewhat more calcareous than that at 402 ft	13	443
Brown banded limestone, mingles with black and gray shale containing *Atrypa reticularis*, etc	4	447
Bell Shale:		
Bluish clay, non-eff	13	460
Same as preceding	22	482

Apparently in none of these wells were there any showings of oil and gas worthy of record, but the Petoskey well is the only one which penetrated the Dundee oil horizon.

The wells are so shallow that they do not reach horizons which outcrop on the northern shore of Lake Michigan. To the south the Grayling well is the only one of accurate record with which comparisons can be made, but this well apparently did not reach the Dundee, hence accurate calculations of dip cannot be made. An approximation may be made, however, by assuming that the Traverse at Grayling (1140 ft. A. T.) is not over 600 feet thick, in which case, the top of the Dundee should occur at about 2880 feet at the latter place. The base of the Traverse in the Petoskey well occurs at 435 feet. Allowing for the difference in elevation of the two places, the base of the Traverse at Grayling is probably about 1905 feet lower than at Petoskey, representing an average dip of over 38 feet per mile slightly east of south.

WEXFORD COUNTY.

Cadillac. In 1913 the Cadillac Oil & Gas Company, C. R. Smith, president, and Bruce Smith, secretary, was organized and in the winter of 1914 began drilling a test well on the C. R. Smith farm near Cadillac. According to reports the well was located by means of an "instrument" invented by T. H. Cross, who superintended the drilling.

Unfortunately the drift is very deep in the vicinity of Cadillac and considerable difficulty has been encountered in getting the drive pipe down. The upper 470 feet was entirely sand and gravel, and at last reports the well was still in drift at 712 feet. A good set of samples was preserved for the Survey from which the following partial record has been compiled.

CADILLAC OIL & GAS COMPANY WELL NO. 1.

Loc.: C. R. Smith farm, S. E. ¼, S. W. ¼ sec. 28, T. 22 N., R. 9 W. Theo. H. Cross, well superintendent. Record by R. A. Smith from samples.

	Thickness, feet.	Depth, feet.
Pleistocene drift:		
Yellow sand with small pebbles. Yellow color due to oxidation of iron minerals	20	20
Fine light yellow sand	80	100
Gravel with pebbles of chert and limestone predominating	9	109
Fine yellowish clayey sand	15	124
Coarse gravel with much white chert and some pebbles of crystalline rocks	13	137
Fine yellowish sand	58	195
Gravel with white chert pebbles, some of fossiliferous limestone, black and white sandstone. Very few pebbles of crystalline rocks	10	205
Fine yellowish clayey sand	82	287
White sand and small pebbles of chert, magnetite, red jasper and green schist	143	430
Slightly finer yellowish clayey sand	40	470
Clay, highly calcareous with considerable white sand (probably from overlying bed). Clay brownish in natural sample, white when pulverized; vigorous eff. with cold dilute hydrochloric acid.		
Well in drift at 712 feet, according to reports.		

CHEBOYGAN COUNTY.

Cheboygan. About 1900, one of the deepest wells in the Southern Peninsula was drilled at Cheboygan for rock salt. Rock outcrops to the west of Cheboygan, and on the adjacent islands, but the drift was found to be 380 feet in depth, indicating the presence of a deep preglacial rock valley. The first rock encountered was the Monroe in-

stead of the Dundee as would have been the case if the latter had not been removed by erosion in the formation of the rock valley.

The well, 2750 feet in depth, was bottomed in dark drab shaly dolomite probably near the base of the Lorraine (Hudson river) shales, and did not reach the Utica or the Trenton.

CHEBOYGAN WELL.

Loc.: At Swifts and Denks (?) near corner Blair and Turner streets. Samples examined by W. C. Alden, U. S. Geological Survey. (See Ann. Rept. for 1908, p. 96).

Elevation of well 600? ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Red clay, highly calcareous	150	150
Sand and gravel	53	203
Sand	2	205
Sand, gravel and red clay	25	230
Gravel	15	245
Sand with some calcareous material	5	250
Sand and gravel	5	255
Gravel	15	270
Fine sand with calcareous material	30	300
Gravel	34	334
Gravel, coarse	18	352
Fine sand with calcareous material	2	354
Fine sand with calcareous material, coarser	6	360
Fine sand with calcareous material, fine	15	375
Much water in drift.		
Fine calcareous sandy clay	5	380
Second box of samples.		
Light to whitish dolomitic limestone at 265 ft.		
Chips of dark grayish dolomite with some quartz sand grains from 265-278.		
Light colored limestone at 300 ft.		
Grayish, dark, porous, earthy dolomitic limestone at 320 ft.		
Monroe (Upper Silurian, Water Lime and Salina).		
Fine chips of brownish buff gray dolomite with a little chert at 380-438 feet.		
Red shaly stuff from 850 to 900 ft.; red sandy shale at 1000 ft.		
Flows of water at 1050, 1350 and 1400 ft.		
Brecciated dolomites with slits and cavities.		
Caved down to 750 ft.		
Salt (March 12, 1901), at ? 1400 ft.		
Fine grayish sand and dolomitic materials with some white chert and bluish and reddish shaly material at 1360?-1550 ft.		
Niagara:		
Beginning of Niagara (Guelph)	?	1550
Fine quartz sand, slightly calcareous	?	1615
Fine quartz sand, slightly calcareous, brownish	?	1625
Fine quartz sand, slightly calcareous, brownish	?	1635
Light grayish crystalline dolomite	?	1652
Light grayish crystalline dolomite	?	1725
Buff fine angular grains of quartz, chert with some dolomitic material	?	1975
Dark gray, very cherty dolomitic material	?	2000
Fine, angular, gray dolomitic material	?	2050
Fine, angular, gray dolomitic material. Lockport about here—2065 ft.	?	2100
Fine, angular, gray dolomitic material; Rochester shale 2136-2200 ft.	?	2150
Fine, angular, gray dolomitic material	?	2175
Fine, angular, gray dolomitic material. Dark colored, nearly black	?	2200
Clinton:		
Fine, angular, gray dolomitic material. Lighter colored	?	2225
Fine, angular, gray dolomitic material. Lighter colored. Contains small particles of iron or magnetite	?	2250
Medina (See Lorraine below):		
Dark purplish ferruginous material, reddish streak, in small flattened, rounded lenticular pellets. With this is some bluish shaly material, moderately calcareous. Some particles rounded. Also few quartz grains. Bluish shaly material increases in lower samples	125	2425
Lorraine. Lower part:		
Dark drab shale, or dolomite, somewhat calcareous. Small particles of iron or magnetite	125	2425
Dark drab shale, or dolomite, somewhat calcareous. Small particles of iron or magnetite	300	2725
Utica at	.....	2750

CRAWFORD COUNTY.

Grayling. In 1901, R. Hanson of Salling, Hanson & Co. drilled three wells at Grayling and one, the No. 3, reached a depth of 2800 feet. This well, though one of the deepest in the State, was drilled very quickly. Work began the last of January and, by May 6, the well was finished at a depth of 2800 feet. This well penetrated about 520 feet of Traverse limestones and shales, but did not reach the heavy shale (Bell or Marcellus) at the base of the formation.

GRAYLING WELL NO. 3.

Salling, Hanson & Co., owners, Grayling. T. Percy, driller. Drilled in 1901. Samples, records from notes of A. C. Lane and F. W. Cooper.

Elevation of well 1140 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand	50	50
Till or boulder clay	50	100
Mainly sand, some clay and gravel, plenty of water. Progress slow through water bearing quicksand	200	300
Sandy clay till	25	325
Coarse cement sand, etc	25	350
Michigan Series:		
Dark shale	30	380
Blue or bluish shale and gypsum	30	410
Dark blue shale	30	440
Upper Marshall or Napoleon:		
White sandstone, micaceous toward the bottom	100	540
Lower Marshall and Coldwater:		
Blue shale	90	730
Brownish and probably sideritic (iron carbonate nodule) at 720 ft.		
Dark blue shale	650	1380
Compact blue shale	220	1600
Berea horizon?		
Apparently not recognized.		
Antrim shale:		
Black shale	20	1620
Blue shale	20	1640
Black shale	60	1700
Dark blue shale	60	1760
No sample at 1740 ft. nor none from 1780 to 1880	120	1880
Light blue shale	80	2060
Black shale	60	2120
Dark gray shale	20	2140
Black shale	40	2180
Gray shale	20	2200
No sample at 2200 ft.		
Black shale	20?	2240
Brown shale	40	2280
Pyritic from 2240-2280 ft.		
Traverse (Hamilton) formation:		
Light blue shale	20	2300
No sample at 2320 ft. Probably shale.		
Fossiliferous light blue shale and limestone	20?	2340
"Salt and pepper" limestone and shale	40	2380
Light and dark limestone	20	2400
Steel gray limestone	20	2420
Light colored limestone	20	2440
"Salt and pepper" limestone	20	2460
Light colored limestone and blue shale	20	2480
Light colored limestone	100	2580
Dark limestone, fine grained	20	2600
Steel gray fine grained limestone	20	2620
Light colored fine grained limestone	80	2700
Steel gray fine grained limestone	40	2740
Dark steel gray fine grained limestone	20	2760
"Salt and pepper" fine grained limestone	40	2800
Bell shales should occur just below 2800 ft, and the top of the Dundee at about 2880 ft.		

ROSCOMMON COUNTY.

Roscommon. Many years ago a drilling was made for oil near Roscommon, but statements concerning it are so contradictory that nothing very definite can be asserted. It is not known that the well reached bed rock before it was abandoned, but it appears that the drift is at least 365 feet thick, and is mainly sand with some clay at 118 and 365 feet. Mr. Fred Johnson of Roscommon is authority for saying that he and others saw oil at the well, which was claimed to come from it. Many consider that the well was "salted" and a fraud. One morning the well was found to have been filled with scrap and railroad iron, and the enterprise was abandoned.

PRESQUE ISLE COUNTY.

Onaway. In 1913 the Presque Isle Development Company was organized, H. T. Moeller of Detroit, president, and Judge W. H. Martin of Saginaw, secretary. Drilling was started with the intention of penetrating the Trenton unless oil or gas should be struck before reaching that horizon. The well was bottomed in the Niagara at a depth of 3106 feet without encountering any noteworthy signs of either oil or gas.

The Monroe beds and the Salina show a remarkable development, the former being nearly 1150 feet in thickness and the latter, 1175 feet, including about 800 feet of rock salt. The combined thickness is several hundred feet greater than any thickness previously known in Michigan or Ontario. The upper portion of the Monroe appears to be composed largely of limestone or dolomitic limestone instead of dolomite and for 200 feet below the middle of the formation, the dolomite is very cherty and somewhat sandy. Most of the salt is red or tinged with red. The first salt bed, 145 feet thick, varies in color from a reddish pink to a deep br ck red and the 150 foot bed below 1950 feet is also red, but the 225 foot bed at the bottom is nearly all white or gray salt. Below the salt beds there are 281 feet of hard white and gray limestone.

Notwithstanding the fact that shale everywhere overlies the Trenton limestone and that none had been penetrated in this well below the salt beds, the drillers, according to statements of the officials of the company, pronounced these limestones of Trenton age and barren of oil or gas. Upon this supposition, the well was abandoned.

The hard white limestones below the salt beds probably belong in part to the Salina, but, if they are considered as wholly Niagara and this formation has its normal thickness of 600 feet for the northern part of the State, there is still about 300 feet of Niagara limestone to be penetrated before reaching the top of the shale series which

lies between the Niagara and the Trenton. This shale series in a descending order includes the Rochester, Clinton (generally dolomitic), Medina, Richmond, Lorraine and Utica and, while no close approximations can be made of the thickness of each of these formations, the total thickness is probably between 600 and 700 feet. From this it would appear that the bottom of the well is from 900 to 1000 feet above the top of the Trenton.

The company very kindly furnished the Michigan Geological Survey with a log of the well and a set of samples from which the following record has been compiled:

PRESQUE ISLE DEVELOPMENT COMPANY WELL.

Loc.: S. E. ¼, N. W. ¼, Sec. 5, T. 34 N., R. 2 E., on Merrit Chandler property, 40 rods W.-N. W. from Detroit and Mackinac railroad station at Onaway. Contractors, Schrier and Kerr, Lancaster, Ohio. Well started July 14th and finished November 14, 1913. Record by R. A. Smith from driller's notes and log and from samples.

Elevation 830 ± ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene of glacial drift:		
Pink calcareous clay	10	10
Traverse (Hamilton) formation:		
Gray limestone; moderate eff	15	25
Buff and dark gray limestone, and very argillaceous limestone; viol. eff. with strong smell of petroleum. Dark brown oily scum	100	125
Gray granular limestone; bituminous; fossiliferous, crinoids and corals; Viol. eff.; much white calcite	15	140
Soft calcareous gray shale	10	150
Gray limestone with much disseminated calcite; fossiliferous (corals); vigorous eff	20	170
Dark limestone; highly calcareous black shale; disseminated calcite	80	250
Gray, brown and black shale, slightly calcareous	60	310
Dundee (Corniferous) limestone:		
Light buff, brown and black limestone, with much white calcite; vigorous eff. Limestone mottled and streaked	165	475
Reddish buff and light gray limestone. Buff violently eff. Red apparently an oxidized zone. Crevice from 480 to 510 feet. Water	35	510
Upper Monroe, Detroit River series:		
Hard, light buff limestone with rusty spots (from pyrite?); violent eff.; crevice at 525 feet	15	525
Dark gray and buff limestone; pyritic; vigorous eff	50	575
Gray to brown bituminous limestone; oily scum; violent eff	50	625
Mainly buff limestone; violent eff	25	650
White friable marl and fine grained light colored limestones; violent eff. No sample at 675 feet. Crevice from 655 to 700 feet; more water	50	700
Very hard white to light buff limestone, vigorous eff	25	725
Very hard white and brown limestone; vigorous eff. Crevice at 750. No drillings obtained from 740 feet.	40	765
White limestone and dolomite; cherty; some fragments eff. vigorously, others slowly	15	780
White limestone, cherty, some gray and brown limestone, vigorous eff	45	825
White and black limestone; vigorous eff	30	855
Mainly black limestone, some white; bituminous oily scum; vigorous eff	5	860
Brown to dark brown limestone, some white limestone and chert; vigorous eff. "20 feet of black limestone"	15	885
Grayish brown limestone; vigorous eff	15	900
Grayish buff limestone; cherty; vig. eff	25	925
White to buff gray limestone and dolomite; some particles eff. vigorously, others slowly	25	950
White to gray limestone; vigorous eff	50	1000
Argillaceous marl and gray limestone; vigorous eff	25	1025
White and buff gray limestone—"salt and pepper;" cherty; vigorous eff. Much water above 1050 ft. rose to within 160 ft. of surface; could lower head	25	1050
Sylvania? (Middle Monroe):		
White limestone, very cherty; vigorous eff	50	1100
White limestone; vigorous eff	25	1125
Extremely hard white and very cherty limestone, medium eff	100	1225
Marl and dolomitic limestone; medium eff "Water (brine) not shut off."	25	1250
Hard white sandy limestone; vigorous eff	50	1300

PRESQUE ISLE DEVELOPMENT COMPANY WELL.—Concluded.

