PORT HURON DISTRICT.

It appears from the wells just quoted, and those already given in Vol. V of Adrian, Pontiac, Royal Oak, Mt. Clemens, etc., that through most of Monroe, Lenawee, Wayne and Washtenaw counties the beds dip quite steadily, at a rate of 30 feet to the mile or more, somewhat west of northwest. When we go on from Mt. Clemens we find that the strike suddenly veers from north of northeast to due east, as is clearly shown by comparing the well at New Baltimore with those at Mt. Clemens and Marine City.

The region north of Mt. Clemens is therefore much more favorable for oil explorations. (See Plate IX.)

This is the only district in the State where there is a commercial production of oil, a refinery being conducted at Port Huron by Mr. George B. Stock. It seemed, therefore, wise to me to engage Prof. C. H. Gordon, who prepared our report on Sanilac county, to make a special study of the wells around Port Huron for oil and gas. These do not go to a depth of over 800 feet. He finds some indications of an anticlinal near Port Huron, but his report has not been received in time for insertion here; it will be found at the very end of the annual report. Besides these wells, a great many of which have already been published in Vol. V, there are a large number along the St. Clair river, Lake St. Clair and Detroit, which have been put down deeper for salt. The new well at New Baltimore, with a fine set of samples, is an important connecting link. We have also a very good set from the Diamond Crystal Salt Company at St. Clair.

NEW BALTIMORE.

The record of the New Baltimore well, put down by J. J. Mason & Co. for C. M. Swift, is as follows:

NEW BALTIMORE.

Name.	Thick.	Depth.	Comparisons.
Pleistocene—			
Surface	120	120	
Neodevonian Shale—			
Blue shale	5	125	
Black shale	335	460	St. Clair, 400; Marine City, 460: Pontiac, 965; Mt. Clemens, 218.
Traverse—			
Limestone and calcareous shales	20	480	
Limestone	50	530	St. Clair, 630; Pontiac, 1065.
Blue shale	160	690	St. Clair, 790; Algonac, 513; Marine City, 740 to 635; Pontiac, 1235; Mt. Clemens, 400.
Dundee—			
Limestone high grade	130	820	St. Clair, 910; Marine City, 825 to 770; Mt. Clemens, 610.

Monroe Group—			
Dolomites including	290	1110	Marine City, 1060.
Gypsum bed (anhydrite)	10	870	St. Clair, 990.
Gypsum bed	10	895	
Brown dolomite	20	940	
Limestones	165	1275	St. Clair, 1380; Marine City, 1220.
Brown dolomite and gypsum	85	1360	
Blue dolomite, shale and gypsum	35	1395	St. Clair, 1480; Marine City, 1390.
Buff dolomite	50	1445	
Blue and brown dolomites and gypsum	155	1600	St. Clair, 1600; Marine City, 1604.
Salt	40	1640	

The Diamond Crystal Salt Company at St. Clair have recently furnished a careful set of samples, from which a record may be made as follows:

SAINT CLAIR.

Name.	Thick.	Depth.	Comparisons.
Pleistocene—			
Surface	172	172	
Neodevonian—			
Blue shale (Erie)	110	310	
Black shale (Huron)	220	530	Marysville, XL, 298; Marine City, XXXIV, 360; Oakland, LXII 840; New Baltimore, 400-460.
Traverse—			
Blue argillaceous limestones and dolomites, etc.	100	630	
Blue shale	160	790	Marysville, XL, 588; Marine City, XXXIV, 630; Oakland, LXII, 800; Mich. Salt No. 2, 575; New Baltimore, 695.
Dundee—			
Limestone	120	910	New Baltimore, 820.
Monroe—			
Dolomites	80	990	Marine City, XXXIV, 800 ft.
Gypsum and dolomite	40	1030	Marysville, XL, 345; New Baltimore, 860-920; Oakland, 1000-1250 and other mineral wells water here.
Dolomite probably sandy about	1270		
Offset through Sylvania sandstone	240	1370	New Baltimore, 1370.
Dolomite	80	1450	
Anhydrite largely	50	1500	
Dolomite	40	1540	
Dolomite	70	1610	New Baltimore, 1600; Marine City, 1577-1633; No. 3, 1668; LXI, 1630.
Salt and cavity	30	1640	
Lime, i. e	10	1650	
Dolomite and anhydrite	97	1747	
Salt	50	1797	
Lime (?)	10	1807	

It seems clear that corresponding beds are 100 feet or so deeper than at New Baltimore, nearly 200 feet deeper than at Marine City,[16] and, what is especially remarkable, deeper than at Marysville or Port Huron.

[16] The following is a record of a recent well furnished by S. C. McLouth, in which the top of the Dundee is at 575 feet, instead of 635 feet as in Plate XXXIII of Vol. V.

Well No. 2. Commenced to drill June 7, 1898. Finished August 29, 1898. Pipe in September 2. Pumping well September 4.

Clay to 150 feet, 15 feet hardpan, clay and gravel to 200. Two hundred feet of black slate, 15 feet of lime. (Put in 218 feet 10-inch pipe to shut off surface. From 200 to 1400 is 8¼ hole.) 50 feet soft white soapstone, hard to mix. Could cut about 4 feet per hour with a 4-inch stem 43 feet long. Rock became darker and a little harder to 575 feet. Struck limestone, then we strung a 5½ stem 38 feet long. The average then was 2 feet per hour to 710 feet. We struck sulphur water, 725 feet salt water, 730 feet brownish limestone, soft. Continues limestone easy on bits to 780 to 795, a streak of gypsum. 800 feet hard streak of lime. 825 feet gypsum. 830 feet hard. 850 to 860 gypsum, bothered. 870 hard streak of lime. 875 soft blue gypsum. 900 shelly limestone to 970 feet, average 15 inches per hour from 970 to 1000. Flint limestone from 1000 to 1040 feet. Good drilling, 18 feet in 12 hours. Continues the same kind of rock to 1100 to 1160. Sandy limestone. Hard. Continues awful hard. 8 inches per hour from 1160 to 1225. Hard to 1300, bothered with caving rock and gypsum. Gypsum in limestone to 1370. No trace of gypsum from 1370 to 1400. Cased at 1400, 6¼-inch casing. Awful hard to 1500. Continues hard to 1570, where we struck salt. 25 feet salt in the first bed, 10 feet lime and 10 feet salt to 1605. Lime to 1612. Lime 11 feet. Top salt bed 1623 feet. Lime 1751, total depth of hole.

We find here, therefore, irregularities of dip such as are favorable to the collection of oil. If we are right in our correlations of the Algonac and Port Lambton wells in Vol. V, here, too, there is a corresponding drop,—from Algonac to Port Lambton, the top of the Dundee dropping from 513 to 710 feet. About 10 miles southeast of Port Lambton in Canada, at Wallaceburg, a well was sunk in 1899, the record of which I owe to the kindness of Mr. Ami,[17] and it will be well to repeat it here with my correlations.

WALLACEBURG.

Name.	Thick.	Depth.	Comparisons.
Pleistocene—			
Sands and clays	35	35	
Boulder clay	85	120	
Shale	180	300	
Limestones	75	375	
Shale and sandstone	74	449	cf. Marine City, XXXV, 370-480 ft.
Traverse—			
Limestone, "top limestone"	106	555	
Shale, "top soapstone"	95	650	" 600 ft.
Limestone, "middle limestone"	15	665	" 640 ft.
Shale, limestone and clay	85	750	" 730.
Dundee or Corniferous. (Top of Monroe not separated)—			
Light colored limestone	250	1000	
Perhaps the lower part is dolomite.			
Sylvania—			
Sandstone[18]	100	1100	
Fine grained dolomites	280	1380	
Gypsiferous "	320	1700	
(No salt reported, the record may be imperfect.)			
Niagara—			
Dolomites	120	1820	
Limestone	105	1925	
Oil at 1865.			
Calcareous and arenaceous shales	110	2035	
Medina—			
Gray sandstone, Red shale and marls	65 +	2100 +	

It seems that even at Wallaceburg the top of the Corniferous or Dundee is not quite as high as it is at Marine City, and lower than at New Baltimore. The indications for an anticlinal or some other disturbance which might collect oil and gas in large quantities between Mt. Clemens and St. Clair and northward are not bad. The anticline which Dr. Gordon finds trace of lies even nearer Port Huron. See his paper at the end and Plate IX.

SAGINAW.

The structure of the rocks of lower Michigan is basin-like. This is shown by such cross sections of lower Michigan as are given, for instance, in Vol. V of our reports. This structure is not favorable for the gathering together of large and valuable deposits of oil and gas. For oil and gas are formed by the slow decomposition of animal and vegetable matter which was buried with the rocks in the bottom of the sea when they were formed. If now there is an upward bend or dome of the strata, known technically as an anticlinal, covered over by impervious beds, such as

[17] Jour. Can. Min. Inst., Vol. II, pp. 186-191. Ottawa.
[18] Suggested as Oriskany by Mr. Ami.

clays or shales, the oil or gas may collect in large quantities in porous beds or fissures beneath. Otherwise they are likely to be scattered in too small quantities to be of much value.

It is easy to see that a basin structure will tend to produce scattering rather than an aggregation.

There are, however, two possible exceptions.

Around the margin of the basin there may be radial flutings like those around the edge of some cake-tins, and in the upward bends of these oil may accumulate. For instance, the strata which run northeast past Detroit through Monroe and Wayne counties, turn in Macomb and St. Clair counties and run almost east. Thus from Macomb county toward the center of the basin (north or west) somewhere there must run the top of a bend which might accumulate larger quantities of oil.

Again, near the center of the basin, minor upward flexures or flutings may occur, which would serve to collect the gas.

Now there have been a very large number of wells put down along the Saginaw river, and from them we may infer that the crest of an anticlinal or upward fluting crosses the Saginaw river in the city of Saginaw not far from the Wylie Brothers' wells.

This is shown in Plate IX of Vol. VIII, Part II,—the report on coal by A. C. Lane.

For we have:

At the northern part of Bay City, Marshall sandstone from 830 to 920 feet down. General depth of brine wells, 1050 feet.

South part of Bay City, Marshall from 840 to 970 feet.

Wells at Melbourne are about 890 feet deep. At East Saginaw the first well in the north part struck Marshall sandstone at 633 to 742 feet, and the same sandstone comes in Gov. Bliss' well across the river in Zilwaukee at 665 feet, and two miles north in the New York and Saginaw Salt and Lumber Company's well, it is from 760 to 867 feet deep. Going south, however, the salt rock, i. e. the sand rock is said to rise, and at Wylie Brothers' well it is said to be but 715 feet through the salt rock. Beyond this, however, the salt rock deepens again; in South Saginaw, where it is 715 feet to the top of the sand rock; at Garfield, where the salt well was over 800 feet deep, and at St. Charles, where the new salt wells are between 800 and 900 feet deep.

Inasmuch as the wells at Midland, Alma and St. Louis find the Marshall sandstone at 1000 to 1200 feet, it is there much deeper. The upper bend indicated by the wells along the river may be a fluting pitching to the west.

If the oil and gas-yielding strata conform to the Marshall, however, the region of Wylie Brothers' well might contain oil or gas in commercial quantities.

The first stratum of importance in this connection below the Marshall is the Berea grit. This showed strong signs of oil and gas at 2080 feet in the well at South Bay City, the record of which is as follows:[19]

Pleistocene—			
Surface (made land and slabs)	10	10	Began Dec. 30, 1898.
Clay, thin seams of sand	40	50	
Sand	5	55	
Clay	15	70	
Sand (black at 92 feet)	30	100	
Clay	5	105	

[19] The dates give some indications of hardness.