Elevation 830 ± ft. A. T.	Thickness, feet.	Depth, feet.
Lower Monroe; Bass Island series:		
Hard reddish brown limestone; very ferruginous; very red at 1375 ft.; vigorous eff	50	1350
Very hard cherty gray dolomite; slow eff	25	1375
Hard gray dolomite, with rusty spots either from pyrite or from particles of the drill. Selenite crystals, slow eff. More or less anhydrite down to the salt	25	1400
Hard gray dolomite; slow eff	25	1425
Light buff and gray dolomite; slow eff	125	1550
Red shale and dolomite; slow eff	15	1565
Gray dolomite; slow eff	15	1580
Brown dolomite; slow eff	50	1630
Cased to 1640 feet.		
Salina:		
Reddish salt	145	1775
Red shale	30	1805
White salt	25	1830
Light shale and anhydrite	100	1930
Reddish salt	150	2080
Hard shale	10	2090
Reddish salt	65	2145
White salt	25	2170
Buff shale	10	2180
Gray salt	15	2195
Dolomite	15	2210
White salt	35	2245
Pink to very red salt	75	2320
Mainly anhydrite; some shale	10	2330
Mainly salt, some dolomite	15	2345
Dolomite and anhydrite	75	2420
Salt	50	2470
Anhydrite, dolomite and salt	10	2480
Soft red shale	15	2495
Dolomite and anhydrite	25	2520
Mainly anhydrite	25	2545
Salt and anhydrite	15	2560
Gray dolomite and anhydrite	10	2570
White salt; "caving at 2625 and at 2740; have to drill three screws to two of hole"	225	2795
Driller's record. No samples below 2825 ft.		
Gray limestone. 6 5-8 in. casing; no water	15	2810
Brown limestone, very hard; 25 ft. per day	40	2850
Hard gray or white limestone; 10 to 15 ft. per day	226	3076

In the Onaway well, the base of the Traverse is 310 feet below the surface and in the Grayling well it is over 2800 feet as the Bell shale at the base of the formation was not penetrated. Since the Traverse is about 600 feet thick in the northern part of the Lower Peninsula, and as the Grayling well penetrated 520 feet of Traverse limestones and shales, the base of this formation in the Grayling well should occur at 2880 feet. The exact elevation of the mouth of the Onaway well is not known but it is about 830 feet above sea level. Allowing for the difference in elevation between Onaway and Grayling (1140 ft. A. T.), the base of the Traverse at the latter place is about 2250 feet lower than at Onaway. The distance from Onaway to Grayling is about 54 miles by map measurement, therefore the average dip south-southwest is nearly 42 feet per mile.

Grand Lake. A number of years ago, a well 1712 feet in depth was drilled by the Alpena Land Co. at Grand Lake. A careful record was

kept and a set of samples preserved. This well was started directly in the Bell shales at the base of the Traverse and penetrated the Salina 425 feet, passing through salt beds aggregating more than 300 feet in thickness. Strong flows of salt water were struck at 1000 and 1257 feet. Fresh water was probably struck in the Dundee and Upper Monroe, though not mentioned in the record.

ALPENA LAND COMPANY WELL NO. 1.

Loc.: About 14 miles north of Alpena at Grand Lake. Lot 1, Sec. 8, T. 34 N., R. 8 E.

	Thickness, feet.	Depth, feet.
Traverse:		
Bell shale	50	50
Dundee:		
Crinoidal and fossiliferous limestone, bituminous and pyritic	215	265
Upper Monroe:		
Mixed samples of dolomite and limestone	30	295
Lucas:		
Stylolitic limestone	15	310
Amherstburg:		
Blue and buff dolomite	70	380
Anderdon limestone:		
Brown limestone	55	435
Dolomite and lime	15	450
Limestone	85	535
Black shale mixing with sample below, and limestone. (Cf. Milan 820)	80	615
Flat Rock?:		
Limestone, crinoidal in many places	85	700
Sylvania horizon. Cf. Milan 845-890:		
Cherty, crinoidal limestone	100	800
Largely chert	30	830
Cherty limestone	170	1000
Lower Monroe:		
Gashed dolomite and limestone	20	1020
Limestone, sometimes deep brown (dolomite also)	85	1105
Bluish dolomite, often gashed, with a few grains of sand	25	1130
Limestone, with a little sand, brown at top, then yellow. Water at 1257 feet	130	1260
Dolomite, Cf. Carmen 1210	24	1284
Top of salt formation or Salina, just about 450 feet below the cherty crinoidal limestone horizon that cannot be far from the Sylvania horizon. Compare Goderich groups IV and V.		
Salina:		
Salt	6	1290
Brown dolomite	50	1340
Salt and dolomite	7	1347
Hard layer	5	1352
Dark salt	5	1357
Salt, very clear from 1360-1395	80	1437
Anhydrite	28	1465
Reddish sand, marl or anhydrite	5	1470
Salt (top eight feet reddish)	40	1510
Salt and anhydrite?	4	1514
Brown salt	14	1528
Salt and shale	5	1533
Dolomite, anhydrite and shale	19	1552
Salt and anhydrite	20	1572
Salt, clear	17	1589
Impure salt with shale and anhydrite	5	1594
Salt, mainly clean, white	57	1651
Salt with clay and anhydrite streaks at 1655-1678. Cf. Carmen well 2105	50	1701
Anhydrite and dolomite	11	1712

ALPENA COUNTY.

Alpena. The early borings at Alpena were drilled for salt. One of the deep holes was drilled about 1872 near the bed of Thunder Bay river and "salt," probably brine, was reported at about 1025 feet. The record shows 400 feet of Traverse limestone followed by 80 feet

of blue fossiliferous Bell shales. Beneath the shales is 120 feet of Dundee limestone variable in color and hardness. Below the depth of 600 feet are light colored dolomitic limestones.

Later, the Churchill well was drilled in Alpena close to the bay. A very careful record was obtained and a summary of the same is appended below. The top of the well is in the Alpena coral limestone of the middle Traverse, hence there are about 130 feet of Upper Traverse shales and limestones unrepresented in the record. Down to 444 feet there is a continuous succession of hard limestones and blue or calcareous shales. The hard and cherty Dundee limestone appears to be 99 feet thick, but perhaps the shale, and heavy limestone just below should be included with the Dundee. Farther north near Rogers City, Mr. Hindshaw reports the Dundee as being 215 feet thick. The Monroe beds down to 777 feet are alternations of relatively thin shale beds and heavy beds of hard limestone. Following this series is 480 feet of hard white limestone (dolomite).

The first flow of water in the rock was struck at 427 feet and a strong flow in the Dundee at 489 feet, which kept increasing down to 590 feet. This last flow was exceptionally strong. Other flows occurred at 605 feet and apparently at various intervals down to about 1050 feet. No oil or gas was encountered worthy of mention.

CHURCHILL WELL.

Elevation of well 585 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand and boulders	41	41
Traverse:		
Hard white (light colored) limestone	25	66
Shale	9	75
Very hard white limestone	49.5	124.5
Shale	2.5	127
Extra hard gray limestone	40	167
Blue shale	20	187
Hard white limestone	34	221
Shale, 7 ft. white and slimy, possibly gypsum (?)	18	239
Hard white limestone	23	262
Very sticky blue shale	27	289
Hard white limestone	32	321
Shale	3	324
Hard white limestone, upper two-thirds extra hard	39	363
Bell:		
Shale	24	387
Hard white limestone	5	392
Shale, mostly blue. Some water at 427 feet	52	444
Dundee:		
Hard white and gray limestone, mostly extra hard. Strong flow of water at 489 feet	60	504
Extremely hard (flinty) limestone	39	543
Monroe:		
Shale	25	568
Hard gray and white limestone (Dundee?) Great flow of fresh water at 590 feet. Vein of sulphur water at 605 feet	103	671
Shale	20	691
Hard white limestone water	86	777
Sandy lime and shale	10	787
Hard white limestone	480	1267
Salina:		
Rock salt	20	1287

There are several other wells in the city or near it, but they only penetrate the Dundee for fresh water. Among these are C. Moench & Sons, the Tannery, and the Fletcher wells. (Ann. Rept. 1901, pp. 172-73).

Local structures. The Grand Lake well is slightly west of north of the Churchill well at a distance of a little over 14 miles. The elevation of the former well is not given but from the indicated location it appears to be about 630 feet A. T. or higher than the Churchill well which is near the level (580 ft. A. T.) of Lake Huron. If this elevation is used in the calculations of dip the error probably will not be greater than a foot per mile. Since the Bell shales in the Grand Lake well are 50 feet thick, the top of the Dundee would come at the same level as the mouth (585 ft. A. T.) of the Churchill well in which the Dundee was struck at 444 feet. This figure therefore represents the amount of dip in 14 miles, or an average dip of nearly 32 feet per mile a little east of south. This agrees fairly well with Grabau's determination, which is about 30 feet per mile. As the strike of the rocks is northwest-southeast and the above dip is along a line (see fig. 17), very oblique to the strike the above figure does not represent the maximum dip, which should be to the southwest. The 30 to 32 foot dip along the line from Grand Lake to Alpena should be equal to about 42 feet per mile to the southwest, and Grabau found that the average local dip, determined in several places, is approximately this figure.

Along the lake shore, however, northeast of Alpena, N. H. Winchell in 1870 noted marked dips toward the lake, yet at some distance from the shore he observed, in almost the opposite direction, a dip of 10° to the southwest. In the case of the Traverse beds, however, such dips may be due to the presence of the coral reefs, the dips being away from the reefs. Others have noted the same discordant dips. As noted on previous pages Mr. Wm. L. Hindshaw reports the same lakeward dips near Rogers City and associates them with the slumping of the formations due the ablation of the underlying salt beds along the margin of the lake.

The distance from the Grand Lake well to Grayling, according to map measurement, is about 74 miles. Comparing the wells at these two places, the latter being about 510 feet higher, the average dip appears to be about 32 feet per mile. As Grayling is not in direct line with the center of the Basin, and apparently is to the west of the north-south median line, this figure must be less than the maximum dip, i. e., 42 feet. As will be seen later, the dip southward from Partridge Point, Alpena county, where the Antrim shale outcrops, to the Killmaster wells in Alcona county is approximately 35 feet per mile,

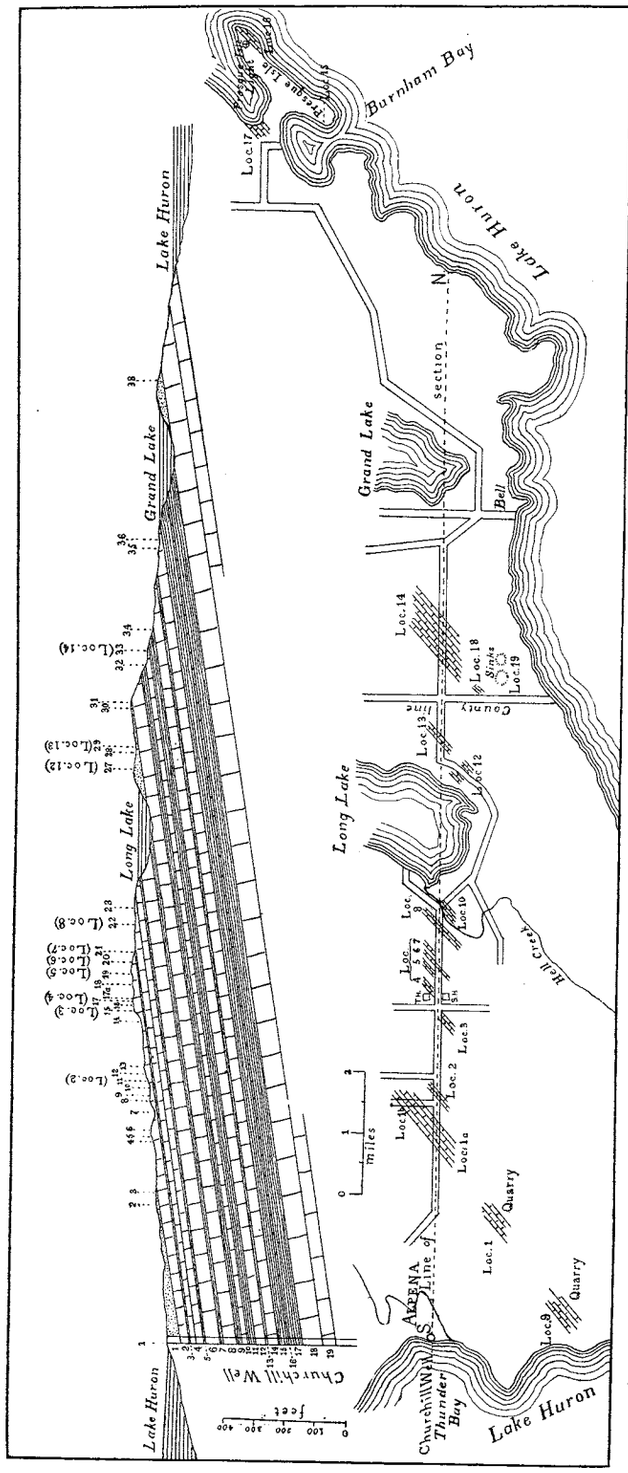


Figure. 17. Geological section from Alpena north through Grand Lake, Presque Isle county, to Lake Huron. (Annual report Mich. Geol. Surv., 1901, Plate VII).

Bed 1 = sand and gravel.
Bed 3 = thin shale bed.
Bed 5 = " " "
Bed 13 = " " "
Bed 16 = thin limestone bed.

and this should be equal to about 50 feet per mile to the southwest. From the foregoing approximations, it seems that the average southwest dip in the northeastern part of the Sourthern peninsula is between 40 and 50 feet per mile, 42 feet being about the average for the Alpena district.

While the Antrim, Dundee, and Traverse formations are bituminous, or contain bituminous horizons, yield a strong petroleum odor, and small quantities of gas in the northeastern part of the Southern Peninsula drillings have not shown any very promising signs of oil.

ALCONA COUNTY.

Relation of the rock formations to surface signs. Alcona county is underlain by the Marshall sandstone which crosses the southwestern corner, the Coldwater shales, the Berea sandstone, and Antrim black shale, the latter crossing the northeastern corner of the county. The strike of the formations is approximately northwest-southeast, therefore the dip is southwest toward the central part of the Basin. No rock outcrops are known in Alcona county. The Berea underlies the drift at Harrisville, as shown by the well at that place, and extends northwest toward Atlanta in Montmorency county and Vanderbilt in Otsego county. It is along the strike of this horizon and the Sunbury black shales that surface signs are most abundant.

There is another source of gas, however, and this is in the drift itself which contains an abundance of bituminous shale fragments, evidently from the Antrim. Apparently this bituminous material yields small but appreciable quantities of gas which collect in gravel beds in the drift.

In Alcona county, there are a large number of springs, some of which yield gas in considerable quantities. One of these near the center of sec. 26, T. 26 N., R. 8 E., yields so much gas that it led to the Killmaster drillings. According to reports, the gas from this spring when lighted will blaze up two or three feet above the water. There are several other similar gas springs in the same township as on secs. 14 (2 springs), 32, and 34. Gas springs also occur in sec. 15, (2 springs) T. 25 N., R. 8 E., and along the bed of the east branch of Pine river. Oil has also been noted on the Angus Cameron farm, sec. 12, T. 28 N., R. 5 E., and gas was struck in gravel, just above bed rock in the No. 1 Killmaster well.

Most of the county is deeply drift covered and there are no rock outcrops even in the deepest river valleys. Practically all knowledge of the bed rock geology has been obtained from drill holes at Killmaster and Harrisville, and from wells in Alpena and Iosco counties.

Killmaster. Three wells were drilled at Killmaster. The No. 3 well, drilled in 1892, was the last and deepest (1530 feet). Some gas with a very small amount of oil was struck in the top of the Berea which yielded an abundance of brine lower down. The latter overcame the oil and gas, but according to reports some years ago the well was still yielding bubbles of gas. Below the Berea the hole was absolutely dry.

KILLMASTER WELL NO. 3.

Loc.: Five hundred paces N., 1000 paces W. of the south line of sec. 22, T. 26 N., R. 8 E. On the east side of the stream 10 rods from the bridge. No samples.

Elevation 670 ± ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand, then till, no gravel at the bottom	240	240
Coldwater Shale:		
Sandstone	4	244
Gray shale	6	250
Sandstone	4	254
Gray shale	275	530
Sunbury (Berea) Shale:		
Red shale	20	550
Black shale	20	570
Berea Grit:		
Sandstone: Gas in top of sandstone, and a very small quantity of oil, which was overcome by salt water in the sandstone below the gas. However, bubbles of burning gas (not H_2S or CO_2) are now coming up continually in the water	40	610
Antrim Shale:		
Gray shales (compare Bedford shales)	150	760
Dark shales (compare Cleveland shales)	150	910
Gray shales (compare Erie shales)	25	935
Dark shales (compare Huron shales)	65	1000
(The top of the Traverse may be here.—Lane.)		
Gray shale and limestone	32	1032
Black shale (compare Huron shale)	58	1090
Traverse (Hamilton) Formation:		
Hard limestone	8	1098
Soft limestone	80	1178
Hard limestone	90	1268
Hard limestone	4	1272
Soft limestone	20	1292
Limestone	238	1530
Color varies from light to dark from 1090 ft. down.		

The No. 1 well is about 80 rods from No. 3, a little east of south, and it is about 10 feet higher. It is only 600 feet deep and stopped in a hard bed supposed at the time to be limestone, but it appears that this is only the hard upper crust of the bed at 570 feet in the No. 3 well. The formations are similar to those in No. 3 well except that there is a bed of gravel just above the rock which served as a reservoir for gas. (See Fig. 18), with a pressure of 103 pounds. The gas, however, was afterwards overcome by a large flow of nearly fresh water from the sandstone below.

Harrisville—In 1904 a well 506 feet deep was bored at Harrisville at the courthouse striking the Berea sandstone directly under the drift (Fig. 19) at 230 feet. There were signs of oil in the drift at 100 feet, but no further signs of either oil or gas were observed at any other horizon in the well.

HARRISVILLE WELL.

Loc.: Court House, Harrisville.

Elevation of well 640 ft. A. T.	Thickness, feet.	Depth, feet.
Post Glacial and outwash:		
Yellow loamy soil	12½	12½
Quicksand	14	26½
Red clay	6½	33
Gravel	6	39
Glacial:		
Wisconsin. Last till sheet (sand of mixed character, boulders, etc.)	60	99
Interglacial:		
Sand, signs of oil	30	129
(Quicksand, solidified to a blue hard pan at base).		
Earlier till sheet:		
Red hard pan	59	188
(Weathered till sheet).		
Red clay	4	192
Blue hard pan and pebbles	38	230
Berea Grit:		
White fine grained sandstone	30	260
Antrim shale:		
Light gray shale (Bedford) or weathered black shale	149	409
Brown and black shale	97	506

The Killmaster No. 3 well is about 8 miles west and 2¾ miles south from the Harrisville well, and allowing for the difference (30 feet) in altitude, the top of the Antrim in the former is 320 feet lower than in the latter. This represents a dip of 38.4 feet per mile in a direction a little south of west. This is exactly the same as the southward dip of the No. 2 well of the Alpena Business Men's Association at Partridge Point to the Killmaster wells. The direction of the maximum dip is probably between the two directions given above, or approximately southwest and would be about 42 feet per mile, or the same as the southwest dip in the vicinity of Alpena.

Comparing the Harrisville well with the James Norn well of Standish, Arenac county, the Berea appears to dip southwest at about 25 feet per mile. At Tawas City and Oscoda, a brine bearing sandstone occurs at 680 feet and 960 feet respectively. If the Tawas brine horizon is the Berea, then there is a pronounced syncline between Harrisville and Tawas and an anticline at the latter place. The sandstone at Tawas, however, appears to be above the base of the Coldwater, hence it corresponds to the Richmondville rather than the Berea sandstone.

Conclusions. The wells at Killmaster show that, locally, the Berea grit is not only a porous sandstone, but that it might contain gas and oil in commercial quantity if proper structural conditions were found. At Harrisville, however, the sandstone is too fine grained to be a free yielder and there was no showing of either oil or gas in the top of the Berea, although there is apparently an impervious cover of clay over

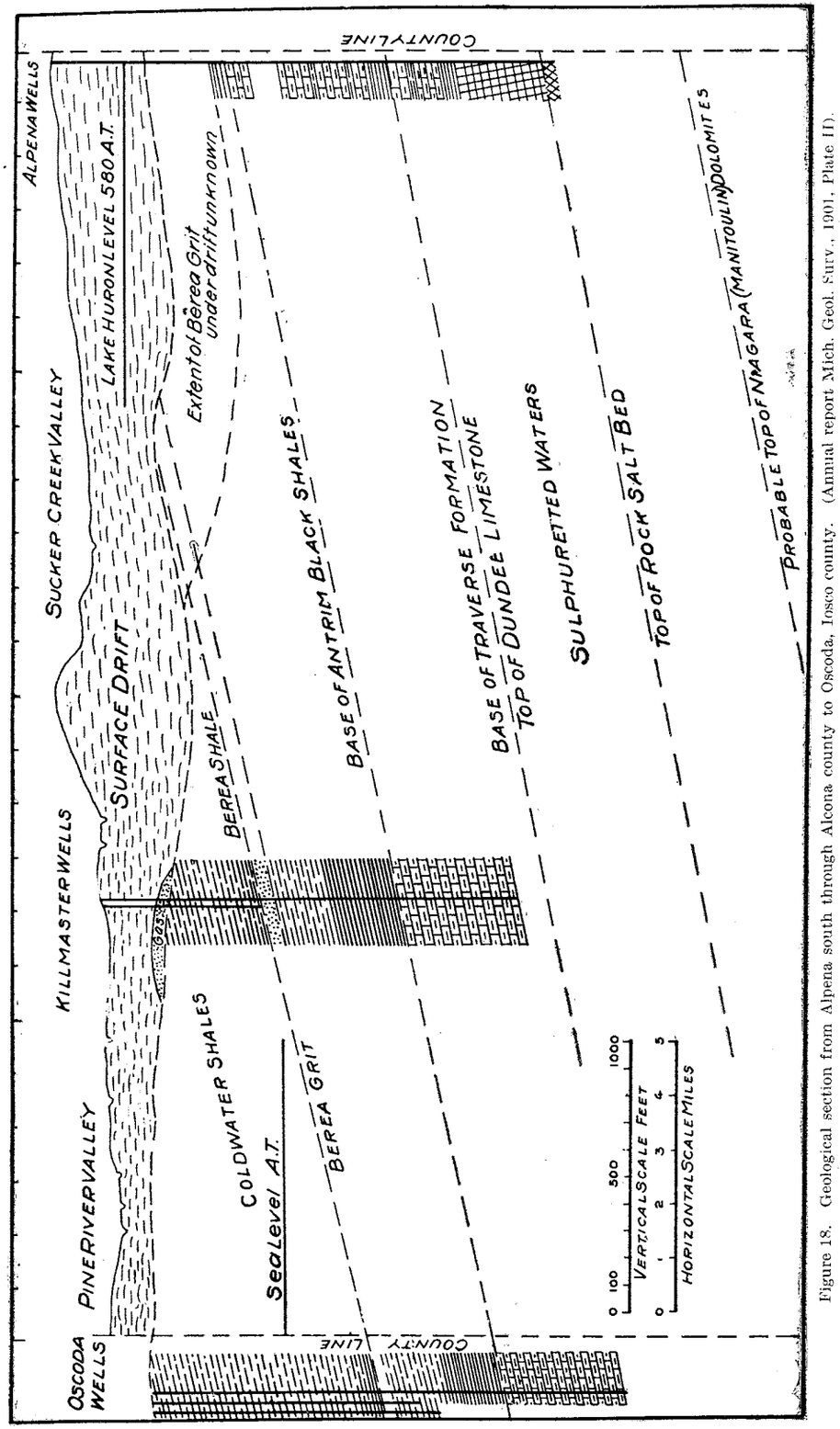


Figure 18. Geological section from Alpena south through Alcona county to Oscoda, Iosco county. (Annual report Mich. Geol. Surv., 1901, Plate II).

the outcrop (see Fig. 18) which ought to have trapped small quantities of oil and gas in the top of the sandstone itself. Elsewhere along the outcrop, these products probably escape into the sands and gravels of the overlying drift as illustrated in Fig. 19.

As the drift is very thick over most of the county, there are ample chances for the accumulation of considerable quantities of gas in the drift, especially along the strike of the Berea grit and the overlying and underlying black shales. Such accumulations are more apt to be found northwes from Harrisville toward Hubbard Lake, Atlanta in Montmorency county, and Vanderbilt, Otsego county. In order to test the possibilities of the Berea, explorations should be made at some distance to the southwest of this line of outcrop and belt of leakage.

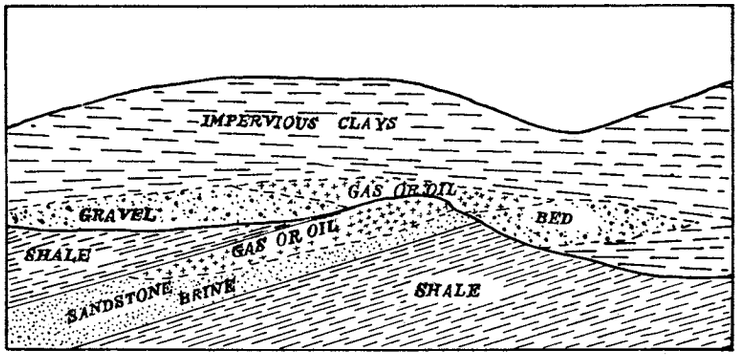


Figure 19. Diagrammatic sketch showing the possible occurrence of oil and gas along the strike of the Berea sandstone in Alcona county.

In Alcona county, he Traverse and Dundee formations are comparatively shallow and could be easily and cheaply tested. While the Traverse at Saginaw has three oil and gas bearing horizons, at Killmaster it was free from water and showed no signs of either oil or gas. The porosity of this formation, however, varies greatly in short distances and this is favorable for the occurrence of accumulations as in the so-called Saginaw sand in the Garey-Casamer No. 1 well at Saginaw.

Below the Traverse is the Dundee limestone which was not reached in the Killmaster drillings. Under favorable structural conditions oil may be found in considerable quantity in this formation, but the drillings are too few in Alcona county to indicate the presence or location of an anticline or structural bench, if either should exist. The oil and gas horizons beneath the Dundee, the Niagara, Clinton, Medina,

and Trenton are so deep that the cost of testing them would be out of proportion to any reasonable chance of success.

IOSCO AND OGEMAW COUNTIES.

AuSable and Oscoda Wells. In Iosco county at AuSable and Oscoda, eleven or more wells were put down by lumber companies for brines. The wells, all located within a radius of a mile, are in three groups which may be termed the Pack, the Smith, and the Loud. No detailed log of any of these wells is available, but from various sources the following information, which may be relied upon with a fair degree of confidence was compiled by Dr. A. C. Lane.

The Pack wells are from 20 to 25 feet above the lake, the Smith about 15 feet, and the Loud 6 to 8 feet. The drift, 90 to 100 feet thick, is mainly sand. The rock strata down to 200 feet, or more, are a series of sandstones and shales, apparently belonging to the Lower Marshall formation, which yields a very weak brine (one-half — one per cent of salt). Below the Marshall blue shales with an occasional red horizon predominate down to the Sunbury black shale which overlies the Berea grit. The latter in the Pack wells was struck at 950 feet, in the Smith at 960 feet, and probably at a little greater depth in the Loud. The brine of the Berea is strong (90°— 98° salinometer test) and pure, but the sandstone is so fine grained and shaly that there is not a free flow.