Coal Measures—			
Shale	33	138	
Quicksand (probably fissure)	2	140	
Sandstone, 165 on Jan. 5, salt at 220, oily at 280	138	278	
Shales black and white and sandy	122	480	
Thin seam of coal at		480	
Pyrites (top of sandstone)	10	490	
Parma—			
Sandstone	50	540	
Eocarboniferous, Upper Grand Rapids. (Maxville)—			
Limestone	70	610	
Sandstone	10	620	
Lower Grand Rapids—			
Limestone	5	625	
Shale	25	650	
Gypsum, etc.	10	660	
Limestone 10 ft., shale 10 ft., sandstone 10 ft.	30	690	
Gypsum 15 ft., limestone 5 ft., gypsum and shale 10 ft.	30	720	
Shale and sandstone	60	780	
Limestone	10	790	
Limestone, gypsum and shale	10	800	
Limestone and shale	20	820	
Shaly limestone and pyrites	20	840	
Upper Marshall or Napoleon—			
Sandstone and salt water	130	970	Feb. 2, 1899.
Lower Marshall—			
1000 ft. Feb. 4, 1040 ft. Feb. 6.			
Red sandstone	90	1060	
Blue shale	30	1090	
Red shale	20	1110	
Red sandstone	20	1130	
White shale	50	1180	
Red and white shale	5	1185	
1210 ft. Feb. 8.			
Red sandstone	105	1290	
Coldwater. (Cuyahoga)—			
Light white shale	620	1910	
1310 ft., Feb. 9; 1380 ft., Feb. 10; 1580, Feb. 14; 1660, Feb. 15; 1750, Feb. 16; 1840, Feb. 17; 1900, Feb. 18.			
Red and blue shale	30	1940	
1990 ft. Feb. 19; 2000 ft. Feb. 20	10	1950	
Blue and white shale	100	2050	
Berea Shale—			
Red and white shale	10	2060	
Black bituminous shale with signs of oil and gas	30	2090	
2070 ft. Feb. 21, 2110 Feb. 22.			
Berea Grit—			
Grey sand rock,			
2140 ft. Feb. 24; 2170 ft. Feb. 25; 2210 March 1	10	2100	
White sandrock, strong brine, analyzed[20], flowing over the surface	160	2265	
2230 ft. March 3; 2244, March 4; 2250, March 6; 2265, March 9; 2270, March 10.			
Neodevonian (Antrim Shales)—			
Blue shale (Bedford)?	25	2290	
Black shale, oily with gas	14	2304	
Rock salt (?) March 13	6	2310	
2315. March 14; 2350, March 22; 2360, March 23.			
Black shale only	60	2370	
2370, March 24; 2380, March 25.			
Black shale, signs of limestone	10	2380	
2400 ft., March 29; 2410, March 31; 2420, Apr. 1; 2430, Apr. 4; 2440, Apr. 5; 2450, Apr. 6; 2460, Apr. 8; 2470, Apr. 10; 2480, Apr. 12.			
Black calcareous shale	110	2490	Apr. 16.
2500, Apr. 19; 2510, Apr. 24; 2520, Apr. 25; 2540, June 19; 2550, June 24; 2560, June 27.			
Black shale, hard, with pyrite and signs of oil and gas	90	2580	June 28.

[20] U. S. G. S. Water supply paper No. 31.

Mesodevonian (Traverse Group)—			
Limestone and shale	30	2610	June 30.
2620, July 1.			
"Limestone" dolomite	20	2630	July 3.
"Sandstone" dolomite	10	2640	July 5.
Sandy limestone	10	2650	July 6.
2660, July 7; 2690, July 8			
Blue shale	50	2700	
2715, July 10; 2730, July 11.			
Limestone, mixed	16	2716	
Shale	18	2734	
Sandy limestone with gypsum	6	2740	July 12.
2750, July 13.			
Dolomite like bottom of Alma well with gas and brine (Canadian oil horizon). Some H_2S.	20	2760	July 14.
2770, July 15; 2780, July 17; 2790, July 19; 2800, July 20; 2810, July 21; rope broke,—2818, Nov. 10; 2828, Nov. 11; 2838, Nov. 12; 2860, Dec. 2; 2905, Dec. 5; 2912, Dec. 7; 2925, Dec. 9.			
Limestone, yellow hard like Corniferous, compare Alpena limestone	180	2840	Dec. 11.
2960, Dec. 13; 3020, Dec. 14; 3060, Dec. 15; 3100, Dec. 16.			
Blue shale (slate)	180	3120	Dec. 17.
Blue limestone and gypsum	40	3160	Dec. 18.
Blue limestone, shale and gypsum	20	3180	
Limestone and shale, slightly browner	10	3190	Dec. 19.
Black shale and limestone	60	3250	Dec. 20.
Dark brown limerock, shale and gypsum	20	3270	Dec. 21.
Dundee or Cornifcrous—			
3280, Dec. 28; 3290, Dec. 30; 3300, Dec. 31.			
Limerock	40	3310	Jan. 1, 1900.
Lighter limerock and white sand	20	3330	Jan. 2.
3340, Jan. 3; 3370, Jan. 24; 3380, Jan. 5; 3390, Jan. 6; 3410, Jan. 7; 3420, Jan. 8; 3450, Jan. 9.			
Light limerock	130	3460	Jan. 11.
3470, Jan. 12.			
Limerock and sand	20	3480	Jan. 14.
3490, Jan. 15; 3500 Jan. 16.			
Limerock	28	3508	Jan. 18, 1900.

It will be noticed from the above that the signs of oil and gas occur from the base of the Berea shale down, and this is 1120 feet below the base of the Napoleon sandstone, which is the main salt rock. If we suppose this at Wylie Brothers' well to be but 715 feet down, then the beds most likely to yield oil or gas, the next 500 feet below the top of the Berea Grit, will be from 1825 to 2325 feet down at Saginaw, and there would be two or three brines to be encountered. Next would come a rock salt and dolomite formation for 1000 or 1500 feet more, perhaps. Then comes the Niagara for 400 to 800 feet, which has occasionally yielded oil and gas. Before we reach the Trenton oil horizon, which has a great reputation among oil drillers, there will be possibly 600 feet more of shale, red, blue and black. This is the lowest oil horizon of which we have any knowledge, and it would take a well 5000 feet deep to explore it.

But in regard to any of these horizons there is a good deal of uncertainty. The Berea Grit is not always present. It may not conform in such a matter as slight undulations of a hundred feet or so to the Marshall, and it may not be porous enough to yield gas in considerable quantity. As in most underground operations, there are large prospects of failure, with proportionate rewards in case of success.

The Trenton and Niagara are so deep that the cost of exploration bears no ratio to the chance of success. But the Berea Grit is at a reasonable depth and a glance at the dates given with the Bay City record shows that the drilling between it and the Napoleon rock is easy, only three weeks' work or so. In case oil or gas was not encountered, the brine might be of value.

NORTHERN PART OF THE STATE.

The prospects around Alpena county have already been referred to.

Recent wells on St. Joseph's Island just over in Canada, Neebish, St. Ignace, Cheboygan and Grayling, put down for salt or oil, give material for a pretty good section from north to south, and seem to indicate but little prospect for oil or gas. The only qualification that need, perhaps, be made is that near the possible outcrop of the Berea, that is along a line from Harrisville to Atlanta[21] and Vanderbilt, and thence southwest there is the same possibility of moderate accumulations. The records of the wells referred to are as follows:

On St. Joseph's Island a well 200 feet deep is said to have struck the Huronian without striking oil, but we have no farther details.

NEEBISH ISLAND.

On Neebish Island near Sailors' Encampment, T. 45 N., R. 2 E., only a few feet from and above the water, a well was put down by A. W. Palmer for the American Alkali Company to a depth of over 527 feet[22] with the following results:

No samples, drift?	111	111
Trenton—		
Argillaceous limestone	5	116
Light fossiliferous limestone	12	128
Light dolomitic "	10	138
Bluish " "	10	148
Light " "	10	158
Chazy (?)—		
Thin bluish dolomitic limestone	5	163
Light bluish limestone	48	211
Calciferous (?)—		
Sandy dolomite	3	214
Mixed drillings	4	218
Dark slaty	5	223
Potsdam, Upper—		
Clean white sandstone, a glass sand, like that on the north part of Sugar Island	161	384
Light red sandstone	33	417
Potsdam, Lower (Lake Superior Sandstone)—		
Coarse red sandstone, conglomeratic with pebbles of red Huronian quartzite	110	527 to 565?

According to Rominger's description the location of this well should be close to the top of the Trenton, and I think it likely. The divisions of Chazy and Calciferous are lithologic and very uncertain.

ST. IGNACE NO. 2.

The new well at St. Ignace is about two miles north of the old well on Sec. 31, T. 41 N., R. 1 E., about 600 feet north of the town line, 300 feet from Lake Huron, 590 A. T. or less.

[21] Near which, on Sec. 7, T. 30 N., R. 3 E., is a spring that yields gas like those near Killmaster.

[22] Five hundred sixty-five feet says the Michigan Miner, December, 1901, p. 16.

Comparing with the first well reported in Vol. V, it appears that the beds dip about 40 feet per mile to the south. The record is:

Pleistocene—		
Surface	34	34
Gravel with gypsum	9	45
Monroe—		
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—400 and other spots to 426.	
400 ft., Jan. 16.		
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 feet.		
589 feet, Jan. 29.		
Hard mixed cherty dolomite	7	592
White sandy dolomite	196	788
681, 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

As neither the previous well nor this shows the Medina Lorraine and Utica shales, at least the middle group of which is known to exist, it follows that at the bottom of the well the dip from the Neebish Island well must be *over* 1200 feet in 30 miles, or over 40 feet per mile by about a foot for every 30 feet of strata of these groups. If they are 600 feet thick, as is quite likely, then the dip will be 60 feet per mile.

An estimate of 600 feet for this group, though very much more than any previous Michigan estimate, is not out of harmony with estimates in Canada, and the following well from its position should show only about the lower third of the interval between the Niagara and Trenton.

BAY DE NOC.

Escanaba, Delta county, S. W. ¼ of N. W. ¼ of Sec. 8, T. 39 N., R. 21 W.:

Pleistocene—		
Gravel and clay	9	
Lorraine (Hudson R.)—		
Blue shale	45	54
Fossiliferous shale	13	67
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	83	334
Fossiliferous limestone	58	389
White limestone	8	397
Dark limestone	9	406
Quartzite	6	412
Limestone	44	456
Quartz	1	457
Limestone	24	481
Blue shale	4	485
Black limestone	14	499
Limestone	19	518
Blue shale	4	522
Sandstone, soapstone and limestone	38	560
Red clay shale	1	561
Sandy shale	1	562
Limestone, soapstone and sandstone	66	628
Crystalline limestone	12	640
Depth of hole	640	

ASPHALT IN THE UPPER PENINSULA.

Near by at Rapid River there has recently been considerable interest in an asphaltic oil, which occurs in cavities in the Trenton limestone. I take no stock in the idea that there is a great pool of it at a considerable depth in a "Synclinorium," but it might occur in fissures in the Trenton, where covered by clay drift, and especially where covered by the Utica black shales. I take the dip of the formation to be fairly uniform to the southeast and not less than 40 feet to the mile. Both where it is struck in borings and in the outcrop, the Trenton generally shows signs of oil. In particular in cavities where exposed along Rapid river there is more or less semi-fluid, dark-brown, almost black oil residuum or "gum," which gave Fr. Ruschhaupt of Milwaukee the following results: Odorless until heated, then gives off an asphalt smell. At 185° F. foams, fully liquid at 200° F., foaming at 300° to 350° F. Near 430° F. slight decomposition with evolution of a small amount of empyreumatic matter. At 556° F. boils, and after about one-half hour thickens, and boiling point rises. Boiled at 600° F. for three-quarters of an hour, the residue, cooled to 70° F., gave a hard, tenaceous asphalt. Perfect combustion left 5.08 per cent ash.

Soluble almost perfectly in gasoline, petroleum, ether, benzine, turpentine and chloroform, separating some water, and leaving only a small residue, to wit, the mineral and organic matter. Of the crude bitumen, 42.05 per cent was soluble in petroleum, ether, and 69.02 per cent in chloroform; none of it soluble in alcohol.

Summing up the result of distillation we have—

	1.	2.
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
	100.00	

No. 2 is the result of a second test by Ruschhaupt.

The oils were soluble in all the solvents mentioned except alcohol. Mr. Ruschhaupt says there is no petroleum in the distillate, and no paraffine, gum asphalt being the only base. A company has been formed at Mil-

waukee, M. D. Kelley secretary, to see if it cannot be found in commercial quantities.

The region of interest just now is between the Rapid and Whitefish rivers in Delta county. There is said to be but a thin coating of drift.[23]

CHEBOYGAN.

Returning once more to the north and south section, we have a very deep well at Cheboygan, the samples from which just arrived in December and have not been carefully studied, but is of so great interest that we will insert a provisional record. The driller, Mr. F. P. Rust, showed me many courtesies and took for me some temperature measurements with a Green self-recording thermometer, which are elsewhere given.