According to Mr. E. E. Holmes, the sandstone runs out to the north, yielding less and less brine. This can be the condition only for a short distance, however, as the sandstone is well represented at Killmaster and Harrisville. At Grayling, Alma, Mt. Pleasant, and in other places in the central and western parts of the State, the formation appears to be represented by shales, generally red or sandy.

According to the records of wells in various parts of the State the Berea, while locally coarse grained and porous, yielding an abundant flow of brine, is apt to be very fine grained or shaly as at Oscoda, Harrisville, Bay City, and Saginaw. In such localities, it cannot be a free yielder of oil and gas.

One of the Pack wells was drilled to a depth of about 1800 feet, reports varying from 1760 to 1850 feet. Only blue and black shales with thin streaks of limestone were penetrated below the Berea, and no water or signs of oil and gas were encountered. It is almost certain that the well did not reach the Dundee, but the bottom must have been very close to the top of this formation for the drill stopped in black shale, quite possibly the Bell (Marcellus) at the base of the Traverse. The hardness, light color, and the mineral waters of the

Dundee would have been noted and remembered if the drill had reached this horizon.

At Harrisville the Berea is only 30 feet thick, being in part eroded. If it was originally as thick as it is at Killmaster, about 10 feet must have been removed, and the top of the Berea would have occurred at 220 feet instead of 230 feet. Using the first figure and allowing for the difference (35 ft.) in elevation of the mouths of the Harrisville and Oscoda wells, the Berea is approximately 765 feet lower at the latter place about 16½ miles to the south. This is equal to a dip of over 46 feet per mile, or about 8 feet per mile more than from Partridge Point, Alpena county, to Harrisville, or from Harrisville west-southwest to Killmaster. Computing the dip to the south-southeast from Killmaster to Oscoda, it is found to be about 30 feet per mile. If the black (Bell) shale at the bottom of the Pack well is the same as that at the top of the Grand Lake well, the dip southward from Alpena to Oscoda must be between 30 and 40 feet per mile.

From the above, the general or maximum dip for eastern Alcona and Iosco counties appears to be nearer south than southwest. From Oscoda south to Caseville across Saginaw bay in Huron county and south-southwest to Bay City, there is a decided flattening of the dip of the Berea, as the dip is only about 22 feet per mile toward the former and less than 20 feet per mile toward Bay City.

Tawas City. Several drillings have been made by the lumber companies of Tawas City for brine, which was struck in a coarse white or gray sandstone, apparently in the Coldwater shale but at some distance above the true Berea horizon.

TAWAS CITY WELL.

Loc.: Grant & Sons Mill.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Sand		
Clay, yellow	30	30
Napoleon or Upper Marshall:		
Sandstone, whitish	20	50
Lower Marshall and Coldwater:		
Sandstone, red	60	110
Sandstone, gray	15	125
Sandstone, red	5	130
Shale, light colored	40	170
Shale, arenaceous red	10	180
Shale, light colored	30	210
Shale, arenaceous red	5	215
Shale, blue	88	303
Sandstone, red	35	338
Shale, hard, light colored	40	378
Sandstone, red	60	438
Shale, white	5	443
Sandstone, red	15	458
Shale, hard, light colored	5	463
Sandstone, red	40	503
Shale, white	5	508
Shale, arenaceous, light colored	3	513
First indications of brine.	3	516
Shale, white, hard		
Richmondville?:	164	680
Sandstone, gray		
Abundant supply of strong brine.	195	875
Appears to be too near the top of the Coldwater to be the Berea.		
Shale, blue	10	885

The general dip of the strata in Iosco county is apparently south-southwest at about 25 to 30 feet per mile. According to this the Berea should occur about 300 or 400 feet deeper at Tawas City than at Oscoda. Since the Berea is struck at approximately 950 feet in wells at the latter place it should be 1250 or 1350 feet below the surface at Tawas City. As the brine bearing sandstone at this place is struck at a depth of only 680 feet it appears that it is not the Berea but the Richmondville or some stray sandstone in the Coldwater shales 600 feet or more above the Berea horizon.

If the sandstone in question is the Berea proper, there is a very pronounced anticline in Iosco county with its crest near Tawas City.

OGEMAW COUNTY.

Prescott. In 1912 Mr. F. Jahncke of Alpena drilled a well for water near Prescott in southeastern Ogemaw county. The Upper Marshall was struck at 308 feet and the Coldwater shales were penetrated about 170 feet.

PRESCOTT WELL.

Loc.: S. W. Cor. of sec. 36, T. 22, R. 4 E., Ogemaw county. Franz Jahncke, contractor, Alpena, Mich., March 16, 1912. Record furnished by Mr. Jahncke, also samples.

Elevation of well about 768 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Red clay	6	6
Blue clay	9	15
Fine white sand	6	21
Red clay	37	58
Gravel	2	60
Red clay	55	115
Red clay and grit	14	129
Blue clay, round fragments of gypsum and rock	25	154
Michigan Series:		
Gray rock (Sample missing)	4	158
Blue shale	27	185
Gypsum	3	188
Blue shale	4	192
Dark rock	3	195
Dark shale	3	198
Gray limestone	4	202
Blue shale	5	207
Dark rock	1	208
Gypsum	2	210
Dark blue limestone	10	220
Brown limestone	3	223
Gypsum	8	231
Blue shale calcareous	3	234
Blue limestone	4	238
Brown limestone	12	250
Gypsum	3	253
Blue limestone	9	262
Hard gray limestone	12	274
Chert (a little flow of water)	2	276
Dark blue limestone	12	288
Blue shale and dark	18	306
Chert very hard	2	308
Upper Marshall or Napoleon:		
White sand (water rises from 26 ft. to 22 ft. 4 in. from top of casing)	10	318
Chert (Sample missing)	2	320
White sand	16	336
Red sand (Sample missing)	3	339
White sand (Sample missing)	21	360
Light blue sand	68	428
Water 16 ft. 7 in. from surface.		
Lower Marshall:		
Red rock with mica	55	483
Coldwater?		
Blue shale (Sample missing)	45	528
Brown rock with mica	62	590
Blue shale sandy	44	634
Brown shale sandy	16	650

ARENAC COUNTY

Standish. In Arenac county, there are a number of wells penetrating rock, but they are shallow excepting a 1900 foot well drilled by James Norn at Standish of which no log was kept but it appears to have reached the Berea (Sunbury) black shale just above the Berea grit. Below the Marshall, blue shales of the Coldwater which yielded a little brine, predominated.

The record given below has been largely compiled from notes and statements of persons connected with the drilling of the well, and may be taken as fairly representative of the general character and thickness of the formations penetrated.

JAMES NORN WELL.

Loc.: Standish.

Elevation of well 626 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Clay, sand, etc	60	60
Saginaw Coal Series:		
Gray sandstone	40	100
Blue shale	20	120
Black shale	10	130
Upper Grand Rapids:		
Blue and gray limestone	70	200
Gray sandstone	40	240
Lower Grand Rapids:		
Blue rock	40	280
Shale?	20	300
Shale?	30	330
Blue rock	60	390
Blue shale	10	400
Hard gray rock; streaks of shale; big flow of water	50	450
Upper Marshall or Napoleon Sandstone:		
Gray sandstone, rapid drilling	200	650
Lower Marshall Sandstone:		
Red sandstone and blue shale (brine easily exhausted.) Blue shale with some red shale	250	900
Coldwater Shale:		
Mostly blue shale. Some water at the top	100	1000
Blue shale, some brine but scarce	400	1400
Blue shale	400	1800
Berea Shale:		
Black shale, some water	50	1850

CHAPTER X.

NORTHERN PENINSULA.

THE PALAEOZOIC AREA.

That part of the Upper Peninsula west of a line drawn from Marquette to Menominee is mainly underlain by pre-Cambrian rocks. Palaeozoic rocks from the Cambrian up to and including the Silurian occupy all of the area to the east of this line.

The Niagara limestone extends in an accurate belt along the western shore of Lake Michigan through Green Bay peninsula and along the northern shores of Lakes Michigan and Huron from Garden Peninsula to Drummond Island and into Cockburn and Manitoulin Islands, Ontario. The St. Ignace Peninsula, however, is composed of Monroe beds.

The Niagara in the Upper Peninsula is a massive limestone and dolomite formation with an average thickness of about 600 feet. The prevailing dip is lakeward from 40 to 60 feet per mile and this gives rise to low rocky shores with few deep harbors. Toward the interior the rock surface rises to considerable heights and the outer margin of the formation is marked by a prominent line of landward facing bluffs 100 to 200 feet high. The elevation of the interior and the lakeward dip of the rocks give rise to general artesian conditions along the lake shore. As a consequence much drilling for water has been done at several points but as water from limestones is nearly always very hard, some relatively deep drillings have been made in search of softer waters. These drillings, together with observations afforded by extensive outcrops, indicate that the Niagara contains very little bituminous matter and that in the Upper Peninsula it gives little promise of yielding oil and gas.

The Clinton, Rochester and Medina are doubtfully recognized in outcrops or in borings and can not be distinguished from each other. The Lorraine and the Utica are well represented and are easily recognized in drill holes. These shaly formations, being very soft, occur in a belt of depressions on the north side of the Niagara escarpment and outcrop in but few places. The Utica shale is exposed in the beds of streams on the east side of Whitefish river.

The Trenton limestone forms the western shore of Green Bay and

Little Bay de Noc, turns eastward in Delta county, describing an arc through the Northern Peninsula, and crosses St. Mary's river at St. Joseph Island into Ontario. Nowhere in the Northern Peninsula is the Trenton very deep, yet it offers certain oil and gas possibilities, for, aside from its bituminous and petroliferous character, it has a suitable cap rock, being overlain in most of the Peninsula by the impervious shales of the Utica and Lorraine.

The Trenton outcrops over a very large area and in general is under a very thin cover of drift in the vicinity of Rapid and Whitefish rivers. Wherever exposed, it shows signs of the former presence of oil and gas. The rock is bituminous and petroliferous and very frequently the cracks and fissures are found to contain dried oil residue or asphaltum "gum."

Comparatively little exploration has been done in the Upper Peninsula except for water. Thus far wells have been sunk at Marinette (Wisconsin), Menominee, Rapid River, Escanaba, Gladstone and Flat Rock, near Stonington, at Pickford, Neebish Island, and St. Ignace.

THE WISCONSIN SECTION.

Milwaukee. In order to show the relation of the eastern Wisconsin rocks to the Michigan Basin, the following log of the Lake Park well is given below. Comparing it with the western Michigan borings, it is to be observed that the formations in eastern Wisconsin are merely the western edges of the lower formations of the Michigan Basin. The dip from Milwaukee across Lake Michigan to Muskegon is rather flat, being only about 20 feet per mile. Farther north in the Northern Peninsula the dip toward the center of the Basin becomes much greater ranging from 40 to 60 feet, or even more per mile.

LAKE PARK WELL, MILWAUKEE.

	Thickness, feet.	Depth, feet.
Hamilton (Traverse) Group:		
Soapstone	80	80
Cement rock	12	92
Soapstone	30	122
Dundee absent:		
Waterlime? Brown limestone	30	152
Niagara limestone	320	470
Cincinnati shale (Medina to Utica)	180	650
Galena and Trenton limestone	300?	950?
St. Peters sandstone at	.....	958
Potsdam sandstone	.....	?

Marinette. A number of wells were sunk in Marinette by the Hon. Isaac Stephenson, A. C. Merriman, and the city at the waterworks.

The record of Mr. Stephenson's well is incomplete, but the well apparently penetrated limestone and dolomite and a little light reddish sandstone, and a thin stratum of shale in the first 200 feet. A flow of water was struck in a crevice in the Calciferous (or the St. Peters) at 405 feet. At 410 feet, there was a large crevice, the tools dropping four feet and breaking the cable. The flow of water from this crevice was stronger and rose 21 feet above the surface. Below this point there was no increase in the amount of water though the well penetrated mainly lime rock until "granite" was struck at 716 feet. The granite, according to Lane, is probably a cherty or jaspilitic arkose quartzite which was struck in a later well drilled at the waterworks.[1]

At Oakwood, three miles south of the city, it was claimed that a well reached a depth of 999 feet, but the samples at 860 (white sand) and at 920 feet do not resemble the Huronian rocks which should be struck at those depths. From a comparison with the records of other wells in the vicinity there seems to have been a mistake of 100 feet in the record.

A well two miles south of the Stephenson well was drilled in 1902-3 for oil and gas to the depth of 850 feet. This well may have reached the pre-Cambrian as red "sand," similar to Huronian well samples from other wells, was struck at the bottom.

The first deep well drilled at the city water works was not completed as the tools were lost in the hole and could not be recovered. Another hole was drilled about 8 feet away and this struck the first hole at about 860 feet. Artesian water, struck above 860 feet in the second well, flowed out of the first after the intersection of the two. The tools were deflected on the old ones in the bottom of the first well and the hole was drilled to the depth of 978 feet, penetrating over 180 feet of Huronian rocks. The well yielded a little oil along with the water, but the oil probably came from the vugs or cavities in the limestone and not from the pre-Cambrian rocks as supposed by some. In the Rapid River well, Delta county, oil occurred in limestone in this way and at the same horizon.

[1]Ann. Rept. for 1903, p. 123.

MARINETTE WATER WORKS WELL NO. 1.

Loc.: Waterworks, Marinette, Wis

	Thickness, feet.	Depth, feet.
Pleistocene:		
Red sand and gravel	70	70
?	15	85
Galena limestone:		
Round chipped limestone (or to 196 ft.)	59	144
Trenton limestone:		
Blue shales (Galena?)	52	196
Chipping limestone coarse	44	240
Chipping limestone	10	250
"Slate" light blue and white	70	320
(Base of Trenton uncertain, St. Peters sandstone absent?)		
Lower Magnesian (Calciferous) limestone:		
Chipping limestone, coarse	130	450
Coarse chipping limestone light colored and dolomitic	100	550
Potsdam group?:		
White sandstone, very white, mealy-looking	10	560
White and greenish, calcareous sandstone	110	670
White sand	15	685
Rounded white sand	27	712
Huronian? (Potsdam wholly or in part?):		
"Granite" (broken and lost)	4	716
Dark red quartzite	?	716+

MARINETTE WATER WORKS WELL NO. 2.