I may note that "pepper and salt" generally refers to drillings from a cherty brown dolomite. It will be noticed that there are some 500 feet of shaly beds at the bottom, and neither the Utica nor the Trenton appear to be yet struck. Very curious is the alternation in the samples of typical Medina material with that which looks like Clinton.

	Total.
Pleistocene—	
Surface, till	150
Gravel, chert	203
Sand	205
Gravel and sand	230
Gravel with many dolomite pebbles	245
Sand	250
Mainly dolomite, few other grains	255
Coarse pebbles, chert, quartzite, amphibolite, etc	270
Sand, quartz largely	290
Clayey or calcareous sand	300
Broken fragments of dolomite and pebbles	334
Aug. 5, 1899.	
Aug. 8, 1899. Pebbles of granite, dolomite, etc	352
Sand	354
Sand and cherty dolomite	356
Coarser sand, fine gravel with dolomite	360
Aug. 12, 1899.	
Monroe or Salina—	
This was a brecciated acicular dolomite, with slits and round or square cavities. It worked back so that the 8-inch casing had to be reamed down to 800 feet.	
Aug. 17, 1899. Dolomite and sand	375
Large angular fragments of dolomite	380
Cherty dolomite	438
Aug. 28, 1899.	
Oct. 12, 1899. Very cherty	512
Sept 5, 1900. " " ; Sept. 12, 1900, at 540 quicksand	570
Darker dolomite	685
Nov. 27, 1900.	
Still darker dolomite	700
Red shaly stuff	850-900
At 1050, water which "dissolved" red sandy shales above.	
March 6, 1901. Tubing to	1050
	1100
	1300
Red and blue shales	1360
March 9. Dolomites, gypsum and brine (61° 6F at 1360)	1460
(Just below 1400, March 12, 1901, brine)	1475
Dark dolomite	1478
Lighter dolomites	1525
Buff dolomites speckled with chert	
Niagara (Guelph)—	
	1550
	1565
Light cherty, March 26	1575
Lighter brown	1585
Finer powder	1615
	1625
No. 1, light	1635
No. 2, red rock, slow eff. in acid (1635)	1640
No. 3, red rock	1652
	1665
Coarse chips, dolomite	

[23] Artesian wells are struck at 250 feet, more or less.

Fine grained light dolomite	1670
Coarse chips dolomite	1700
" dolomite	1775
" dolomite	1868
" little darker, a little black shale	1880
Large pieces, dark bituminous	1904
" " " "	1942
Smaller pieces " "	1958
Lighter	1963
Much chert	1980
Coarse chert and dark dolomite	1987
June 13. Fine brown and white chert, agate, quartz	2005
"	2014
Brown	2027
Coarse dark with black shale	2033
Brown	2040
Very fine powder	2046
Lockport—	
Brown pepper and salt dolomite	2065
Light colored	2070
Coarser brown	2073
Coarse pepper and salt	2077
Fine grained	2080
Some with quite a little darker fragments	2090
" " " " " " "	2094
Finer grained and no darker	2105
" " " " "	2110
" " " " " (oölitic?)	2115
Similar but with more rusty pepper and salt appearance	2123
Rochester Shale—	
With darker fragments	2136
All darker	2143
Slightly lighter	2150
Very dark	2165
Black to drab, black tinge	2170
Dark	2173
Lighter	2180
Tends to shale, dark, not so shaly (2200)	2206
Clinton—	
Rusty white limestone	2236
" " "	2245
Bluer slightly shalier	2252
Blue shale and limestone	2257
Bluish shaly limestone	2261
Similar not well washed	2265
Medina—	
*Red, shaly, with a little green	2881
White limestone	2307
*Some limestone, mainly red and green shale	2311
Limestone and blue shale	2316
Black shale and limestone	2367
Fine white limestone	2375
Red and green shale	2407
Lorraine—	
Bluish limestone	2425
Dark dolomite	2430
Very dark dolomite	2432
Very dark dolomite	2437
July 18. Very dark dolomite	2455
Dark blue shaly limestone	2750

Inasmuch as the Cheboygan well does not reach the Trenton, the dip of the same from Neebish, about 45 miles north, must be over 60 feet per mile, but I do not think it is over 66 feet per mile.

GRAYLING.

A scientifically important well has been put down by T. Percy for Salling, Hanson & Co. It is the quickest sunk of its depth of any in the State, being started the last of January and reaching 325 feet March 11, having met quite a little quicksand. By the 21st it was down about 500 feet. By April 29 it was down 2200 feet, and was finished May 6 at 2750[24] (?) feet.

[24] Detroit Free Press, May 7, 1901.

The record from the samples is as follows:

Pleistocene—		
Sand	50	55
Till	50	100
Mainly sand, some clay and gravel, plenty of water	200	300
Sandy clay, till	25	325
Coarse cement, sand, etc	40	365
Lower Grand Rapids—		
Calcareous sandstone	15	380
Dark limestone	28	408
Gypsum!	132	540
(Record probably imperfect)		
Coldwater—		
Blue calcareous shale, 8 in. casing to 600 feet	35	575
Blue shale	385	960
Limestone	190	1150
Blue shale	390	1540
Berea Horizon (?)—		
Red and blue shale	50	1590
Neodevonian shales (Antrim Shales)—		
Dark shale	210	1800
Blue shale	100	1900
Green and black shale	100	2000
Green and blue shale	125	2125
Bituminous black shale	40	2165
Mesodevonian (Traverse Group)—		
Blue argillaceous limestones	210	2375
Blue and buff dolomites	50	2425
Light limestones	75	2500
Buff dolomitic limestones, last sample.		
Temperature 95. 9° F. at 2600 ft.; at 2625 ft. bottom of well when sounded with steel tape, Aug. 6, 1901. This may have reached the top of the Dundee or Corniferous.		
Brine, Sp. Wt. 1.138, strong in earthy chlorides		2750

If this well does not reach the top of the Dundee,[25] it reaches nearly the horizon of the top of the Cheboygan well,[26] and the dip, since the well is 1140 A. T., or say 550 feet higher, would be somewhat over 31 feet per mile, which is similar to that which we found from Alpena to Killmaster. It is not surprising that it is less than farther north, for we are nearer the center of the basin.

LAKE MICHIGAN SHORE.

MUSKEGON.

There have been a number of deep wells put down here at various times for various purposes, mainly for salt manufacture. Omitting the nearly fresh water wells which go less than 700 feet down into the Marshall sandstone, we have:

I. The oldest and farthest west is the Whitney or Truesdell well, also called the Hacker well, about 586 feet A. T. Reported by Rominger.[27] It is 1230 to 1600 feet deep.

II. The Mason well, 23 feet above the lake, began in January, 1872, and in June, 1874, reached, at 2000 feet, 50 feet of salt-bearing rock. In January, 1875, it was 2400 feet deep, cased 225 feet to rock, with 1400 feet

[25] It is possible it does not penetrate the Traverse, but I think that it does and that the filling in at the bottom is due to the blue shales at the bottom thereof.

[26] Supposing there were no drift, the well would probably begin in the Corniferous.

[27] Vol. III, Part I, p. 84, of our reports.

of 4⅝-inch casing inside. This was reported in Vol. V,[28] and the only additions we can make from recent data are that from 625 to 685 feet are beds of sandstone or limestone, and that the petroleum and gas located as about 1200 feet down is probably near the horizon of the Berea Grit, as the quality of the oil indicates, but the quantity is much over-estimated. The brine at 2030 feet is from the Dundee, judging from the analyses.

MUSKEGON BRINE ANALYSES.

	1.	2.	3.	4.	5.
$CaCl_2$	58.205	54.10	77.74	40	57.69
$CaSO_4$	.548	4.22	tr	tr	.29
Al_2O_3	tr	.....	.....	.....	.....
Fe_2O_3	tr	.....	.....	.....	.....
$CaCO_3$	.....	small	.....	.....	.....
$MgCl_2$	17.034	14.97	28.6	.....	6.41
$MgBr_2$	2.346	2.37	tr	.....	.....
KCl	.....	22.16	.....	.....	.....
NaCl	174.933	158.17	129.46	280	193.78
Sum	233.103	255.99	235.8	320	258.17
Water of crystallization, etc	33.3	.....	.....	.....	.....
By Evap	236.4	.....	.....	.....	.....
H_2S	present.	small	.085	strong	.....

1. A. B. Prescott, Sept. 8, 1883, at 15.6° C. Sp. Gr.=1.20342, neutral, sediment of iron sulphide, Ryerson well, pump at 1650—cased to 1400 feet, depth 2050 feet and brine probably from last fift feet, K probably included with Na.
2. C. A. Crossman, Sept. 25, 1883, at 62°.5 F. Sp. Gr.=1.21. Ryerson well.
3. H. Drasch, Sept. 29, 1881, at 90° F. Sp. Gr.=92° brine, NaCl by difference residue of salts? This, 4 and 5 are from the same well, probably not a pure brine.
4. S. S. Garrigues, Aug. 12, 1881, Sp. Gr.=1.210, evidently very rough.
5. Prof. DeLa Fontaine, of Chicago, at 65° F. 1.215 Sp. Gr. Computed from pounds, ounces and grains per gallon, supposing Av. weight to be used, and the Imperial gallon of 10 lbs. The gallon may be the U. S. gallon by measure, in which case the figures should be divided by 1.005. Nos. 3, 4, and 5 are from the Mason well, when cleared out and torpedoes exploded at 2015 and 2035, left blocked below 2100, 102° to 105° Salometer brine.

III. The Ryerson-Hills well is farther east, about 588 A. T., and a record could be obtained complete only to 1427 feet, as follows:

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 (? see V.)	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

[28] Plate XLIII.

This well was continued to between 2050 and 2200 feet and the pump set at 1650 feet, and at 40 strokes per minute gave 52½ gallons of brine in 3 to 4 minutes. It was cased 200 feet to rock, then 1400 feet (shutting off the oil horizon), then to the brine. Early in 1900 it was cleaned out, plugged at 1200 and tested for oil. It yields a little. I made temperature observations on it July 18. It was full of water, with a little oil on top, to the top of the casing.

IV. Near the Ryerson well, but closer to the water, a well was put down for oil in 1900. The record of the Ryerson well was used for comparison, and the new record, which was not kept in detail, is said to be about the same.

Surface	114	214
Shale and lime	161	375
Water bearing strata	25	400
Shale, etc		
6¼ inch casing to		730
A little salt and oil at		1227
Dry at		1515

V. A well was put down in the fall of 1900 about 44 feet southwest of the Mason well and about 12 feet above the lake, for the Michigan Oil Company, C. K. Macfadden, manager, of which Prof. McLouth kept a careful record for me, with a number of samples, as follows:

Pleistocene—		
Sand becoming finer downward	60	60
Calcareous blue clay free from pebbles	163	223
Gravel in clay and sand, till	12	235
Marshall—		
White micaceous sandstone	105	340
Coldwater—		
Blue micaceous shale—drilled 65 feet in 7 hours	280	620
Harder shale with carbonates of iron and lime-drilled 70 feet in 10 hours	80	700
Soft blue shale, calcareous	190	890
Brown limestone	24	914
Flagstones, shales with thin laminæ of white sandstone and calcareous bands, drilled 40 ft. in 4½ hours, and once 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

Now it is about 86 miles across to Milwaukee, where the feather-edge of the Hamilton and Helderberg rocks appear, which are not less than 1700 feet down at Muskegon. The dip to the center of the basin should therefore be, normally, 20 feet per mile or more.

Unfortunately the wells so far are so close together and have such inaccurate records that there is no sure indication as to whether the local dip conforms to this or not. The first thing to do, therefore, if explorations are to be continued, is to spread the wells so as to see what prospect there is of abnormal dips, and incidentally it may be that some place will be found where the sandstone at about 1200 feet, which is so very fine-grained, will be more porous.

If the "red shale" and limestone at 877 to 888 feet in the Ryerson is the same as the brown limestone at 890 to 914 feet of the last well, the bed in the Ryerson well would not be deeper, as it should according to the normal dip. This may be a slight indication of an abnormally flat dip.

MANISTEE.