	Thickness, feet,	Depth, feet.
Surface sand and gravel	69	69
Galena dolomite	121	190
Trenton dolomites, brown and blue shaly (at 260 to 275 sandy)	135	325
St. Peters sandstone	75	400
Calciferous (Lower Magnesian)	180	580
Potsdam	215	795
Pre-Cambrian:		
Cherty or jaspilitic arkose quartzite	183	978

MENOMINEE COUNTY.

Menominee. Several deep wells have been sunk in Menominee just across the river from Marinette. The records of all of the wells are incomplete and are of little value. A well drilled in 1895-6 at the residence of the Hon. S. M. Stephenson is reported to be 500 to 1000 feet deep. The water has a head of 15 feet and it is said to come mainly from sandstone, perhaps the Potsdam. A well on Mr. Stephenson's farm which, like the one at his residence, begins in the Trenton and perhaps reaches the pre-Cambrian. The water is hard, therefore it probably comes from limestone.

DELTA COUNTY.

Escanaba. In Delta county, there are several wells from 600 to nearly 1000 feet in depth. In 1890 the Escanaba Brewing Company drilled a well for soft water 730 feet in depth at Escanaba, but only a meager record was obtainable. The record below is given from memory by Nick Welch:

ESCANABA BREWING COMPANY WELL.

	Feet.
Surface	39
Limestone	150–200
Sandstone	300–400
Struck "iron" at	730
Water very red.	

The Escanaba Manufacturing Company made a drilling to a depth of 972 feet for water, but no record was kept. The Richter Brewing Company also drilled a well 810 feet and the record furnished by the brewmaster, Mr. Richter, is one from memory:

RICHTER BREWING COMPANY WELL.

	Feet.
Sand	50
Hard clay	9
? ((probably limestone mainly)	300
Sandstone	410
"Granite" at	810

Stonington. A. Wagner drilled two holes on his farm, three or four miles northeast of Stonington and, according to reports, the first was for coal and the second, a diamond drilling for iron. Mr. J. Wagner, present owner of the farm, furnished Mr. L. P. Barrett of the Survey with a record given from memory. A core was preserved but Mr. Barrett was not permitted to see this.

A. WAGNER WELL.

Loc.: Delta county, S. W. ¼ of N. W. ¼ of sec. 8, T. 39 N., R. 21 W. Drilled for coal. Formerly A. Wagner farm; present owner Jno. Wagner.

Elevation over 650 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Gravel and clay	9	9
Lorraine (Hudson River):		
Blue shale	45	54
Fossiliferous shale	13	57
Brown shale	28	95
Blue shale	20	115
Brown shale	8	123
Gray shale	70	193
Light gray shale	8	201
Utica:		
Bituminous shale	50	251
Trenton limestone:		
Galena:		
Limestone	83	334
Fossiliferous limestone	55	389
White limestone	8	397
"Upper blue" of Wisconsin, Trenton?		
Dark limestone	9	406
"Upper buff?"		
Quartzite (geods?)	6	412
Limestone	44	456
Quartz (geods?)	1	457
Limestone	24	481
"Lower blue."		
Blue shale	4	485
Black limestone	14	499
Limestone	19	518
Blue shale	4	522
"Lower buff."		
Sandstone, soapstone and limestone (perhaps in part St. Peters)	38	560
St. Peters:		
Red clay shale (weathered surface of Lower Magnesian?)	1	561
Sandy shale	1	562
Calciferous:		
Limestone, soapstone and sandstone	66	628
Crystalline limestone	12	640
Depth of hole	.....	640

A. WAGNER HOLE NO. 2.

Loc.: S. W. ¼ N. W. ¼, sec. 8, T. 39 N., R. 21 W. Formerly A. Wagner farm; present owner, Jno. Wagner. Three or four miles northeast of Stonington. Drillers, Gunter of Escanaba and Chris. Skaug of Stonington. Drilled about 1910.

Elevation over 650 feet.	Thickness, feet.	Depth, feet.
Surface:		
Sand and gravel	8	8
Clinton, Medina, Lorraine and Utica:		
Fossiliferous limestone	32	40
Alternate shale and limestone	200	240
Bituminous shale (Utica in lower part)	250	490
Trenton, Calciferous, St. Peters, Potsdam:		
Limestone, sandstone and blue shale	490	750
Hematite. Two veins two and seven inches thick, interbedded in sandstone (Huronian?)	1	751
Sandstone	29	780
Huronian:		
Hard white quartzite with pebbles in it	68	848

Gladstone. The St. Paul and Ste. Marie railroad drilled a well for water at Gladstone, but the precise location is not given.

ST. PAUL AND STE. MARIE RAILWAY WELL.

Loc.: Gladstone.

Elevation 605 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or surface:		
Sand (old dug well)	13	13
Quicksand	38	51
Till (clay and hardpan)	10½	61½
Sand and gravel	15	76½
Clay and limestone	10½	87
Boulders	4	91
Trenton:		
Limestone	234	325
St. Peters:		
Lime and sandstone in mixed layers. Some water at 400 feet	89	404
Calciferous (Lower Magnesian):		
Limestone (crystalline dolomite at 632 feet)	228	642
Potsdam:		
Shell sandstone (white round sand at 742 ft.) Main water flow; 150 gallons per minute. Soft water.	101	743

Rapid River. In the central part of Delta county, there are a number of water wells, mainly artesian, said to be from 250 to 900 feet in depth, as at Flat Rock, Lathrop, Maple Ridge, Parkins, Gladstone, and Rapid River. In some of the more northerly wells, it is only from 80 to 150 feet to the water bearing sandstones. At Rapid River, a dozen or more wells are supposed to be deep enough to go through the Trenton, which yields strong flows of water.

Seven miles north and two miles east of Rapid River, a well was drilled for oil. The set of samples taken for the Survey was stolen so that a very incomplete and perhaps inaccurate record can be given. The surface rock is the Trenton which apparently consists of about 300 feet of more or less oily and bituminous limestone. The rest of the well is largely in white sandstone, except at the bottom where decomposed schist of Huronian or Archean age was struck. There were strong flows of water, probably from the same horizons as in the Rapid River wells. A small quantity of oil was obtained in the Trenton. According to newspaper reports at the time, the flow, greatly exaggerated, was given as 400 barrels per day. The oil probably came from the vugs or cavities in the Trenton limestone rather than from the Archean rocks as was claimed at first.

The following record was made from scattered samples.

RAPID RIVER WELL.

Loc.: Two hundred paces W., 505 S. of N. E. Cor. of sec. 34, T. 42 N., R. 21 W.; 7 mi. N. and 2 mi. E. of Rapid River.

	Thickness, feet.	Depth, feet.
Surface:		
Swamp peat and muck	3–6	6
Marl	10	16
Fifteen ft. 10 in. casing.		
Trenton limestone:		
Dolomite with geods lined with fine dog-tooth spar calcite and filled with oil "gum"	264	280?
St. Peters horizon:?		
Signs of oil. Strong flow of water, over 1 quart a second. Temperature 47° 3 F.		
An old well 300 ft. west was 202 ft. deep	350	630
Calciferous?		
S. at 620 box 380, a dolomite.		
Potsdam sandstone:		
"White sandstone comes in 600-700 ft. down," Clear white glass sand (Upper Potsdam of Rominger).		
Samples, boxes 300 to 370	80	710
Reddish sandstone coarse:		
Sample, box 290	10	720
Coarse red sandstone.		
Sample, boxes 250 to 280	40	760
Feldspathic sandstone.		
Box 290	10	770
Coarse mixed very micaceous red sandstone.		
Box 210-230	30	800
Last samples, large fragments of decomposed chloritic schist, like Archaean rocks.		

Another well 1000 feet in depth was drilled a year or two later 7 miles northeast of Rapid River on the property of A. E. Neff. This record is more satisfactory than the foregoing one and shows that the pre-Cambrian is at comparatively shallow depths in the vicinity of Rapid River. The following record was compiled from samples.

A. E. NEFF WELL.

Loc.: Seven miles N. E. of Rapid River, Mich. Owner, A. E. Neff. Driller, Cisco. Drilled in 1904.

	Thickness, feet.	Depth feet.
Surface materials	12	12
Trenton limestone:		
Top limestone—dark, mixed, some sand	218	230
Limestone—mixed brown and blue	60	290
No record 290–302	12	302
St. Peters:		
Sand—round quartz sand, white	18	320
Calciferous:		
Limestone—fine grained, white, massive	35	355
Sand—clean, white, quartz sand	20	420
Sandy lime—white powder	10	430
Sand—clean white quartz sand	20	450
Sand—white dolomitic powder	25	475
Sand—quartz and white dolomite mixed	25	500
Sand—cemented by dolomite	30	530
Cased 9 5-8 in. pipe.		
Slate—dull bluish	25	555
No record 565-630	75	630
Lake Superior or Munising Sandstone:		
Gray, sandy round quartz and rarely other grains	45	675
Red sandstone—light pinkish quartz grains	35	710
White sand—white quartz grains	15	725
Red sand—pinkish quartz grains "725 grit." Water flow	25	750
Sand—mica, quartz, feldspar, etc., mixed	30	780
Sand—mica, quartz, feldspar, chlorite. Arkose? but not rounded. "780 red granite"	50	830
No record 830-875 ±.		
Pre-Cambrian:		
Rusty, much mica. "Wedged in bottom from description in gabbro"	125	.....
Quartz and feldspar? a pounded aplite?	.....	875 ±
Feldspar, chlorite, mica hornblende	.....	890 ±
Fine grained dark feldspar, chlorite, etc	.....	900 ±
Bottom	.....	1000 ±

Oil and Asphalt. In many places there is an asphaltic oil in the cavities of the Trenton limestone. The oil is a more or less semi-fluid, dark brown to almost black oil residuum or asphaltic "gum." The "gum," according to Fr. Ruschaupt of Milwaukee, who made some analyses and tests, is odorless until heated and then gives an asphalt smell, foams at 185° F., fully liquid at 200°, foams from 300° to 350°, slightly decomposes at 430° with an evolution of a small amount of empyreumatic matter and boils at 556°. After about one and a half hour's boiling the asphaltic gum thickens and the boiling point rises. Boiling the residue at 600° F. for three-quarters of an hour and then cooling to 70°, gave a hard tenaceous asphalt. There is no

paraffin or petroleum in the distillate, gum asphalt being the only base. The results of two tests by Fr. Ruschaupt are given below:

ANALYSES.

	No. 1. Percent.	No. 2. Percent.
Distilled at 212° to 347° (mainly water)	25	2.21
Distilled at 570° to 600° (mainly oil)	45.36	46.55
Asphalt	24.56	46.73
Balance ash or decomposition products	5.08	4.51
Total	100.00	.....

Upon the supposition that a great pool of asphalt exists in a "synclinorium" in northern Michigan, a company was formed in Milwaukee to prospect for commercially important quantities but nothing came of the project. Oil might be found in quantity in the Trenton, especially in those regions where the formation is overlain by the Utica and Lorraine shales.

The wells of reliable record are so scattered in Delta county that there are no indications of favorable structures such as anticlines or benches. The general dip is southeasterly at from 40 to 50 feet per mile, but since no wells of accurate record on the opposite side of Lake Michigan reach any of the horizons represented in the region under discussion, no exact calculations can be made.

SCHOOLCRAFT COUNTY.

Manistique. At Manistique, the flowing wells are from 200 to 800 feet in depth. At 800 feet in the Hiawatha House well, a flow was struck which lifted the drill. The head was 30 to 40 feet and the water bearing stratum is in a "not hard, shell rock," probably the Trenton. The wells furnishing the municipal supply obtain their water from depths between 250 and 500 feet. The deepest well was drilled for salt but the tools were lost in the hole. The water is hard as it is from limestone. Possibly soft water could be obtained from the Potsdam, but the depth probably would be at least 1400 feet or much greater than at Escanaba.

In 1903 a number of new city wells were put down. Mr. Coleman, the driller, gave the following record:

MANISTIQUE MUNICIPAL WELL.

Loc.: Cor. of Garden Ave. and Potter St. Finished August, 1903.

Elevation 595 ft. A. T.	Thickness, feet.	Depth, feet.
Sand	2	2
Dolomite, light buff, massive	2	4
Light dolomitic limestone	9	13
Bluish white dolomite (harsh feel)	11	24
Brownish crystalline dolomitic limestone	16	40
Light bluish dolomitic limestone	12	52
Buff crystalline cherty limestone	13	63
White limestone	7	70
Buff, crystalline dolomitic limestone	10	80
Hard drilling from 0 to 80 ft.		
White limestone (Blaney—Fiborn bed?)	27	107
Mottled gray dolomite	18	125
Buff dolomite	11	136
Soft drilling from 80 to 140 feet.		
Yellow dolomite	22	158
Gets harder; very little water at 140 feet but no flow.		
Yellowish limestone	30	188
Yellowish dolomite	12	215
This may be base of coralline, top of Byron beds of Wisconsin, Rominger's lower division.		
White thin banded lithographic dolomite	10	225
At bottom white limestone	15	240

All of the above wells are artesian and the flows are from the Niagara, with the exception of the Hiawatha House well, which probably obtains its flow from the Trenton. Usually, abundant water is found in the Niagara from 60 to 70 feet below the top as shown by other wells which penetrate this formation in Michigan and Ontario.

In the Manistique region, the Trenton, which is locally very porous, is overlain by the Utica, the Lorraine, and the Niagara, and, should favorable structures exist, oil and gas may occur in commercial quantities The shallowness of most of the wells and the incomplete records of the deeper ones do not permit a close approximation of either the general or the local dip, and much less, a determination of the presence of local structures. From surface observations, however, the dip appears to be fully 40 feet per mile to the southeast.

MACKINAC COUNTY.

St. Ignace. In 1887, the Mackinac Lumber Co. drilled a well at St. Ignace to the depth of 919 feet. As the rocks on the St. Ignace peninsula are practically all of Monroe age, good water supplies are hard to obtain, the surface waters and those from bed rock being strong in sulphates. Plenty of good water, though hard, may be found in the Niagara. A cherty layer at the bottom of the well yielded some gas.

ST. IGNACE WELL NO. 1.

Mackinac Lumber Co. O. W. Johnson, Racine, Wis. W. A. Burt. Drilled in 1887 by Henry Errata.

Elevation about 600 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sawdust and clay	15	15
Monroe Formation:		
Red and blue slates, principally red. Strongly impregnated. Salt water with a bitter taste	385	400
Red marl and a vein of salt	4	404
Blue slate	100	504
Niagara (Guelph and Lockport):		
Limestone (contains a little dolomite and gypsum.) Very light buff. Dolomite with slow eff. Upper strata are probably Monroe; see well No. 2	300	804
Driller's name, sandstone; with a strong smell, oily. S. white limestone; contains a little gypsum, 2 per cent	95	899
S. Calcareous sandstone (gray); 90 per cent chert, etc.; rusty. Some gas	20	919

St. Ignace Well No. 2. Well No. 2 at St. Ignace is about two miles north of the old well, 300 feet from Lake Huron, and only about 10 feet above lake level. A comparison of the two wells show that the beds dip rather steeply, the dip being over 40 feet per mile. Neither of these wells show the Medina, Lorraine, or Utica. The Lorraine and Utica are known to exist in the Upper Peninsula and from the Neebish well the total drop of the formations must be over 1200 feet in 30 miles, or over 40 feet per mile. If 500 feet is allowed for the thickness of the shaly beds, above the Trenton, the total drop would be over 1700 feet, which would be equal to a dip of about 55 feet per mile from Neebish southwest to St. Ignace. As the general dip is nearly south and not southwest, the maximum dip is probably 60 to 65 feet to the mile.

ST. IGNACE WELL NO. 2.

Loc.: Two mi. north of No. 1 on sec. 31, T. 41 N., R. 3 W.; 600 ft. N. of town line and 300 ft. from Lake Huron.

Elevation 590 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Surface	34	34
Gravel with gypsum	9	45
Monroe Formation:		
Dolomite	63	to 89
Dark dolomite	100	to 104
Gypsum	174	to 187
Red shale	.....	.....
Blue shale	.....	.....
Gypsum	255	to 260
Red shale	.....	.....
Blue shale	.....	.....
Gypsum, about	.....	300
Blue shale with gypsum at 329 and 364 to 400 ft. and other spots to 426 feet	126	426
Gypsiferous dolomite	18	444
Light dolomite	19	463
Dark brown dolomite	47	510
Niagara (Guelph):		
Light dolomite	60	570
White sandy dolomite	15	585
Good water at 575 ft. 589 ft., January 29.		
Hard mixed cherty dolomite	7	592
White sandy dolomite	196	788
581 ft. Feb. 10; H_2S water for over 100 ft.; 870, March 23.		
Brown and mixed dolomite	232	1020
Lockport (?):		
Limestone	90	1110
Rochester (?):		
Blue shaly dolomite	35	1145
Brown cherty dolomite	5	1150
Light dolomite	16	1166

CHIPPEWA COUNTY.

Neebish A well was drilled on St. Joseph's Island to the depth of 200 feet and, according to reports, it penetrated the Huronian without striking oil. No further details are known. On Neebish Island, near Sailor's Encampment and close to the water, a well over 527 feet in depth (563 feet according to the Michigan Miner), was drilled by A. W. Palmer for the American Alkali Company. It appears that the drilling began in the top of the Trenton, but if this is true the Trenton must be very thin.

Dr. Lane considers that the bottom of the well is in conglomeratic Potsdam and that the limestone is in part Trenton. The white sugary sandstone appears to be Calciferous, and, in that case, the St. Peter is absent as at Pickford. The top of the Potsdam is locally very similar to the St. Peters, and if the Calciferous is absent the two may be easily confused.

The record given below is chiefly that of the driller. Notes on the samples and the record are given in brackets. The correlations are by W. Alden of the U. S. Geological Survey.

NEEBISH WELL.

Loc.: Near Sailor's Encampment, Neebish Island, or across the west channel on the mainland opposite Trombleys and about 1000 ft. south of north line of Trombleys; about 100 ft. from river, 6 or 7 ft. above water, and about 1½ miles below the rapids in the river. Reported by A. W. Palmer, Jan. 15, 1900.

Elevation about 587 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Clay, boulders and sand	33	33
Trenton limestone:		
Limestone, hard	1	34
Limestone, vein water, soft	1	35
Limestone, hard	14	49
Limestone, gritty, softer	40	89
Limestone, darker in color, not so gritty but harder (111-138 light colored)	17	106
Limestone, softer	13	119
Limestone, shale	2	121
Limestone, hard	3	124
Limestone, softer	3	127
Limestone, hard	7	134
Limestone, softer	6	140
Limestone, shale	2	142
Limestone	7	149
Limestone, hard (148-158 light colored)	4	153
Limestone, softer	5	158
Limestone, shale (bluish, thin chips)	5	163
Limestone, brittle (bluish, chipping, 163-200)	22	185
Clay	1	186
Limestone, brittle	4	190
Shale; cased here for first time	8	198
Limestone	2	200
Shale (large chips, thin bedded)	5	205
Limestone, darker in color (sandy dolomite)	9	214
Limestone, shelly, full of little seams	9	223
St. Peters (Calciferous?):		
White sand rock	10	233
Shale	2	235
White sand (glass sand) rock, got first flow water at 250 ft., and more in several places in going through the sand	149	384
Potsdam:		
Light red sand	27	411
Sand; harder, looks like granite boulders pounded up	6	417
Pre-Cambrian:		
Sandy shale; sand pumpings look red but when washed out are black. (Coarse red conglomerate; grows coarser)	89	506
Sand rock	21	527
(At 430 ft. red pebble? of Huronian quartzite; 506-510 ft. and 510-527 ft. material mainly Huronian.)		

Pickford. In 1906-1907, a deep well was drilled for oil at Pickford, Chippewa county. A heavy flow of water with a 25 foot head was struck somewhere below 1000 feet, probably about 1400 feet. There was some water between 500 and 800 feet, but it would rise to the top of the casing only on standing over night. Very little signs of oil and gas were struck anywhere, though an oily sandstone was encountered toward the bottom of the well. The record, compiled by Dr. Lane from a partial set of samples down to 1000 feet, is as follows:

PICKFORD WELL.

Loc.: Sec. 6, T. 43, N., R. 1 E. F. G. Holden, H. D. Van Campen, Sault Ste. Marie; Mr. Taylor, Pickford.

Elevation about 670 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Lake Superior red clays	119	119
Sand, source of local flows of water	13	132
Described by Leverett. Head 6 to 7 ft., light flow.		
Niagara (Lockport):		
Hard dolomite; slow eff., a few loose shaly layers at top; then very hard. About 3 miles S. of town the land rises to the Niagara escarpment.	128	260
Lorraine:		
Blue shale	215	475
Utica:		
Black shale, "slate"	50	525
Trenton limestone:		
White limestone; ready eff.; residue of pyrite cubes and chert	275	800
St. Peters:		
Thickness unknown	.....	600
Water at 600-700 ft. said to be in white sandstone but it is doubtful; no samples.		
Samples of water 575 to 650 ft. show 70-79 per million Cl and are hard and have SO_4.		
Calciferous?		
At 800 ft. 10-24-06 Iron Mtn. Tribune-Gazette.		
Potsdam or Lake Superior sandstone	700	1500
Red rock at 800-900. (Holden.)		
J. L. Ward also thought they passed Trenton at 900 ft.		
Said to be muddy. (VanCampen).		
At 1360' red as blood. (J. L. Ward).		
Flow of water March 22?, 07 "warm."		
Into an oily sandstone—Detroit Times.		
VanCampen thought the casing was crushed at 1200-1300 ft. Water flowed with over 25 ft. head.		
Depth—Marquette Mining Journal, 3-23-07, 1500; 6-7-07, 1425.		

Concerning the interpretation and the correlations, Dr. Lane makes the following statements:

"Down to the top of the Trenton, the record is verified by samples and agrees perfectly with other holes; below that, it must be made out by statements from memory, and the only thing of which one can be reasonably sure is that it struck the red Potsdam above 1360 feet and probably at 800-900 feet and did not penetrate the Huronian. The most that can be said of the correlation above is that there is nothing known to make it impossible. The Neebish Island well shows that there is about 400 feet or more between the Utica and the red sandstones there; at Wagner's well (near Stonington) there was 310 feet. And here, there is (525 to 800 or 900 ft.) 373 feet or less. This must then include the Trenton, St. Peters, Calciferous, and perhaps the upper white part of the Lake Superior sandstone, affiliated with the Calciferous.

The water at 600 feet is hard, a regular limestone water and does not suggest the St. Peters. There will hardly be less limestone than in the Neebish well and along St. Mary's river and it makes a conspicuous ridge to the north. The dip seems to be about 66 feet to the mile to the south and, with any such dip, the Trenton must be 200

feet or so thick, judging from the breadth of the outcrop. Not only that, but the Neebish well shows a good thickness (Alden thinks 112+ ft.) for the Utica does not show, and the Manitoulin Island wells also show 250 feet, which is assigned to the Trenton. It seems most likely that the Calciferous has been eroded and the St. Peters and Potsdam can not be separated.''

Assuming that the Niagara has its average thickness of 600 feet at Pickford, if it were not eroded, the dip of the Niagara, as calculated from its projected top toward the center of the Basin, would be only about 50 feet per mile instead of 66 feet as suggested by Dr. Lane for the lower beds. As the Lorraine thickens toward Cheboygan the dip would be greater for the Trenton. In any case, the dips of the strata in the Northern Peninsula are prevailingly greater than in the Southern.

MANITOULIN ISLAND, ONTARIO.

Gore Bay. In 1904-05, several oil wells were drilled on Manitoulin Island, and the record of one is given by M. J. L. Ward. Some oil was struck at 425 feet, about 85 feet below the top of the Trenton.

GORE BAY WELL.

	Thickness, feet.	Depth, feet.
Pleistocene or drift	1	1
Niagara:		
Limestone extra hard and gray	45	46
Rochester:		
Blue shale	89	135
Clinton? Lorraine?		
Limestone	1	136
Shale	29	165
Limestone	1	166
Lorraine:		
Blue shale	90	256
Utica shale:		
Brown shale	60	316
Black shale	15	331
Trenton limestone:		
Limestone	250	581
Oil at 425 ft.		

APPENDIX A.

THE REGULATION OF DRILLINGS AND CARE OF DEEP BORINGS.

In all oil and gas fields a larger or smaller percent of the wells drilled are dry holes or holes with a yield which is too small for profitable operation. In ''spotted'' fields, such as in Randolph county, Indiana, 40 per cent of the wells may be dry. In many fields, such wells are abandoned without plugging with the result that water, which is generally encountered at one or more horizons, makes its way into the oil and gas sands with disastrous consequences. Sometimes the casings are left in the wells but this is only a temporary protection as the corrosive action of the brines or mineral waters generally will destroy ordinary casings in two to five years.

Most oil and gas bodies are surrounded by salt water but this water, known as ''edge water'' invades the reservoirs only as the oil and gas are withdrawn (providing these products are not withdrawn at too rapid a rate), so that a maximum recovery is possible. When water is introduced directly into the productive portion of a field through an uncased, or improperly cased well, the oil is forced back into the sand, so that pumping may produce nothing but water. As the sheet of advancing water reaches other wells, their production becomes partly, or entirely water, and the final result will be the ruin of the entire field.

In the older oil and gas fields of the country, little or no attention was given to abandoned and unplugged wells and the life of many pools has been greatly shortened or abruptly terminated by the flooding of the sands by water. In California[1], investigations by the State Mining Bureau has disclosed the fact that the productivity and life of many of the oil fields of that state are menaced by water from improperly cased and unplugged wells. Reports obtained from 41 per cent of all the wells in operation show that 25 per cent of these wells produce from 10 to 50 percent or over of water. Similar menacing conditions exist in most of the fields of the country, and had proper means and methods been used in the drilling and care of wells, these conditions could have been largely avoided.

Abandoned or improperly cased wells are not only a menace to pro-

[1]R. P. McLaughlin, Preliminary Reports on Petroleum, Nos. 1 and 2, Cal. State Mng. Bur., 1914.

ductive wells in an oil and gas field, but they are a source of pollution to potable waters or valuable brines and mineral waters. Brines or mineralized waters from one horizon may invade another containing fresh water, or, vice versa, fresh water may find ingress to brine bearing or mineral water strata. In the first case, supplies of potable water, the most valuable of the natural resources, are destroyed and, in the second, the quality of the brines or mineral waters is injured or ruined.

Along Saginaw river, most of the former supplies of fresh water in the surface deposits have been ruined through leakage from the abandoned salt wells unplugged or improperly plugged. In the vicinity of Grand Rapids, drillings for salt and gypsum have permitted the sulphate brines of the Michigan Series to percolate down into the underlying Marshall, and, locally, the former supplies of fresh water in this formation have been destroyed. As these old test holes and many others scattered over the State are still unplugged, the injury to valuable supplies of brine and fresh water grows greater from year to year. The above cases are not exceptional but are rather typical of conditions obtaining in many portions of the country.

Many oil and gas fields are located in coal fields, particularly is this the case in Pennsylvania, West Virginia, Ohio, Indiana, Illinois, Kansas and Oklahoma. Oil and gas wells penetrating workable coal seams or active mines add greatly to the hazards of mining on account of the dange of the escape of ga or oil nto the mines with the consequent danger of explosion. The casings may be improperly placed, breached by the corrosive action of brine or mineral water, broken by the caving or subsidence of the overlying strata subsequent to the mining of the coal, or removed upon abandonment of the wells. In several instances, severe explosions of natural gas from this source have occurred in coal mines, and many others have been narrowly averted.

In Pennsylvania, there are over 50,000 oil and gas wells in coal territory, and it is estimated that 3000 new wells are drilled each year, 2000 of which are abandoned. Most of the latter are abandoned without being properly plugged or charted. Many of these though not producing commercial quantities of gas, yield enough to cause explosions and fires, if it were to leak into a mine. In some localities, the oil and gas wells are so numerous and close together that they not only seriously interfere with mining operations but cause much loss of coal through the large pillars which must be left to protect the wells. Owing to the close drilling and the number of unplugged and uncharted wells, the leases on certain coal properties in Pennsylvania have been surrendered on the ground that the estimated recovery of

coal is too small and the hazards too great to pay for mining. In addition to the danger from gas and the loss of coal noted above, water from unplugged and uncharted wells may flood the mine workings. This has happened in a number of cases. Water, under a head of 400 feet, broke into two mines in Illinois in 1912 and caused much trouble and expense before it was controlled.