Near Manistee the wells are more scattered than at Muskegon. (See map, Plate X.) They extend five or six miles from the Canfield and Wheeler well, close to Lake Michigan and about 592 A. T., to the wells at Stronach and Filer City at the head of the lake. Four plates are given in Vol. V. Mr. J. J. Hubbell has kindly assisted me with notes on these wells, locations, elevations and profiles. There are some twenty-eight[29]

No.	Owner.	Location.			Elevation above lake.	Total depth.	Depth to top of salt rock.
1	Canfield & Wheeler	0.7 mile N., 0.68 mile W., Sec. 11, T. 21 N., R. 17 W.			12	2,270	1,900
2	" "	0.7 mile N., 0.68 mile W., Sec. 11, T. 21 N., R. 17 W.			"	1,947 1,926	
3	Manistee Lumber Co.	.28	.72	Sec. 1,			
4	" " "	"	"	"			
5	Louis Sands	.04	.44				
6	" "	"	"	"		2,012	
7	Canfield S. and L. Co.	.1	.08	"			
8	" " "	"	"	"			
9	R. G. Peters	.92	.28	Sec. 7, T. 21 N., R. 86 W.		2,026.5	
10	" "	"	"	"			
11	" "	"	"	"			
12	" "	"	"	"			
13	" "	"	"	" " "			
14	Buckley & Douglass	.54	.40	Sec. 12, T. 21 N. R. 17 W.			
15	" " "	"		"			
16	" " "	"		"			
17	" " "	"		"			
18	" " "	"	"	"	30	2,015	1,955
19	Canfield S. and L. Co.	.18	.36	Sec. 7, T. 21 N., R. 16 W.		1,947	
20	" " "						
21	State Lumber Co.	.18	.21	Sec. 12, T. 21 N., R. 17 W.			
22	" " "						
23	" " "						
24	Louis Sands	.69	.97	Sec. 18, T. 21 N., R. 16 W.			
25	" "						
26	Filer & Sons	.96	.86	Sec. 19 T.			
27	Union Salt & Lumber Co.	.72	.68	Sec. 20	25	1,982 or 2,016 to 2,025	1,924 or
28	" " " " "	"	"	"			

J. P. Miller and Co. report that they put down four wells 1900 feet deep, two each for the Engelman Saltworks and Chas. Rietz and Bros., in March, 1883, and Feb., 1882, respectively. The depth given is however obviously only a round number.

[29] Jan. 1, 1901.

in all, but of many we have few notes, only the depth to the salt, or the total depth. Beginning at the west, we have the Canfield and Wheeler wells already described.[30] It is important to add, however, that the well was later deepened some 500 feet for them by T. Percy. The samples were sent me and show that they entered the white Guelph dolomites, which form the opposite shore of Lake Michigan. Analyses[31] agree therewith. It appears, accordingly, that the dip across the lake is not less than 39 feet per mile, and probably not over 50, a dip intermediate between that from Milwaukee to Muskegon, and that from Neebish to Cheboygan. Their second well was drilled 1926½ feet deep, but probably not to the bottom of the salt.

The Buckley & Douglass Lumber Company well No. 5 is not hitherto reported, and to the kindness of Mr. Hubbell we owe a record. It is higher than the Canfield and Wheeler wells, being about 610 A. T. The record is:

Pleistocene—		
First casing 10-inch pipe driven 400 feet		400
Second casing 8-inch pipe to bed rock through sand, clay and gravel	616	616
Devonian—		
Hard shale	324	940
4½-inch casing to		985
3-inch casing to		1032
A 3-inch pipe for brine inserted 985 ft.		
Limestone	630	1570
Soft shale, 7-inch hole drilled, brass lining to caving rock	110	1680
Silurian—		
Limestone, 6-inch hole, no lining	195	1875
6-inch hole brass lining caving rock salt and gypsum	20	1895
Limestone, 5-inch hole, no lining	90	1985
Brine cavity	30	2015

An air lift is used, the air being carried down to 985 feet and the brine raised from 400 feet to the surface.

Upon the names of the rocks we evidently cannot depend, but the salt is plainly about 70 feet deeper than in Canfield's well, and it may be that the casing from 1460 to 1520 feet in the latter hole corresponds with that from 1570 to 1680 feet in this, but the Canfield record is as unsatisfactory as this, in that the samples do not at all match the "log." Between this Buckley & Douglass well and the Peters well[32] the correlation is easier. The bottom of the salt being in one case at 2015 feet in the other at 2026, the two are about on a level there, but the Peters well showed quite a little oil and gas at 1905 feet. The soft shale at 1490 to 1600 feet in the latter must be that at 1570 to 1680 feet, in the former, however, being at the base of the Traverse Group, and 960 feet will correspond to 940 feet.

Now when we go down to the head of the lake at Stronach,[33] we find the salt down at only 1930 to 1964 feet. The Bell (Marcellus) shale at the base of the Traverse is higher, too,—from 1450 to 1625 feet,—with signs

[30] Vol. V, Plate XXXI. Letter of E. D. Wheeler, Feb. 13, 1900. J. J. Hubbell, Jan. 16 and 19.

[31] No. 322 in Water Supply Paper No. 31 of the U. S. G. S. is of the brine before deepening, No. 323 after. Compare the Britton analysis.

The elevation of the two C. and W. wells is but 12 feet above the lake.

[32] Plate XXXII.

[33] Plate LXV. Mr. Hubbell says that the Union Salt and Lumber Co. wells, 25 feet above the lake strike the top of the salt at 1949 feet and the bottom as supposed at 1982 feet, but as the wells afterwards spontaneously deepened to 2016 respectively to 2025 feet, he doubts this latter fact.

of oil and gas immediately beneath. The base of the black shales is, however, if rightly given, at about the same depth, 970 feet.

Therefore, instead of corresponding beds being 200 or 300 feet deeper than in the Canfield and Wheeler wells at Stronach, as they should be, were the dip across Lake Michigan continued, they are about as high, and higher than in the beds between. Gas was also noted at 600 feet.

It seems to me, therefore, that near Stronach there must be an arch, which ought to collect oil or gas in commercial quantities at its crest. But, of course, as there are no wells southeast of Stronach for many miles, we cannot tell either its course or position as yet.

SALT.

SALT.

The development of the salt business has been mainly along the St. Clair and Detroit rivers. A number of the well records have already been given, e. g., those at St. Clair, Marine City, New Baltimore and Detroit.

At St. Clair the salt comes at 1668 feet in well No. 3, with the following record:

Salt	25	1693
Limestone	77	1770
Mixture	15	1785
Salt	20	1805
Mixture	5	1810
Salt	45	1855

At Marine City the Michigan Salt Company have—

Salt	25	1595
Limestone	10	1605
Salt	10	1615
Limestone	11	1622
Salt	125	1751

The Davidson and Wonsey well had black shale at 600 feet, and at 1565 feet 250 feet of salt.

The well of the Pennsylvania Salt Company, below Wyandotte, is said to go through a bed of salt 103 feet thick at about 1200 feet.

The Pennsylvania Salt Company have a well near the Lake Shore tracks and Ecorse river with 25 feet of salt at 830 feet, and other beds below,—80 feet between that and 1050 feet.

Salliote and Ferguson, at the River Rouge, also have salt wells, and the Michigan Rock Salt Company are putting down a shaft to mine rock salt. The waters above the rock are strong of H_2S and their amount and character is the chief difficulty in the way of mining it, which has been under consideration now for some years.

The rock salt beds themselves are dry and water from the St. Clair or Détroit rivers is pumped down to dissolve the salt. In one case Mr. Hill, for many years salt inspector, found that an off tinge in the salt which was causing much trouble, was due to the water not being quite pure at the intake. When this was changed the difficulty was remedied.

The temperature of the upcoming brines is, according to reports, remarkably low, and deserves farther study.

The rock-salt brines contain more lime, especially as sulphate, and the salt is more likely to cake and be "sharper," and so for some purposes less desirable, than the natural brines. A group of analyses of these brines at Detroit is as follows:

Analyses of Detroit brine, from M. M. Green:[1]

	Jan.	Feb.	Mar.	April.	May.	June.
$NaCl$	311.72	312.69	309.45	308.78	311.78	310.16
$MgCl_2$	.228	.258	.278	.278	.219	.255
$CaSO_4$	5.943	6.04	5.892	6.05	6.05	5.754
$CaCl_2$	.248	.....	.265	.210	.196	.307

As the analyses show, they are very free from the earthy chlorides as compared with the natural brines, and hence there is not much of bittern to throw away.

With these natural brines the quality of the salt is affected, and a disproportionate amount of the heat[2] is needed if the evaporation of the brine is carried too far.[3] Hahn's papers contain a great many analyses. The following[4] is an analysis of a Saginaw valley brine by E. M. Vanflint:

$CaCl_2$	25.91
$CaSO_4$	1.19
$FeCO_3$	.92
Al_2O_3	.22
$MgCl_2$	6.27
$MgBr_2$	2.36
I, K, Li	tr.
$NaCl$	179.49
H_2O	783.73
	1000.00

In the Saginaw valley the most interesting feature is the putting down of a number of wells at St. Charles, to use the waste of the coal mines. These wells pass through the lowest coal at about 425 feet, and below this are said to find a good deal of limestone, striking the "salt rock," the Napoleon limestone, at 700 to 810 feet.

It is a pity that the deep well at Bay City, whose record is elsewhere given, was not put down through the salt formation so as to touch the Niagara beneath, and see what there may be in the way of rock salt beneath the valley, and it may be hoped that sometime there may be, even for the scientific interest of the matter apart from any definite prospective value, a hole in the lower peninsula as deep as in the upper.

[1] In grammes per litre.
[2] See a series of articles by H. C. Hahn in the Berg Huettenmænnische Zeitung for 1867 and 1881.
[3] Hahn, loc. cit., recommends concentrating Saginaw valley brine only to a density of 1.25.
[4] And many more will be found in U. S. G. S. Water Supply Paper No. 31.

METEORITES.

There has recently come to my office a paper by Merrill and Stokes[1] on a meteorite which fell July 10, 1899, on Thomas hill, on the Saugatuck road near Allegan. "The total weight cannot have been far from 70 pounds."

Specks of magnetic matter are common in all the samples of drillings, and a test with copper sulphate shows that metallic iron is often present. Usually these can be safely assumed to be worn from the drill, but there are a few cases, where the softness of the associated rock or the abundance of the iron or some other feature makes this explanation hardly satisfactory. An iron mica decomposed in the presence of organic matter seems to be responsible for one case. Are some of them meteoric?

The numerous suites of specimens representing the geological column of the State, and the Allegan meteorite together suggest an interesting field of research. According to the Encyclopedia Britannica, probably about 20,000,000 visible meteorites or shooting stars strike the earth each day, and if all those which the telescope would reveal are counted there would be perhaps 20 times as many. Suppose each to contain one gram of matter of which 10 per cent was nickel. The surface of the earth is about 510,000,000 square kilometers. Thus the average contribution each year to each square kilometer of the earth's surface would be about 28.6 grams, so that if one millimeter in thickness of a certain stratum was formed each year and received an average share of meteoric dust, a square kilometer in area, 1,000 cubic meters in bulk, would contain 28.6 grams.

If the stratum had, for instance, the specific gravity of 2.86, which is nearly that of many limestones, the bulk in question would weigh 2860 metric tons, and the percentage of nickel contained would be one-millionth of one per cent.[2] If, therefore, methods of chemical analysis were refined enough to enable us to determine such small amounts of nickel or any other element characteristic of the meteorites, we could get a notion of the rapidity with which any bed was formed, or if we should test a sample representing the average of the Devonian strata, which our well samples would readily give us, we could find their mean rate of deposition, and from that infer the duration of the Devonian period. In fact, we have material enough pretty well to infer by the same way the duration from the end of the Potsdam to the beginning of the proper coal measures. Even now we can see that any estimate which would allow thousands of millions of years for the accumulation of the 6,000 feet or so of strata which represent the interval in question, is likely to be extravagant, for it would mean an average meteoric constituent of .01 per cent or more.

Chemical methods for the determination of nickel are, however, not yet delicate enough to apply this test.

[1] Proc. Washington Acad. of Sciences, Vol. II, pp. 41-68: Am. J. S., Dec. 1899.

[2] If the ratio of the number of meteorites falling annually be n, average percentage of any element p, thickness of stratum formed per annum t, and specific weight of the same s, to the numbers we have supposed, then the per cent of nickel in the stratum would be nwp÷st 1,000,000.

GEOTHERMAL GRADIENT.

During the year my assistance has been sought by Prof. Wm. Everett,[1] secretary of the committee of the British Association for the Advancement of Science, for the study of underground temperatures.

The rate of increase in the temperature of the rocks as we go down, which is known as the geothermal gradient, is a matter of keen scientific interest, since we can gain from it some idea how long the earth has been cooling.[2] It is of especial interest in this State, because it has been reported to be uniquely low in our deepest mines, which are now not far from a mile beneath the surface. The increase is so great, nevertheless, that it is a practical question just how soon it will be a serious hindrance to mining.[3] I am inclined to believe, moreover, that when we have more facts to base our conclusions on, we shall be able to trace irregularities and find the thermometer quite useful in detecting leaky casings, locating the depth of the sources of flows, waters, etc. In fact, I have already[4] received help from the thermometer along these lines. Finally, we may possibly get light upon the movements of underground waters which, according to Prof. Van Hise, are the great conveyors and concentrators of mineral deposits.

In 1886 Prof. H. A. Wheeler published in the American Journal of Science[5] an article in which he called attention to the low rate of increase of temperature in the copper mines of Keweenaw Point, and attributed the same to the cooling effect of Lake Superior on the flanks. His observations are summarized in the following table:

Mine name.	Gradient.	Depth.	Distance between stations.	Highest temperature.	Character of lode.
Atlantic	99.5	907	796	51.6	Melaphyre.
Central	101	1950	1860	61	Fissure vein.
Conglomerate	95	617	527	48.3	Quartz p'y, Conglom.
Osceola	76.5	996	860	54.5	Melaphyre.
Tamarack	110.7	2240	2104	62.	Quartz p'y, Conglom.
Quincy	122	1931	1820	58.5	Melaphyre.

From his table we find the lowest temperatures he noted in the various mines must be[6] close to 43° (43.3° F. at 112 feet or less). Prof. Wheeler

[1] See reports of this committee in the Annual Proceedings, especially for 1882 and 1901. Also the Geological Magazine for December, 1901.

[2] Under certain suppositions, Sir W. Thomson (Lord Kelvin) estimates from 100,000,000 to 400,000,000 years.

[3] See my paper in Mineral Industry, 1895, Vol. IV, p. 767.

[4] And Mr. R. E. Bacon of the air lift also uses it right along.

[5] Vol. 32, Art. 13, pp. 125 to 137, Temperature Observations on Lake Superior Mines; also Trans. St. Louis Acad. Sci.

[6] 43.6° at 111; 42.6° at 90, 42.8° at 90, 42.3° at 136, 43° at 136, and 43° at 111 feet respectively.

thinks that the Tamarack observations especially may be affected by the ventilation of the mine.

By meteorological observations the mean air temperature of Keweenaw Point is not far from 40 degrees.[7] Thus a mean surface-soil temperature is indicated some 4 degrees above the air temperature. The British Association report that the soil temperature for the year is usually above that of the air from ½ to 2 degrees,[8] and that this is mainly due to the blanketing effect of the snow. We refer to this point again below. Wheeler's results, therefore, agree well enough with what might be expected, for Keweenaw Point has a very heavy burden of winter snow and often the ground does not freeze all winter. Furthermore, I took the occasion of a visit to the newly opened Champion copper mine, July 24, 1901, to make some tests of temperatures, through the courtesy, and with the help, of my predecessor, Dr. L. L. Hubbard, the manager, to obtain some light on the upper temperatures. The mine is recently opened. In the north end of the third level of B shaft, 378 feet below the surface, where there was no working or drift, the temperature at the top was about 49° F., of the air 47° F., in the moist rubbish at the bottom of the level 46° F. In the second level north, 250 feet down, the thermometer left in a short hole 20 minutes or more stood at 45° F.

In the first level 130 feet down in similar circumstances it stood at about 44½ degrees.

The observation at the bottom of the mine agrees in its rate of increase with Wheeler's. The others are perhaps warmed by air convection in the mine, but agree in pointing to a mean soil temperature of 43 to 44 degrees.

Some years ago (in 1893-4) the Centennial mine drove a cross-cut from the foot of a shaft which they had sunk between 3100 and 3200 feet on the Calumet conglomerate, over to what was supposed to be the Osceola amygdaloid. The temperature at the foot of the shaft was 62 and at the end of the long cross-cut about 19 feet below the surface, 69. It was said to have been 72 degrees the previous summer. There was a fair ventilation furnished by the air drill, but the temperatures are not out of harmony with those of Wheeler for a similar depth.

In 1895 A. Agassiz, president of the Calumet & Hecla Mining Company, published in the American Journal of Science[9] some figures for that mine, to wit, 59° F. at 105 feet and 79° F. at 4580 feet, the air temperature at the bottom of the shaft being 72° F.

It is clear, however, that the upper temperature is abnormally high, probably from the effect of the mine circulation during a long term of years, while the lower temperature is perhaps a little low from the same cause. The balance of Agassiz's observations have never been published, though if they could be carefully studied with due regard to the various factors they would be of much interest.

That this gradient is not something very local and peculiar to Keweenaw Point may be inferred from a few observations in the iron country. On July 19 last, with Mr. André Formis, one of the engineers, I went to the bottom of the Lake Superior hard ore mine at Ishpeming. The bottom of this mine at the 19th level is 900 feet vertically from the surface. It is

[7] 38.6° F. at Calumet.
[8] 1882, p. 72. At the Kew Botanic Garden, 0.4 degrees F. Over the St. Gothard tunnel from 2 to 3° C. to 5 to 6°, i. e., from 4 to 10° F., here being more snow.
[9] 1895, Vol. L, p. 503.

barely opened up down there and the skip goes only to the 14th level. It is connected with but one shaft. The water in the floor of the drift was at 49° F., and a little spring in a crevice on the east side of the shaft at 48.5°. The air was at 50°,[10] and a thermometer left in a diamond drill hole five feet in for 20 minutes registered the same depth.

In the Vulcan mine at Menominee I found[11] 56° at 1210 feet; the mean annual air temperature ought to be about 40° F., but Per Larrson found that a heavy flow at 80 to 90 feet had a temperature of 44 degrees. In the same paper I quoted the temperature of the North Tamarack at 4400 feet as 84 degrees F. according to R. M. Edwards. Captain J. Hall, the mining inspector, in his annual report for 1901 says that the rock temperature at the bottom of the Tamarack No. 5, and at the Red Jacket shaft of the Calumet & Hecla, at 4900 and 4935 feet, is 87 degrees. I believe that Mr. W. E. Parnell has stated that at a depth of 4662 feet a thermometer placed against the rock and covered with cotton batting registered 82 degrees.

Considering that the tendency must be to get the lower observations not high enough and the observations in the upper levels at low temperatures if anything too high, we may say that a line, which gives values for the upper levels as low as any, and for deeper levels as high as any, must be near the truth. It implies a gradient of 1 degree F. in 107 feet. It is a pity that a careful and expert physicist like Prof. Hallock of Columbia University, who has done special work in this line, should not have been allowed to make accurate tests.

I find it difficult to get thermometers thoroughly reliable, even to a large fraction of a degree, for this work.

It will be noticed that such a gradient line points to an average soil temperature at the surface of about 42½° F., i. e., about 4° F. above that of the air temperature of Calumet. This is probably not wholly because mine ventilation has made the deep observations too low and the shallow ones too high, though that is the kind of effect it would produce, but observations of temperature close to the surface of the soil show that it differs materially, even in the average, from the air temperature, and gives us not merely a starting point from which to measure the rate of increase downward, but a measurement of the mean blanketing effect of snow, and of the physical condition of the soil, its diffusivity for heat, mean wetness, etc., for the former is very dependent on the latter.

Generally speaking, the denser matter is, the better does it diffuse heat. Air is a poorer conductor than water, and water diffuses heat (except by convection) less rapidly than rock. Accordingly a porous, dry soil is a warm soil, i. e., loses heat more slowly than a damp, heavy soil.[12]

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[10] In a downcast shaft at the 14th level it was 43°.

[11] Am. Journal of Science, Vol. IX, June, 1900, p. 435.

[12] Hugh L. Callendar and C. H. McLeod of the McDonald chair of physics in the University of Montreal have recently published in the Transactions of the Royal Society of Canada, Section III, Second Series, 1895-6, Vol. I, pp. 1-19, and 1896-7, pp. 109-116, experiments that show not only this blanketing effect of snow, but also that the effect of sunshine can be most effectively studied.

For instance, the mean annual temperature of the soil within two feet of the surface of the ground was 47 degrees when the mean annual temperature of the air at Montreal was 42.63 degrees F.,—over four degrees higher. (Quite comparable to Keweenaw Point observations.) "It is not improbable that this difference may afford a convenient measure of the protective influence of the snow and will be found to differ materially in different years."

The maximum heat at the surface occurs in Montreal in June and July. It is coldest in December, but remains cold and the underground temperatures near 32 degrees until April.

At the depth of 9 feet the cumulative effect of the long winter cold did not come until the first of May, and that of the summer heat until the middle of October.

In Angstrooms' experiments from 1838 to 1844 at Upsala, the lowest temperature at two feet depth was March 2 to 11 (.075), and the highest July 11 to 20 (16.20° C.) and Aug. 11 to 20 (16.21° C.), while at 10 feet depth the lowest was the last of April (3.89° C.), and the maximum the last week of September (10.22° C.).

The mean air temperature for 8 years was 4.826 degrees C., and that of the soil 6.814 degrees C. At Stockholm we have for 1833-4, 6.637 degrees C. and 6.992 degrees C.; for 1842-49, 7.994 degrees C. and 8.61 degrees C. respectively, showing how much they vary according to the local climate.

Observations of underground temperatures at Grayling and at the Agricultural College have been published, but not for the winter months, and therefore give us no data as to the blanketing effect of the snow, though they may be made to let us know the thermal capacity of the soils.[13] It would be interesting to compare the upper and lower peninsulas in this respect, for the latter has much less snow.

The same variation in diffusivity also exists among rocks, and the following tables, compiled mainly from the report of the British committee aforesaid, are arranged to bring that out, and also the obvious fact that generally the lighter and more porous the rock the poorer conductor it is.

	Diffusivities.	
Quartz	.0086	
Sandstone	.006	Conducts 8 per cent better wet.
Flagstones	.0046	
Sand dry	.0009	Kew experimental garden.
Wet	.007	" " "
May 23—June 6	.006	Callendar and McLeod, (from .0379 to .0015).
Ave	.0036	Callendar and McLeod.
	.00872	Forbes and Thompson.
Sandy loam	.0054	1889 Report Brit. Asso.
Slate	.004	
Clay slate	.0027	
Clay	.0025	
Shale	.0019	
Knoxville pink marble	.00757	B. O. Peirce.
Vermont white	.00681	Fine grained.
Carrara	.0050	
Limestone	.0052	
Granite	.0053	
Flint glass	.00260	B. O. Peirce.
	.00277	" "
Crown glass	.00245	Oddone.
	.00243	Leese.
Pumice	.0006	
Schemnitz hornblende andesite	.0029	
Trachyte	.001	Ayrton & Perry Brit. Ency.
Trap	.0078	
	.007	Brit. Ency.,
Serpentine	.0044	
Rock salt[14]	.0113	
Copper	1.077	Brit. Ency.
Water	.0022	" "
Air[15]	.0016	" "
Wood	.0013	" "

From these tables we may infer that other things being equal, rocks containing much copper will have a high diffusivity and a small gradient, and that there will in general be no marked difference between sandstone, limestone, and our Lake Superior traps and granites. But surface

[13] Reports State Board of Agriculture, 1888, p. 187; 1889, pp. 85 to 101; 1890, pp. 143 to 152; 1891, pp. 92 to 97.

[14] This seems rather high. Has not the diathermic effect of radiant heat been combined?

[15] Air is a poorer conductor than water, when not allowed to circulate. See pumice and wood.

materials, whether sand, gravel or clay, and shales will have a much less diffusivity and the temperature will rise more rapidly. Circulation of water in a hole will tend to make the gradient appear too low, and the circulation of water downward at the sides of a synclinal basin would make a low gradient, while at the center where there was upward pressure the reverse would be the case.

It will be very interesting to compare the results we have found in mines with those in deep wells. There is one such at Lake Linden all the way in red sandstone, which flowed, and another was recently put down at Grand Marais, which did not flow. Observations should be made in these wells.

There are also some deep artesian wells, which flow along the shore of Lake Michigan, the data concerning which are not very satisfactory. Back of the S. M. Stephenson house at Menominee is a well over 500 feet and less than 1000 feet deep, probably about 800 feet, which is flowing with 15 feet head and a temperature of 55½ degrees F. Probably much of the way it is through Trenton and calciferous dolomite. The mean soil temperature ought to be 2 degrees warmer than on Keweenaw Point,—say 45 degrees, and the mean gradient 1 degree in 80 feet.