Since many of the older oil and gas fields have been redrilled from one to three times and tens of thousands of holes are being drilled in coal territory, hitherto unprospected for oil and gas, the situation between the coal and the oil operators has become acute. A number of states have passed laws with the aim of protecting and conserving the oil and gas resources, but only in Ohio, Indiana, and Illinois have measures been enacted to protect the coal mines and coal reserves from the dangers of the promiscuous drilling of oil and gas wells. The laws, however, in all of these states are inadequate.

On the other hand, mining operations are a menace to the oil and gas wells. As noted previously, the slumping of the strata after the removal of the coal or other minerals may bend or break the casings and ruin some of the wells. The broken casings in the case of abandoned mines also permit the entrance of water to the sands with consequent injury to the field.

As a result of these conflicting interests, a bitter antagonism has grown up between the coal and the oil and gas operators. Manufacturing concerns utilizing brines and mineral waters also look with disfavor upon drillings which endanger the purity and strength of their supply of these substances.

It is most regrettable, that in the past the public at large has displayed only an apathetic interest in the conservation of the potable water supplies. Owing to the wave of agitation for the conservation of the natural resources, which has swept over the country during the past few years, strong efforts have been made in many states to secure adequate laws regulating the drilling and care of deep borings, more particularly those for oil and gas. In certain states, opposition on the part of the oil and gas interests has been successful in defeating every attempt at securing much needed legislation on this subject. Oklahoma, California, Wyoming, Illinois, and a number of other states, however, have passed remedial and protective measures. Unfortunately, in some states, the measures are rendered almost nugatory through failure to provide for proper administrative machinery, sufficient funds, or adequate penalties for violations of the law.

In Pennsylvania and West Virginia, the law requires that abandoned wells must be plugged, but there is no competent executive officer to see that the requirements of the law are properly complied with. In

Ohio, owners of wells must notify the Salt Mine Inspector ten days prior to the contemplated abandonment of a well so that, at his discretion, he may notify a district mine inspector to be present when the well is plugged. A man may be an efficient mine inspector but incompetent to supervise the plugging of an oil or gas well. Moreover, mine inspectors, beyond the protection of the coal mines have little interest in the protection of oil and gas sands or water and brine horizons. In the California laws, there is no provision for a central executive authority. The drilling and care of wells is left to the county well commissioner, who is appointed at the request of three or more oil companies operating in the country. The Indiana laws of 1903 require owners upon the abandonment of a well to plug the same according to certain specifications and file an affidavit signed by two witnesses, describing in detail the manner in which the well was plugged. Since the law does not require that the State Natural Gas Supervisor shall be notified, this official has no means of knowing when a well is to be plugged or when the law has been violated, except through information furnished by outside parties. "Fly-by-night" operators take advantage of this, "pull" their casings, and seek more promising fields in other states without plugging their wells.

In Wyoming, the laws prohibit the waste of oil or gas from a well beyond a limit of thirty days, specify the manner in which wells shall be plugged, and provide penalties and liabilities, but there is no central authority to enforce the provisions of the law. No legal action is taken except on the formal complaint of an interested party.

The Illinois statutes provide that all fresh water, during the drilling and after the completion of a well, shall be kept cased off from the oil and gas sands, in addition to the requirement that abandoned wells shall be plugged. The law fails of its purpose as there is no provision for adequate administrative machinery. The only protective measure in Michigan is a law requiring that, in Saginaw and Bay counties alone, salt wells shall be plugged upon abandonment. In short, in none of the states do the existing laws relative to the regulation of the drilling and care of oil and gas wells secure the desired ends.

In order to fully protect the rights of all parties concerned, a law regulating the drilling and care of oil and gas wells or other deep borings must provide for, (1) a competent administrative body having adequate executive powers, sufficient funds and trained assistants to properly carry out the provisions of the law; (2) definite methods of (a) casing and protecting wells through beds of coal, clay or other mineral deposits, and through horizons bearing valuable brine and mineral or potable water and, (b) of plugging wells, (3) the collection

and filing of all information bearing on the geologic conditions, i. e., the character, thickness, and depth of the various formations, the water and the oil and gas horizons, (4) the formal and accurate (a) location and recording and (b) the formal abandonment, plugging, and inspection of wells; (5) the cooperation of all parties concerned; and (6) adequate penalties and liabilities for infractions of the law and for damages.

The chief difficulties in framing a workable and satisfactory law regulating the drilling and care of oil and gas or other deep borings arises from the (1) conflicting interests and (2) the variety of conditions which may be met. A law which will adequately protect the coal operator and minable coal beds may work undue hardship upon the oil and gas prospector. In some districts, there are several coal seams, some of which are of workable thickness under present conditions and others not. The term "workable" thickness is a relative one. Whether a coal bed is workable or not depends upon several factors besides that of mere thickness, viz., quality of coal, mining and labor conditions, nearness to markets, and competition. In Wales, veins of coal under 14 inches in thickness and in Missouri and Kansas beds 12 to 20 inches are operated at a profit, while in some coal fields no beds under four feet thick are being mined. With further exhaustion of the coal reserves, or with the development of new markets or cheaper methods of mining, some of the beds too thin to mine now may become workable.

The churn or percussion drill is generally used for oil and gas explorations, and, with this type of drill, it is very difficult to determine the exact thickness of coal beds and many drillers pass through workable beds without recognizing their presence. In Michigan, there are a dozen or more seams of coal, extremely variable in thickness and extent. Apparently only a few of the beds contain areas thick enough to be mined under present conditions, and these areas are very local. From this, it follows that there is no absolute way of distinguishing the different seams of coal, and it would be impossible in many cases to determine what seams should be protected. To require a driller to case off and protect each coal bed encountered would not only entail prohibitive expense, but it would be practically impossible in many cases on account of the size of the hole which would be required. The same may be said of the water and brine horizons, since, in some regions, there are a number of water or brine horizons, each yielding a water or brine differing in quality from any of the others.

The capping of oil and gas wells within a definite time limit to prevent waste may be very difficult or even impossible as in the case of the great oil wells in the eastern Mexico fields and the gas wells of

Texas and Louisiana. It cost $3,000,000 to put out the fire and cap the great Dos Bocas well No. 2 near Tampico. In many instances, the plugging of a gas well too small to be operated is very difficult, especially where the rock pressure is very high, and it may cost several thousand dollars. To case off the salt water which occurs between the two productive oil sands in the Midway-Sunset field of California costs about $10,000 additional per well, yet it must be done to protect the oil sands.

The designation of a specific method for the casing and plugging of wells is unsatisfactory as no one method is adequate to meet the different conditions which may be encountered in different parts of a state, or even in the same field. A given method may secure the desired results in one case, but may fail of its purpose in another. Two or more efficacious methods, however, may be outlined to meet the conditions more commonly occurring, but certain discretionary powers as to what coal beds and water and brine horizons shall be protected, and what method and means are to be used in a particular case should be given the administrative official or body, but arbitrary power over the casing and plugging of wells should not be placed in the hands of a single individual.

One of the greatest difficulties in intelligently applying the remedial and protective measures of a law lies in the lack of an organized body of information concerning the character, thickness and depth of the (1) formations, (2) the oil and gas horizons and, (3) coal beds or deposits of other minerals and mineral substances having present or possible future value. In some fields where the sands are little disturbed, regular in thickness and character and continuous over large areas, the problem of drilling and caring for wells is comparatively simple, but in fields where the sands are numerous, variable in character, discontinuous and much disturbed, and where there are several water bearing strata, some of which lie between the productive sands, the problem demands the fullest knowledge of the geological conditions and taxes the ingenuity of the most highly trained geologist-engineer.

The usual penalties prescribed in the laws of the several states are nominal fines from $100.00 to $500.00, or both fines and imprisonment. In those states where the maximum fine is but $500.00 and the cost of repairing the casing of a well or of plugging a well is several thousand dollars the fine is ridiculously small in comparison. To obviate this difficulty some states have made the fine cumulative according to the length of time that the offender fails to comply with the requirements of the law.

For many years the drilling and care of oil and gas wells has been

the subject of much study and investigation. During the past few years the United States Bureau of Mines has made an exhaustive study of this subject with special reference to the danger to life and property from drillings for oil and gas in coal territory. In order to secure information bearing on every aspect of the subject, the Bureau of Mines has been in the practice of conferring from time to time with students of the subject and representatives of all interests concerned. The information has been collected with the view of formulating and recommending changes in the present practices in the drilling and care of wells, and also changes in the state laws which might prove effective by being "both reasonable and enforceable." As a result of these separate conferences, a general conference[2] was held February 7 and 8, 1913, between representatives of the coal operators, the oil and gas companies, the geological surveys of the various states, and the Bureau of Mines of the United States. At this conference, problems, arising particularly from the interrelations of oil and gas wells and coal mines, and tentative suggestions for the legal regulation of drillings in coal regions, were discussed at length. The tentative regulations were referred to a committee of twenty composed of three representatives from each of the interests: coal, natural gas, petroleum, state geologists, state mine inspectors, and the Bureau of Mines, together with the president and secretary of the conference. This committee met on March 1 and 10 and made a revision of the proposed regulations which was presented to the general conference on March 11. The proposed regulations as drafted by this conference are in the form of an outline[3] of desirable legislation, to be developed in proper legal form to meet the industrial needs of each state.

The essential features prescribed in the proposed regulations are six in number, viz:

(1) Accurate and formal location and recording of wells.

(2) Cooperation of the several parties interested to obtain a safe location.

(3) Designation of efficacious methods of casing and protecting wells through coal beds.

(4) Formal abandonment of wells.

(5) Safe methods of plugging wells.

(6) Adequate inspection.

The proposed measure placed the administrative power in the hands of a single individual, the Chief Well Inspector of the state, and this is one of the objections strongly urged against it. According to R. P. McLaughlin of the State Mining Bureau of California, experience

[2]Bull. No. 65, U. S. Bureau of Mines, Oil and Gas Wells through Workable Coal Beds, 1913.
[3]Technical Paper No. 53, U. S. Bureau of Mines. Proposed Regulations for the Drilling of Gas and Oil Wells. O. P. Hood and G. Heggem.

has shown that the arbitrary power to order repairs or the abandonment of a well should not be wielded by a single individual. Other investigators hold that the control of drilling and plugging of wells should be in the hands of a commission composed of the State Geologist, the head of the State Mining Board or Inspector of Mines, and a third member chosen from the oil and gas operators. A second criticism refers to the framing of specific regulatory measures designed to protect coal mines and coal reserves without adequate protection of potable waters, valuable brines and mineral waters, deposits of clay, gypsum, limestone, shale, or other minerals or mineral substances. A third criticism may be made as to the lack of explicitness regarding the control of the chief oil and gas inspector over the kind of geologic records to be kept of each drilling. This is most necessary to the intelligent application of the remedial and protective provisions of the law, and the information contained in a log made by the average driller is far from reliable. The Chief Well Inspector should have power to prescribe the kind of record to be kept and to demand, as circumstances warrant, sets of samples of the well drillings and samples of the waters and brines encountered.

In 1912-13, the Saginaw Development Company drilled a number of wells for oil in close proximity to the salt wells in Saginaw and the operators of salt blocks were alarmed lest these borings should be abandoned without being properly plugged. The law requires that only those wells drilled for salt in Saginaw and Bay counties alone must be plugged, hence the Development Company was not legally bound to plug their borings upon abandonment. The company, however, of their own accord plugged all their wells which were near enough to contaminate the brines utilized by the salt blocks along Saginaw river.

In order to protect the fresh and mineral water, brine, coal and other resources of Michigan from the danger of promiscuous drilling and of improperly cased and unplugged wells, an attempt was made during the session of the legislature of 1913 to pass a general law covering the subject of drilling and care of wells, but the bill was permitted to languish in committee. Later, the members from the Saginaw Valley districts introduced a bill to protect the salt industry of the State but this also failed of passage. Michigan has no law governing the drilling and care of deep borings, other than the salt wells in Saginaw and Bay counties.

APPENDIX B.

BITUMINOUS OR OIL SHALES.

Before the great oil fields of the United States and Canada were discovered, the extraction of oil from bituminous or oil shales was an industry of considerable importance in the United States. Prior to the Civil War, there were 50 or 60 plants[1] in the United States distilling oil from shales and coals, high in volatile and liquid hydrocarbons. Some of the companies imported special kinds of coal but most of them used shale and coal from Pennsylvania, Ohio, Virginia, Kentucky, and Missouri. Twenty-five oil-shale plants were in Ohio and ten in western Pennsylvania, but most of the plants in the country were of small capacity and the greater number were hardly in operation before the discovery of the great oil fields of Pennsylvania and other states forced them out of business. The oil-shale industry was practically destroyed by 1865, but the operating companies in many cases saved themselves from ruin "by converting their oil factories into refineries, which was done with very little trouble."

In Scotland[2], unsuccessful attempts to extract oil from coal and shale began more than a century ago, and in France the distillation of shale began even earlier. James Young discovered a process of distilling oil from bituminous and petroliferous substances and began the distilling or refining of petroleum found in a coal pit. Later he experimented with various coals and, finding Boghead coal or Torbanehill mineral suitable for distillation, began work on a commercial scale at Bathgate, 1850. The deposit of Boghead mineral was exhausted in 1862 and then the extensive deposits of bituminous shale west of Edinburgh were utilized. The Torbanehill mineral yielded from 116 to 125 gallons of crude oil per ton, but the black shales only 40 to 45 gallons. The oil-shale industry was carried on for many years with varying success but, with improved methods of mining and distillation, and with more attention to the value of the by-products, especially ammonium sulphate, now much in demand as a fertilizer, and paraffin, the industry has become very profitable, some of the companies paying annual dividends of 50 per cent or more.

In 1904, the production of oil shale in Scotland was 2,709,840 tons yielding 63,000,000 gallons (Imperial) of crude oil and, in 1913

[1]Sir Boverton Redwood, Petroleum and its Products, Vol. 1., 1st ed., p. 14.
[2]R. W. Ells, Oil Shale Industry of Scotland, Mines and Geol. Survey Branches, Department of Mines, Canada, 1910, Nos. 55 and 1107, Pt. II, p. 41.

3,150,000 tons of shale were mined from which about 65,000,000 gallons (Imperial) of crude oil was obtained. From these figures it follows that the average yield of crude oil is from about 20 to 23 gallons (24 to 28 gal., U. S.) per ton. During the same years, the average amount of sulphate of ammonia produced per ton was from 35 to 40 pounds.