At St. Ignace a deep well was put down by A. W. Palmer 1155 feet. The record already given may be summarized as follows:

Dolomites and gypsum.....	174	174
Red and blue shales and gypsum.....	226	400
Dolomites (often very light colored, of the Niagara formation, with abundant water from 575 to 681 feet, and more at 1040 feet)	755	1155

The temperature of the flow was 51° F. This is about 2 degrees less than at Cheboygan and Alpena at that depth.

Not far off, at Cheboygan, we have much fuller information. I attempted to get more data at St. Ignace, but the thermometer broke. At Cheboygan the water works are supplied by a well 408[16] feet deep. It would flow naturally, but the yield is increased by an air lift, and the temperature is 51.8°.[17]

Another old well near the McArthur's mill and the river, which is said to be 839[18] feet deep and cased to 70 feet but is loosely filled up, gave a flow temperature of 48.7° F. on March 10, 1901.

There is another well about as deep (400 to 500 feet) as the water works well on the east side of the river near Nelson's mill. But the interesting well is the one put down recently over 2700 feet. I visited this March 11, 1901. The well was then down 1380 feet and the temperature[19] was 61.6 degrees F.

The mean annual temperature of Cheboygan according to the weather service is 41.6 degrees. At the conclusion I was not able to be present, but a series of tests were made by Mr. F. P. Rust, the contractor, and I

[16] Other reports say over 400 and 464 feet.
[17] Green thermometer 7536.
[18] It is also said that it is 900 feet deep and over 200 feet to bed rock.
[19] By Green thermometer 7812 attached to the top of the bailer, in a perforated brass case.

believe him to be intelligent and careful. The results[20] are: at 100 feet, 53°; 400 feet, 51°; 700 feet, 51.5°; 1000 feet, 55°; 1300 feet, 60°; 1400 feet, 60.4°; 1700 feet, 63°; 1800 feet, 64°; 2000 feet, 65°; 2300 feet, 68°; 2700 feet, 73°. They indicate plainly difficulty in reading fractions of a degree, but taken together with the temperature of the water at the water works from 400 feet and my own reading at 1360 feet, agree quite fairly in a low gradient from 400 feet down of more than 100[21] feet to a degree, and also a much higher gradient from the surface to bed rock, even supposing the mean soil temperature to be 4 degrees more than that of the air. Fissures and water were fairly often encountered. The rock was very largely dolomite. This gradient matches fairly that on Keweenaw Point.

Going down to the opposite end of the State at Britton to get a well through similar rocks, thermometers let down on the rope of a bailer to 945 and 1617 feet read 59° and 53° F. respectively. There is a brine at the bottom of the well, not so strong probably as a little that is seeping higher up. But taking the average of these two observations (63.3) as the temperature at the mean depth (1281 feet) we get a gradient, if the soil temperature is a little above that of the air temperature (48 degrees), about the same as at Cheboygan.

The well of the Diamond Crystal Salt Company at St. Clair was tested at 1635 feet and gave 71.2 degrees. Here, however, we have a new disturbing factor. Water has been pumped down for a good many years in this and adjacent wells to dissolve rock salt, though this well has been idle for some months. Only 200 feet away the tools were in a well which was being fixed. Near by the Salutaris well is said to have flowed at 92 feet with a temperature of 51 degrees, and now, being pumped, stands at 52 degrees, while the Oakland mineral well, 1200 feet deep or so, being pumped, is at a temperature of 69 degrees F.

The old Wells boring at Port Huron, recorded in Vol. V but now stopped at 838 feet, was there at 57.5° F.; at 600 feet, 55.3° F.; at 300 feet, 54.2° F. (?)

The mean air temperature of the neighborhood is about 46 degrees, and it is clear that for the first two or three hundred feet or so there is a very rapid rise of temperature, or the soil temperature is a good deal higher. Even thereafter the gradient must be greater, perhaps about 1 degree F. in 65 feet. There is more shale and gypsum in these wells than in the previous ones, and the record is perhaps comparable with the lower part of that at Bay City.

This I have already mentioned and the record is elsewhere given.[22] The East Saginaw first well flowed with a temperature of 47° F. at 102 feet, 50° at 293 feet, 51° at 531 feet, and 54° at 617 feet. The air temperature is 45.4°.[23] Hahn also gives the mean temperature of the brines as 60.4° F.

[20] By Green thermometer 9114. Mr. Rust followed detailed instructions from me, and noticing the irregular character of the first three observations repeated them to see if any error could be detected, but could not find any. He also writes: "Please note the temperature at 100 feet is 2 degrees warmer than at 400 feet and ½ degree warmer than at 700 feet. This seemed a little strange to me, so when we had gotten all through I went over the first three tests again, but was unable to find the error." Previous to his test of the temperatures, however, he had plugged the well at 1600 feet and had been testing a brine at 1400 feet, and no doubt convection currents have upset these somewhat. There were casings down 950 feet and 1050 feet at the time.

[21] From 1400 to 2700 feet, 1 degree in 103 feet; from 400 to 1360 feet, 1 degree to 102 feet; from 400 to 2700 feet, 1 degree in 104 or 108 feet, while between the temperature at 400 feet and that of the air there is a drop of 10 degrees.

[22] Am. J. S., Vol. IX, p. 434.

[23] Hahn, p. 305, Berg. Hutt. Zeitung, 1867.

from a depth of from 600 to 880 feet, probably mainly below 760 feet. Then we have Davis's observations in the Bay City well, to wit:

At 3455 feet, 97° F., thermometer No. 5688 exposed 8 hours.

At 2934 feet, 90.1 and 90.2° F., thermometer Nos. 5688 and 5690 respectively exposed 1 hour.

At 1793 feet, 77° F., thermometer Nos. 5688 and 5690 exposed 30 minutes.

At 1793 feet, 71° F., thermometer No. 4708 exposed 50 minutes.

At 1304 feet, 65° F., thermometer No. 4708 exposed 1 hour.

It is pretty plain that in the Saginaw valley the snow blanketing is not marked. The mean gradient of 1 degree in 67.07 feet agrees so nearly with intermediate observations that the departures from it may be assigned to insufficient exposure and difference in thermometers, though I am tempted to assign the decrease in gradient at the end down to 1 degree in 75 feet to the fact that we are getting into the same beds that gave the low gradients at Cheboygan and Britton. Still it may perhaps be laid to aqueous circulation.

I have in times past doubted the high temperature given for the bottom of the Alma well, 98 degrees at 2803 feet, but I have more faith in it for various reasons now:

The blanketing effect is well marked at Alma. With a mean annual air temperature of 45 degrees, shallow flowing wells from 30 to 80 feet deep vary little from 50 degrees temperature.

Again, in spite of various difficulties, I managed to get a thermometer down to 900 feet and found the temperature 69.6 degrees. The well had not been pumped for some time, but has been pumped the past 13 years perhaps 50,000 gallons a year.

Finally, some observations on the new Grayling well, which is similarly located and goes through similar strata, show a similar gradient, and allowing for an initial 3° difference, have a very similar temperature at the end. The Grayling observations are:

On June 4, 93.8 degrees F. at 2376 feet

On August 6, with No. 7815:

95.9° F. at 2600 feet, thermometer exposed 1 hour and 18 minutes.
89° F. at 2150 feet, thermometer exposed 1 hour and 20 minutes.
58.4° F. at 900 feet, thermometer exposed 2 hours and 30 minutes.
51.8° F. at 500 feet, thermometer exposed 1 hour and 5 minutes.

There was very little mercury forced through the neck of this thermometer at this last reading and the reading may be low. The water was about 26 feet from the top. The gradients are:

2600 to 2376 feet, 1 degree in 111.3 feet.
2600 to 2150 feet, 1 degree in 65 feet.
2376 to 900 feet, 1 degree in 59 feet.
2150 to 900 feet, 1 degree in 40.8 feet.

This very low gradient is probably all the way in fairly dry shale.

900 to 500 feet, 1 degree in 60.5 feet.

This is not reliable, as the 500 foot reading should, I think, be rejected.

900 to 0 feet, 1 degree in 60 feet.

(Supposing the mean soil temperature to be 1.2° above that of the air.) There is here not so much sign of blanketing. It is obvious here that

except again in the very last part the gradient is even steeper than at Bay City or Alma.

We have tested one other well that goes down mainly in surface deposits and shales, that at Muskegon. The mean air temperature is 46.8° F. The flowing wells from 240 feet depth on are at 53° to 53.5° F. Ryerson's well, plugged at 1200 feet but full of water, gave at 240 feet, 53.2 degrees F.; at 650 feet, 58.7 degrees F.; at 1150 feet, 67.2 degrees F.

The gradients through surface from a soil temperature assumed at 47.2 degrees, sandstone, and shale, are respectively 1 degree in 40 feet, 1 degree in 74 feet, and 1 degree in 59 feet. There is some oil in the bottom.

It certainly looks as though the facts could be accounted for by supposing a difference of air and soil temperature of ½ to 4 degrees according to location, a gradient in the surface deposits of 1 degree in 40 feet more or less, in shale of 1 degree in about 60 feet, in sandstone 1 degree in 60 to 70 feet, and in limestone, trap, and the denser rocks of about 1 degree in 100 feet. This is not far from the ratios their diffusivities would lead us to expect. But we need more facts, and especially more accurate observations of gradients, of the effect of the mine ventilation, and records of soil temperatures continuous throughout the year. The effects of oil formation and salt solution may then be eliminated.

MAMMOTH AND MASTODON.

Remains of large animals of the elephant tribe have been known ever since the early days, and are referred to in the annual report for 1841,[1] and in Winchell's report in 1850.[2]

At the Agricultural College are six teeth and half the lower jaw of a mastodon, from Eau Claire, Berrien county, which may be the one referred to by Hubbard.

It was found in digging a ditch and is well preserved.

There are also remains from Lenawee county, and a lower tooth and part of a pelvis which were sent in in the spring of 1900 from the Shiawassee river, in Howell township, by Ulysses Hilleker. They were obtained in dredging out the river for a light steamer.

During the past year two instances have come under my personal observation of especial interest, because the animal proved to be the mammoth, the rarer, it is supposed, of the two animals, mammoth and mastodon.[3]

Mr. E. R. Grinold of Grand Ledge noticed in ditching north of that town that they had cut through a tusk, and through Mr. C. V. Fuller my attention was called. I went down there and found the remains barely a foot from the surface in a little low swale which Mr. Frank Tabor, the owner, said was a duck pond 40 years ago,—in other words, a good place for a large, heavy animal to get mired. We exposed three teeth which were plainly those of a mammoth, and were lying just exposed. The teeth were, two of them 8 inches long, the third 6. The tusk had flattened into an ellipse about 9x5 inches near the butt, and 6 or 7 feet long.

A second discovery was made about three feet underground in ditching close to the Pere Marquette shaft No. 2 in East Saginaw, by Wm. Leamon, who brought a tooth to Wm. Richter, the well-known taxidermist of Saginaw,[4] who identified it as that of a mammoth. It was about 25 feet above lake, 2½ to 3 feet down, and in size 11x5 inches, and in pretty good condition, though the base was gone.

Not far off in Tittabawassee township, I found pieces of a tusk among the farmers, said to have come from one cut in a ditch on Sec. 20 near the course of the Parker swamp drain about one-fourth mile north of the south line of the section. Mr. Richter also says that three feet of the end of the tusk, the lower jaw and ribs of a mastodon were found in a kind of quicksand six feet underground in digging a tile ditch on the Willis farm.

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[1] Bela Hubbard's report; mastodon in the western part of Macomb county, and on the Paw Paw river in Berrien county.

[2] Page 132. Mastodon at Green Oak, Livingston county, and Plymouth, Wayne county. Mammoth in the northern part of Jackson county, and in Macomb.

[3] For free pamphlet describing the difference, write F. A. Lucas, National Museum.

[4] Saginaw Courier-Herald, Oct. 31, 1901.

Other recent occurrences noted are:

In a swamp in ditching Stafford's farm, Church[5] near Hillsdale, a large part of mastodon acquired by the National Museum.

Olivet,[6] exhumed and acquired by the college, eight teeth and a large number of bones, the largest being 38 inches long and 25 inches around.

Four miles west of Dorr[7] by Frank Fleser and others, a jaw bone 8 inches wide, 22 inches long, with several teeth, one being 7 inches from crown to root and 10 inches in circumference.

Clinton, Lenawee county, by P. B. Gragg, "several teeth and bones."

Mr. W. F. Cooper also found traces of one of these animals in Frankenlust.

According to the notes of Mr. W. F. Cooper (1900, p. 16), a mastodon was found near the southwest corner of Sec. 3, Williams township, Bay county, about 621 A. T., and was sent to Ypsilanti, including a fragment of a tusk, but little curved, 8 feet 9 inches long, a femur and thigh socket 9½ inches across, one vertebra 12 inches high from top to bottom, and one tooth. Found in a small, deep hole of mucky soil which had been a bog hole until drained. The skeleton was buried three feet below the surface, according to Mr. John C. Rowden, to whom the Survey is indebted for this information.

Finally, relics of a mastodon and his meal have recently been found near Niles in the Bakertown marsh southwest of Buchanan, associated with marl, the shells of which have been described by B. Walker.[8]

Now that the presence of mammoth and mastodon in the State are well established, the point of interest to me in these finds is to see how near to the present lake level, i. e., to how recent a date these animals survived. If these finds in Bay and Saginaw counties are of animals mired in place,—it is hardly likely that so many fragments would be found far from shore, and they seem to be in hollows and miry places,—then it is certain that the animals survived at least until the lakes were down to about 30 feet of their present level in that region. This means probably not more than a very few thousand years ago, and of course possibly a much more recent date.

[5] Saginaw Courier-Herald, June 9, 1901.
[6] Sept. 29, 1900.
[7] July 5.
[8] Nautilus, March, 1898, Vol. XI, p. 121; September, 1899, p. 55. Details have been kindly furnished by Wm. Hilles Smith. E. H. Crane of Kalamazoo has the bones.

UPPER PENINSULA.

In connection with limestones and prospects for gas and oil we have given some facts regarding the eastern end of the upper peninsula, a region that has been almost neglected since the publication of Vol. I.

In the section in regard to temperatures we have given some points relative to underground temperatures in the iron and copper mines.

Prof. C. R. Van Hise has published, in the last annual report of the United States Geological Survey (Twenty-first, Part III, p. 313), an admirably lucid summary of their investigations on the iron ranges. There is, however, as it seems, still room for work to be done in the iron country, and especially for the preparation of a map, on as large a scale as can be conveniently handled, to cover the whole upper peninsula and summarize and supplement the work of the United States Geological Survey, and more carefully adapt it to the section lines.

There is yet other work. Outlines of the iron ranges not covered by their detailed maps should be worked up, and the lines of magnetic attraction, which are a key to the structure of the iron-bearing series, should be and can be followed under the surrounding mantle of sedimentaries. There are, however, two men so pre-eminently qualified for this work that it would be a pity to set anyone else at work so long as there is any chance that one of them may be had,—H. L. Smyth, in charge of the Mining Department of Harvard University, who has superintended some important private geological surveys as well as been connected with the United States work, and A. E. Seaman, in charge of Geology in the College of Mines, who has studied these rocks in the field every summer for nearly fifteen years.

Both of these men, however, deserve much better pay, and receive it, for that class of work, than it is easy to provide from our appropriation without dropping practically everything else. An extra appropriation for iron country work, such as I suggested to the last legislature, of $4,784, might easily pay for itself in taxes in a few years, if thereby new mining districts were opened up.

In the copper country, Dr. Hubbard and Mr. Savicki have continued to collect data.

Two other matters of somewhat curious interest may be referred to here that those interested may not overlook them.

Prof. G. A. Koenig of the College of Mines has continued his researches on the basic arsenides of copper, of which a series occur on Keweenaw Point, to wit:

Cu_2	As_1	Keweenawite (+ 20 per cent Ni).
3	1	Domeykite (+ Ni is Mohawkite).
4	1	Ledouxite.
5	1	
6	1	Algodonite.
7	1	
9	1	Whitneyite.

Papers will be found in the current American Journal of Science and Proceedings of the Lake Superior Mining Institute.

The second point is the divergence of the plumb bobs in the Tamarack shaft. In planning connections of Tamarack shaft No. 5 with the rest of the mine plumb bobs were dropped down the shaft 4250 feet long and 17.58 feet apart at the surface. They proved to be 17.65 feet apart at the bottom. They were composed of No. 24 piano wire and had 50-pound steel bobs at the end.

In No. 2 shaft the experiment was repeated with lead bobs, and the divergence was from 12.6 to 12.7 feet.[1] Some discussion has sprung up as to the cause, and President McNair of the College of Mines will undertake further experiments.[2]

The fact is that these deep shafts furnish the finest chance in the world for experiments in geophysics, and so far as the exigencies of mining permit they should be used. This is a work which we should either do or, better yet, cooperate with the College of Mines in doing.

One subject, that of the extent to which the temperature of the surrounding rock may be affected by the ventilation of the mine, is a very important question, practically and scientifically, to solve which business and scientific men of various kinds should work hand in hand.

[1] See Portage Lake Mining Gazette, March 28, 1901, for description of shaft and section down to C. & H. conglomerate; Oct. 8, description of effect. Letter of R. M. M., Oct. 13, Oct. 15, Dec. 29; Prof. W. H. Hallock, Jan. 16; C. B., Oct. 16, etc., for explanations.

[2] Pres. McNair's results have been published while this report is going through the press. See the Portage Lake Mining Gazette for May 1, 1902, and Engineering and Mining Journal for April 26, 1902. The essential result is that ventilation currents are the dominant factor in the effect observed.

RELATIONS OF THE GEOLOGICAL SURVEY.

AGRICULTURAL COLLEGE.

The close relations into which I have been brought with the Agricultural College, to which I referred last year, have been continued and have been a source of sincere satisfaction. The work of the survey is such that questions continually arise which are fit subjects for advanced students to investigate and report on by thesis, such as the composition and character of coal, of water, the connection between botanical distribution and soils and we have been able to furnish advice and in some cases a moderate amount of financial assistance to such students.

There is also a demand for chemical investigation of various raw materials and ores. It seems to me that when the results of the test will be mainly to the benefit of the land owner the one benefited should pay, but in other cases, as has been recognized in the question of public water supplies, the State has recognized the public interest in the matter. Many state geological surveys employ a chemist constantly but it has seemed to me wiser, in view of the fact that the State already supports five or more chemical laboratories, to save expense of equipment by asking their assistance, under such conditions as may be found acceptable, and in this I have been met more than half way by Prof. F. S. Kedzie, and I have him most particularly to thank for much uncompensated work, in addition to that for which we were able to pay. I have also to thank Dr. V. C. Vaughan and A. O. Campbell of the University, Dr. G. A. Koenig of the College of Mines and numerous private chemists, whose names will be found appended to the analyses they have contributed for additions to our knowledge of the chemical relations of our raw materials.

While, however, a certain amount of a certain grade of chemical work can be done by students in the course of their studies, and in return for material supplied by the survey, and not a few questions received at the Agricultural College have been turned over to me to answer, it is only fair and proper that the survey should furnish adequate pay for accurate and elaborate analytic work, and there are a number of lines of investigation for which I should be glad to have larger resources.

A careful and systematic examination of our brines for the potash might be of great technical value for the State. A series of analyses to test Van Hise's theory of the origin of our ore deposits would be of scientific interest, and samples of clay, etc., continually come of interest enough to warrant more extensive investigation. Some of these investigations might be undertaken jointly. The search for nickel to which I have referred is rather a subject for thesis investigation.

I have also Messrs. Beal, R. C. Kedzie, Barrows, Vedder, Wheeler, and Longyear to thank for scientific assistance.

My relations with the experiment station work have continued of a mutually helpful character. As it does not refer to my own work but that of Prof. W. H. Sherzer[1] I beg leave to quote the following letter:

Experiment Station, Agricultural College, Mich., December 7, 1901.

My Dear Sir—It gives me great pleasure to report to you an incident which casts a side light of value of your most excellent work to the practical, every-day industries of Michigan. I was recently asked by certain parties interested in sugar factories and seeking new sites for factories, to make a survey of Monroe county and find its adaptability to this industry. On inquiry I found the work of Prof. Sherzer on the soils of that part of the State. With the map from his work in hand I began the survey. After working two days to verify his map, I found it so correct, even in minute detail, that I stopped my work at once and sent in his map as my report, giving, of course, proper credit to your office. That map was final authority in the hands of the syndicate. Later I have worked elsewhere in the State and have found that you have preceded me and done the work so well that I have simply referred the people interested to your investigations, and they have gladly accepted them. I congratulate you, therefore, in having been of signal benefit to our nascent agricultural industry.

Yours respectfully,
C. D. SMITH, Director.

COLLEGE OF MINES.

I was very glad to let them have the services of our Mr. Cooper to collect samples of the materials of the Lower Peninsula, particularly those of economic value, for the collections which they are preparing to loan to the high schools, but they paid his salary and expenses when thus engaged. But now President McNair has suggested to me the possibility of co-operation in the study of some of the deep shafts of the copper mines. These, unique in depth and in other respects, offer an opportunity for the study of the diffusion of the heat, electricity, magnetism and gravity of the earth which should not be neglected, in which study we ought to work hand in hand with the College of Mines, as the results would be a part of a geological survey of the State. The only question is how much can we do with our money and our other calls.

Another point in our relations with the College of Mines is by no means so agreeable to take up.

As you will remember, the building of the Geological Survey has stood for some eight years upon land belonging to the College of Mines, which they reserved the right to use if needful. I append the vote of the Board of Control of the College of Mines upon the subject which was accepted by your Board.[2] I presume that it is true that at the time of the location none foresaw the rapid growth of the Mining School or supposed that the necessity of removal would be anything but a very remote contingency.

After some correspondence, which was laid before you, and informal conversation with the presidents of the Board of Control and the College, in July, 1901, I met with the Board. I found that they recognized the

[1] On Monroe County, Vol. VII, Part I.

[2] A meeting of the board of control of the Michigan Mining School, duly called, was held at the office of the chairman on the 6th day of October, 1893, at 2 o'clock p. m. There were present: Jay A. Hubbell, chairman; Alfred Kidder, P. C. F. West, T. B. Dunstan.

The following resolution was offered and on motion was duly carried and adopted, viz.:

That the Board of Geological Survey for the State of Michigan be permitted to erect a suitable building on the east side of the Michigan Mining School property for the Geological Survey, on a piece of ground to be designated by the executive committee of the board of control, and to occupy the same free of rent for the purpose of carrying on said survey, but for no other purpose; said ground occupied by said building to be under the general management of the board of control of the Mining School. The board of control reserving the right if at any time the ground occupied by said building should in their judgment be needed for the use of the Mining School, to remove the structure to some other part of the grounds; the said Geological Survey to occupy said ground on which such building shall be erected as tenants at will of the board of control of the Michigan Mining School.

embarrassing position in which we were placed, for we were only notified when it was too late to obtain anything from the Legislature, as well as their obligations to provide for the removal and a new site for the Geological Survey building upon their grounds. But I found a considerable difference of opinion as to where that site should be, and I saw that not only would the site be neither so convenient nor so dignified as the present but it would not be permanent. The new building for the College of Mines might mean a new move and it was a question whether your Board could compel the Board of Control to pay the expenses of moving each time. There was at least a chance of legal controversy, the expenses of both sides of which, as well as of the removal, would in any case fall upon the taxpayers of the State. Of course, too, every remove meant a certain amount of damage to Survey property and interruption of the scientific work of the Survey. Mr. Savicki has done little but look after things for the past few months.

I therefore proposed to the Board of Control that if they would find the balance I would, personally, subscribe $100 for a lot of land upon the slope over against the grounds of the College, upon which to place the building where it might permanently rest. In this they met me more than half way leaving me but $75 to pay. Besides the members of the Board of Control, President McNair and Mr. Charlton, the architect, contributed and a lot was obtained, which was marked on the plat at $350, through the good offices of H. S. Goodell for $250. The removal has, I regret to say, dragged out so that even today the building is not completely on its new foundations, and it will be impossible to give the data regarding publications issued and received which have annually been included in this report I shall try to supply the omission next year. It would be a very wise thing, in view of the ever accumulating mass of valuable material, to veneer the building with brick, now that it is no longer so isolated, and at the same time provide for enlargement.