In Saxony, chiefly brown coal or an earthy lignite is used in the distillation of oil, and the industry, began more than half a century ago, has become very important. In 1880, the amount of lignite mined for the production of crude oil was over 9,000,000 tons but later statistics are not available. The oil-shale industry is carried on in a number of localities in New South Wales, which has some of the largest and most important deposits in the world. The material is called by different names, viz.: kerosene shale, torbanite or Boghead coal, cannel and parrot coal, etc. The yield of crude oil per ton from some grades is over 100 gallons.

Extensive deposits of bituminous and oil shales occur in eastern Canada, particularly in New Brunswick, Nova Scotia, and Quebec. The oil shales of New Brunswick are known as the Albert shales of the Perry formation of early Carboniferous age. The petroliferous character of these shales led to much fruitless drilling for oil and the high oil content of some of the bands of shale resulted in a thorough test being made under the direction of the Department of Mines of Canada to determine their commercial possibilities. Some 45 or 50 tons of material were sent to the Pumpherston Oil Company near Uphall in Mid-Calder, Scotland and the shale, upon distillation, yielded about 48 gallons (U. S.) of crude oil and 77 pounds of ammonium sulphate per ton, or twice the average yield of oil and ammonia from the Scottish shales.

The value of oil-shale depends not only on the oil but also upon the ammonia content. The by-products, particularly ammonium sulphate and paraffin are the chief sources of profit. The failure of many of the early companies was due to the fact that they recovered the oil but not the ammonia. Investigations show, that, in general, as the content of oil decreases, the ammonia increases. From this fact, shales low in oil but high in ammonia can be made to yield a large profit and the low average yield of 20 gallons of oil per ton from the Scottish oil shales is due to the utilization of a greater amount of the "lean" oil-shales, high in ammonia. Some of the latter yield only 10 or 15 gallons of oil but from 60 to 70 pounds of ammonium sulphate.

The value[3] of the crude oil according to 1910 prices would be $0.025

[3]R. W. Ells, Joint Report on Bituminous or Oil Shales of New Brunswick and Nova Scotia Mines, and Geol. Survey Branches, Dept. of Mines, Canada, Nos. 55 and 1107, Pt. I, pp. 34-35.

per gallon and of the ammonium sulphate $0.29 per pound, therefore the value of the products of distillation, i. e., 48 gallons of oil and 77 pounds of ammonium sulphate would be $3.43 per ton. The cost of mining the shale is estimated at $1.00 per ton and the retorting of the shale and the manufacture of the sulphate $0.86, or a total of $1.86 per ton, giving a profit of $1.57 per ton, no allowance, however, being made for depreciation of plant and equipment and for interest on the capital invested. This profit may be materially increased through the refining of the crude oil itself, especially if it is rich in naphtha, burning oil, and paraffin.

The by-products resulting from the present methods of retorting and refining of oil shale are numerous and there is still much chance for improvement in methods and means of treatment. The latest types of retorts have greatly increased the recovery of ammonia from the shales. As stated previously, the average yield of ammonium sulphate for the past few years from the Scotland shales is from 35 to 40 pounds and, with the improved retorts, 60 to 70 pounds have been extracted from the same shales. The common products of manufacture and their principal uses are:

1. Permanent gases, mainly used for fuel.
2. Shale naphtha used for lighting and heating or power purposes.
3. Burning or lamp oils, especially adapted for continuous burning lamps.
4. Intermediate oils used for gas making.
5. Lubricating oils.
6. Solid paraffin, used for water proofing, insulation, and metal protection.
7. Still grease, used for grease making.
8. Still coke, used for fuel where smoke is undesirable.
9. Sulphate of ammonia, used chiefly as a fertilizer, especially for the growing of sugar beets. With the exhaustion of the guano deposits of south America and the impending exhaustion of the nitrate beds of Chile, ammonium sulphate is becoming of great importance as a fertilizer, especially as it contains about 20 per cent of nitrogen, or 4 per cent more than nitrate of soda.
10. Liquid fuel—the acid and basic tars together with the dregs and other residues are generally used as liquid fuels in the stills. These tars with further refining would probably yield a number of tar products.
11. The oil from some shale yields vaseline, but this substance is not contained in the Scottish oil shales.
12. "Spent" shale. The shale after it has passed through the

retort may be used in the manufacture of Portland cement, brick, and road metal.

The future value of the bituminous or oil-shale deposits has been recognized by the British Government and, according to reports, the British Admiralty has purchased a large tract of oil shale in New Brunswick to be held as a reserve for supplying the British navy with fuel oil when the present sources are exhausted. Recognizing that the present and growing demands made upon the oil fields of the continent must sooner or later exceed their capacity of production, the U. S. Geological Survey has made an investigation of the oil shales of Utah and Colorado to determine their possibilities as a future source of oil. The results of this investigation will be issued as a bulletin, which is now in press. According to the Press Bulletin of the Survey of January, 1914, the tests and analyses of the oil shales of these states show that they contain from 10 to 61 gallons of oil per ton with a probable average of a barrel per ton for the better grades. This is practically two and one-half times the average yield from the Scottish shales and compares favorably with the better grades of shales of New Brunswick. Apparently, the investigations did not extend to the nitrogen content of the shales which, as previously mentioned, is of the utmost importance in exploiting oil-shales on a commercial basis since much of the profit comes from the ammonium sulphate, the coming substitute for the guano of South America and the sodium nitrate of Chile.

In Michigan, there are a number of formations containing bituminous or oil bearing shales. The Antrim shale, 300 to over 480 feet in thickness, locally is composed almost entirely of black bituminous shales. In certain parts of the State, however, it contains much light colored shale. In Alpena and Charlevoix counties, this formation is easily accessible as it outcrops at a number of points and is under a light cover of drift in many localities. Even where the drift is of considerable thickness, as in southeastern Michigan, the shales could be easily mined for the formation generally contains little or no water.

In the Northern Peninsula the Utica black shale is about 50 feet thick and outcrops, or lies beneath a thin cover of drift in many places on the east side of Whitefish river, Delta county. In the Southern Peninsula, the formation is thicker, but is too deep to have economic possibilities. From 1851 to 1861, near Collingwood, Ontario, the Utica shales were used for the distillation of oil with fair success until the discovery of the Petrolia oil field. Numerous black shales also occur in the Coal Measures associated with the coal beds. Some of the coal seams are too thin or of too low grade for profitable mining, but it is possible that the coal, usually high in volatile matter, and

the black shales, or the bone, cannel, and "blackjack" coals could be mined together for their oil and ammonia content and made to yield a substantial profit. Certain parties from New York investigated the Michigan coals last year with the view of establishing a coal and shale oil plant and reported that some of the coals high in volatile matter were very suitable for the manufacture of oil and ammonium sulphate, but as yet nothing has come of the project.

The amount of oil or bituminous matter recoverable as oil in the sediments is many times that contained in the accumulations known as pools, and, in contrast to the latter, the amount of oil in a given area of bituminous shale can be estimated within close limits. The average yield of oil from the better grades of Colorado and Utah black shales is estimated at 53 gallons per ton or about 71.5 gallons per cubic yard. A square mile of such shale three feet thick would yield over 1,800,000 barrels of oil, and 300 feet thick 180,000,000 barrels, or more than 75 per cent of the total production in the United States for 1913.

If the oil is present in amounts of only one per cent, a square mile of rock 300 feet thick would contain 15,000,000 barrels of oil. While no extended tests and anaylses have been made on the Antrim shales to determine their average oil content, the two analyses given below indicate that locally the content of oil is about 6 per cent, equivalent to at least 90,000,000 barrels per square mile, 300 feet thick. In any case, the amount of oil in the Antrim shale alone forms a reserve practically inexhaustible which can be drawn with the exhaustion of the oil fields of the country.

ANALYSIS ANTRIM SHALE.

Sample from a depth between 1575 and 1700 feet in the No. 2 Assyria well, Barry county. Analysis[4] by a student under the direction of M. A. Cobb, laboratory of Lansing High School, October 22, 1903.

	Percent.
Moisture	6.595
Volatile carbon	6.025
Fixed carbon	3.95
Ash	83.435
Total	99.985

[4]Ann. Rept. Mich. Geol. Surv. for 1903, p. 277.

ANTRIM[5] SHALE.

Sample from near Alpena, Analyst, W. H. Johnson, Alpena.

	Percent.
Volatile matter (water between 5 and 10 percent)	17.96
Fixed carbon	6.49
Ash	75.55
Total	100.00

While there are no satisfactory analyses showing the oil content of the Utica shale, the table of analyses taken from a report on the geology of Wisconsin shows the bituminous character of the shale.

	I.	II.	III.	IV.	V.
Clay and sand	38.45	34.60	37.26	48.27	73.57
Carbon	6.83	6.63	0.61	6.99	15.03
Hydrogen	0.74	0.77	0.83	1.13	1.65
Oxygen	3.20	2.96	1.71	3.39	5.39
Carbonate of lime	45.02	49.31	52.60	20.30	1.29
Carbonate of magnesia	2.09	2.53	3.42	11.48	0.76
Alum. and oxide iron	2.16	2.09	3.29	7.99	2.79
Total	98.49	98.89	99.72	99.55	100.48

No. I is a brownish black, very fine grained rock from Cape Smith, Lake Huron.

No. II from an island to the north of Maple Cape, Lake Huron and is blackish-brown, fine grained, and of earthy texture, with a laminated structure, and contains no fossils.

No. III from St. Anne, Montmorency, is a dark brown shale, and contains graptolites.

No. IV is from Gloucester, near Ottawa, and is a black shale filled with fragments of trilobites and crinoids. In these analyses, the carbonates of lime and magnesia, with the alumina and oxide of iron, were removed by solution in acids, and the elements of the organic matter were determined in the insoluble portion.

No. V is that of a pyroschist from this formation in the lead region of Wisconsin.

Dr. T. S. Hunt's[6] account of the attempt to exploit the Utica shale for oil in the vicinity of Collingwood, Ontario, gives a general idea of its possibilities as a source of oil.

"These shales contain very variable amounts of combustible matter, and they give when distilled, besides inflammable gases, portions of oily matter, which in the shales of Collingwood, the richest yet

[5]H. Reis, Clays and Shales of Michigan, Geol. Surv. Vol. VIII, Pt. 1, 1900, p. 47.
[6]Geol. Surv. Can., 1863, p. 784.

examined, are equal to 4 or 5 per cent. Though the final results of the retorting of these shales are not now available the following details of operations at this place may be given (Geol. Can. 1863, p. 784):

In 1859, works for obtaining these oils were erected on the locality of this shale, near the town of Collingwood. Twenty-four longitudinal cast-iron retorts were set in two ranges, and heated by wood, of which 25 cords are said to have been required weekly. The shale, broken into small fragments, was heated for two or three hours, from eight to ten charges being distilled in 24 hours. In this way, it is said from thirty to thirty-six tons of shale were distilled daily, and made to yield 250 gallons crude oil, corresponding to about three per cent of the rock. By a further continuance of the heat, a small additional proportion of oil was obtained from the shale; but it was found more economical to withdraw the charge after 2½ hours. The bed of shale available for the purpose adjoins the works, and was furnished, ready broken, at twenty-cents per ton. The cost of the crude oil from the shale was stated by the manufacturers to be fourteen cents per gallon. When rectified and deodorized, it gave from 40 to 50 per cent of burning oil, and from 20 to 25 per cent of pitch and waste, the remainder being a heavy oil fitted for lubricating purposes. After two or three unsuccessful trials, and the repeated destruction of the works by fire, they were at last, in 1860, got into successful operation, and a ready market was found for the oils. Data, however, is wanting to show whether the enterprise was remunerative; and it was after some time abandoned, partly, it is probable, on account of the competition of the petroleum of Enniskillen, which was about that time brought into the market in large quantities, and at a very low price. Should it, however, at any time be found advantageous to renew the experiment of distilling the bituminous shales of this formation, those of Collingwood offer very favorable conditions, from their accessibility, and also for the ready means of transport afforded both by the lake and the railway."

The following tables largely taken and adapted from the Joint Report of Mines and Survey Branches Nos. 55 and 1107 illustrate the difference in the analysis and in the yield of crude oil and ammonium sulphate from various oil shales and oil coals.

	Moisture.	Volatile Hydrogen.	Fixed Carbon.	Ash.
Torbanite, Scotland	.....	*71.17	7.65	21.18
Albertite, N. B	.....	*54.39	45.44	0.17
Joadja oil-shale, N. S. Wales	.....	*89.57	5.27	4.98
New Zealand torbanite	2.83	56.05	26.02	5.10
Kentucky Cannel Coal	1.21	55.36	35.17	8.26
Stellarite, Nova Scotia	0.37	68.38	22.35	8.95
Antrim shale, Barry Co	6.595	6.025	3.95	83.435
Bone coal, Saginaw Valley	8.08	30.74	49.29	11.89
"Cannel" Arenac Co	11.35	35.80	41.10	11.87
St. Charles, Saginaw Co	2.37	36.18	58.99	2.46
English Cannel, Wigan	.....	*39.64	57.66	2.70

*Dry material.

The figures given in the table below refer to the U. S. wine gallons and are the approximate equivalents of the figures given in the above report which refer to the Imperial English gallon.

	Crude oil, gallons.	Ammonium sulphate, pounds.
Geo. Irving seam, N. B. (shale retorted in Scotland)	48	77
Albert mines, N. B	32–58	49–82
Albertite, N. B	135	65
Stellarite coal, Nova Scotia	60–150	.....
Baltimore shales, N. B	55–68	30–112
Taylorville shales, N. B	52–57	85–101
Utah and Colorado black shales	10–61	.....
Torbanite, Scotland	108–156	.....
Pumpherston seams, Scotland	19–24	55–60
Union oil-coal, W. Va	32	.....
Elk River oil-coal, W. Va	54	.....
Kanawha oil-coal, W. Va	88	.....
Wolgan and Capertee, N. S. Wales	120	.....
Kentucky Cannel coal	156	.....
"Old Kentucky Boghead."		

In conclusion it may be stated that Michigan has an abundance of oil-shale and oil-coal which, with the increasing demand upon the oil fields of the country, probably exceeding their capacity of production within a very short time, and with the exhaustion of South American guano and nitrate deposits, will become of very great economic importance as a source of oil and ammonium sulphate.

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