The organizers of the Geological Survey expressed their sense of the close relation in which it stood to the educational interests of the State by making the Superintendent of Public Instruction a member of the Board. The work should stand in close relation with the colleges as well as to the business interests of the State. In regard to its relation to the secondary schools, you have instructed me to furnish the reports gratis to teachers, and a good proportion have gone that way. The demand for Prof. Sherzer's report on Monroe county has been especially lively.

In regard to the question sometimes agitated as to the introduction of geology into the high schools, my opinion is strongly against any teaching of geology as such by itself, and a "fourteen weeks course in geology" is more of a burden than a benefit. Geology, as the life history of the earth as a whole, presumes an acquaintance with most other sciences, and if introduced too early can only lead to half grounded knowledge. But there are several other matters of study often neglected unless introduced under geology, which might and should receive greater attention. Mineralogy, including a recognition by sight or simple tests of the commoner minerals and rocks, exercises the same powers of observation and discrimination as botany, leads also to open air excursions, and gives a freer vent to that instinct for collecting, which finds much less scientific bent in stamp collecting. It is quite as practical as botany on the whole, and

Prof. Gregory of our force, who is also superintendent of schools at East Tawas, has found it is much more attractive to boys. One of the great problems in high schools is to keep the boys in school as long as their sisters. It is not normal nor desirable that the women should be better educated than the men. It is a matter of experience that mineralogy appeals to boys as botany does not. It seems to me that in our county reports or in special bulletins we should assist the local teachers in the local mineralogy. The collections made for them by the College of Mines to which I have referred will be of interest in this matter.

Another subject where the Survey can help the local teacher and should do still more in the future, is in the study of geography, especially physical geography. Between geography properly taught and geology there can be no sharp line. Both should be taught by beginning with facts of common experience to the school. That is to say, the scholars should begin with the map, the raw materials, the river, lakes and physical geography of their own neighborhood. In this study our county reports can be of material assistance, and such men as Messrs. Davis, Sherzer, Gordon, and Gregory, experienced and successful teachers, should be employed in teachers' institutes to inform others in the art which they have learned of making real and interesting the study of geography by the use of local facts.

OTHER SOCIETIES.

I have tried to keep the Michigan Academy of Science, the Michigan Engineering Society,[1] and the Lake Superior Mining Institute informed and interested in our work, as their membership forms the constituency who will most naturally appreciate our work, and brief papers have been presented before these bodies.

A scientific subject of most practical bearing is that of forestry. Not merely the question of keeping up a supply of lumber for those industries which are so weighty a part of the business life of the State is concerned. Room for the manly sport of hunting and fishing, and the preservation of pure sources of civic water supply and of constant water power are also concerned, and perhaps the whole question of climate as well. And in planning forest reserves it is essential that such geological studies as Livingston's and McLouth's, Taylor's and Leverett's, here presented should precede, in order to have intelligent action. The Geological Survey should co-operate and I personally made one trip about Roscommon with the State Land Commissioner and other interested parties and have always tried to give him prompt information. But the amount of work which ought to be done soon is far beyond our present means to co-operate. I would however earnestly recommend that no land belonging to the State either directly or to any one of its great schools be sold until it has been carefully examined, with due regard not merely to the surface but also to the depth of that surface and the general structure and water supply, and availability for farming or other uses.

[1] Which body passed a vote of thanks for what you have done toward topographic survey.

MINERAL STATISTICS.

I am still bothered more or less with applications for the report of the Commissioner of Mineral Statistics, the publication and distribution of which is about as unsatisfactory as it can be. It is curious with what unanimity people who are qualified to speak, condemn the present system, which still goes on apparently by sheer inertia. Whatever else is or is not done the publication and distribution of the reports should be in the hands of a permanent bureau with a fixed office. Hon. C. D. Lawton, State Regent, and the one who was the longest commissioner, the other commissioners, Pres. F. W. McNair, Hon. Chase S. Osborn and other similar men are on record, and I still believe that so far as statistics are concerned they could perfectly well be collected by the mining companies or county mine inspectors reporting to the Commissioner of Labor, who even now receives the report of the coal mine inspector.

Last May I received unsolicited from the gentleman, Mr. H. J. Stevens, to whom was sublet the job of preparing the last two reports, a telegram, collect, advising me to buy Mohawk for a 20 point rise.

Beyond laying the telegram before your Board I paid no further attention to the matter. In this case virtue was its own reward. A large number of others received a similar telegram at the same time, and if they bought their books probably still show a loss. I do not mean to say that Mohawk is not a very promising mine. But I quite agree with the recent Commissioner of Mineral Statistics, Mr. James Russell, that the report might well be left to private enterprise, if it is to be matter mainly for the speculator and stock broker.

It may be questioned whether the business of compiling the mineral statistics of the State should be confided[1] to any one whose principal occupation at the same time is journalism. A journalistic training may be very well for one to have had, but the combination at the time may easily lead on one hand to a loss of the scientific impartiality and accuracy proper to a State publication, or on the other hand may lead to undue weight being given to journalistic words and writings because of the position of the writer as State official.

U. S. GEOLOGICAL SURVEY.

The relations between the U. S. and the State Survey have been as cordial and mutually helpful as heretofore. I have prepared a brief report on coal,[2] the expense of which the U. S. Survey bore, and have acted as their agent in collecting well data. Mr. Robert E. Horton and I have been in consultation in collecting data regarding the water power of the State, and we have assisted in the distribution of enquiries regarding water power, wells, etc. Mr. Frank Leverett of the U. S. Survey has been almost constantly employed upon the surface geology of the State, and has been assisted by Mr. Nellist, Mr. Gregory and others of our staff as well as myself. His work in Alcona county for which the county has paid I have referred to elsewhere.

The necessary removal of our building in Houghton and the upset of any plans for field-work in the Upper Peninsula rendered available a sum of

[1] As it has been for the past eight years.
[2] Twenty-second annual Report, Part III, pp. 313 to 331.

money, which with your permission I employed in preparing, in accordance with a long cherished plan, a sample sheet of a topographic map such as the U. S. is prepared to execute in co-operation with the State. The advantages of such a map have been repeatedly urged,[1] and it seemed to me that by thus preparing a sample sheet where it would be of use to the great number of students at the University and Normal College, the growth of a general public sentiment which would appreciate such maps would be helped. It is obvious also that for all our geologic work, mapping soils, forests, rocks, borings, etc., a good topographic map is a prerequisite to accurate work and that if we can get the U. S. Survey to bear half of the expense of the same we are so much ahead.

Accordingly the subjoined contract with the U. S. Geological Survey was prepared[2] under the provisions of which the following work has been done and expenses incurred.

United States Geological Survey, Washington, D. C., December 31, 1901.

Dear Sir—Referring to my formal agreement with you for the execution of a co-operative topographic survey of a district in the vicinity of Ann Arbor, Michigan, by the terms of which agreement you contributed $2,000, provided that this Survey would expend an equal amount upon the same work, I have to make the following report:

Immediately following the signing of the agreement Mr. John H. Renshawe, geographer, in charge of the central section of topography, was authorized to begin the preparation of plans for field work. Mr. George T. Hawkins, topographer, began work on the horizontal control for the district on August 21 and continued until September 3, during which time he ran 116 miles of primary traverse, starting at the triangulation station of the U. S. Lake Survey at Tecumseh, tying with the astronomic position at Ann Arbor, thence to Detroit, where he connected with the primary position of the U. S. Lake Survey.

Mr. Robert Muldrow, topographer, was placed in charge of the topographic field work, which was commenced September 2 and was prosecuted without interruption until the end of November, during which time 292 miles of primary spirits levels were run, based upon the precise datum established by the U. S. Coast and Geodetic Survey at Gibraltar, and 110 square miles of topography were completed on a scale of 1 mile to the inch, with a contour interval of 20 feet. The topographic work completed lies in Tps. 1 to 3 S. inclusive, R. 6 E. The field work was necessarily slow on account of the complicated glacial forms in the vicinity of Ann Arbor.

From your contribution there has been expended in field work, as shown by the vouchers which have been sent you, $1,012.65, against which this Survey has expended from its own funds for the permanent salaries of Messrs. Hawkins and Muldrow, and for traveling expenses to and from the field, the amount of $601.41.

Field work will be resumed as soon as the weather will permit in the early spring, when the balance of your contribution will be expended and the work continued until the district is completed. It is expected that the work will be finished in the early fall and that the sheet will be published about a year from this time.

Very respectfully,
H. C. RIZER, Acting Director.

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[1] By the Michigan Academy, Engineering Society, Prof. Russell, and others:

SENATE OF THE UNITED STATES.
Committee on the District of Columbia.
Washington, D. C., February 18, 1901.

My Dear Sir—I have your letter of February 11, in regard to a topographic survey of the State of Michigan, the expense to be met partly by the State and the work to be done by the United States Geological Survey. As you surmise, I am familiar with the topographic maps issued according to such arrangements. They are valuable beyond any price that can be put upon them, and the State of Michigan more than almost any other state needs just such a map. The provision that the United States shall share in this expense is an unusually liberal one on the part of the general government, and in my judgment there should be no hesitation on the part of the State of Michigan to take advantage of it.

Yours very truly,
JAMES M. McMILLAN.

Prof. Alfred C. Lane, State Geologist, Lansing, Mich.

[2] Agreement between the State Geologist and the director of the United States Geological Survey for the execution of a co-operative topographic survey of one thirty-minute quadrangle in the State of Michigan:

1. The preparation of the map shall be under the supervision of the director of the United States Geological Survey, who shall determine the methods of survey and map construction.

2. The quadrangle to be surveyed under this agreement shall be that between latitude 40° and latitude 40°30′ and longitude 83°30′ and longitude 84°.

3. The work shall be based upon the triangulation of the United States Lake Survey, and

A very detailed map of the immediate neighborhood of Ann Arbor, may be issued separately.

In regard to the deep seated rocks, the same arrangement by which we have confined ourselves to the copper bearing rocks, and the workers under Van Hise to the iron bearing rocks has been continued. But as the U. S. Survey has nearly completed its work on the iron bearing rocks we ought to begin work on that district again. C. R. Van Hise in charge has just issued, as I have mentioned, an admirably clear resumé of his results and his theory of the origin of the iron ore deposits. The terms upon which the publications of the Survey are to be obtained vary, and enquiry should be made of the director of the U. S. Geological Survey at Washington, D. C.

In regard to the paleontological work, I trust that arrangements may be made so that for detailed correlation and study of parallel forms we may have the assistance of the U. S. Survey, so that descriptions of new species, and comparisons with fossils of other states and such matter of interest to science generally, may be given their wide circulation, and that type specimens may be on deposit in the National Museum, while we may have abundant duplicates for local use and distribution, and illustrations, and stratigraphic and other matter, peculiarly of State interest may also appear in our reports.

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wherever such primary control is deficient it shall be supplemented by the Co-operative Topographic Survey.

4. The survey shall be executed in a manner sufficiently elaborate to prepare a map upon a scale of 1:125,000, exhibiting the hydrography including the courses of the principal drains, hypsography and public culture including the location of farm houses and roads, and all town and county boundary lines and township and sections of land survey lines, as marked upon the ground at the time of its completion, in form similar to the sheets already completed in other states. The preliminary field maps shall be on such scale as the director of the United States Geological Survey may select to secure accuracy in the construction of the final map.

5. The hypsography shall be shown by contour lines with vertical intervals of 20 feet.

6. The heights of important points shall be determined and at least one permanent bench mark established in each township or equivalent area and a list of elevations and descriptions of them furnished to the Board of Geological Survey.

7. The outlines of wooded areas shall be represented upon proofs of the engraved map to be furnished the Board of Geological Survey.

8. For convenience the United States Geological Survey shall, during the progress of the field work, pay the salaries of the permanent employes engaged thereon, while, the traveling, subsistence and field expenses shall be paid for the same time by the State. For office work on the map the salaries shall be divided between the two agreeing parties in such a way as to equalize all expenses, provided that the total cost to the State of Michigan of the field and office work shall not be more than two thousand dollars ($2,000), except as may be hereafter agreed, and provided that the United States Geological Survey shall expend an equal amount upon the same work.

9. During the progress of the work free access to the field sheets and records of the topographers and draughtsmen shall be afforded the State Geologist or his representative for examination and criticism: and should the said State Geologist deem that the work is not being executed in a satisfactory manner, then he may, on formal notice, terminate this agreement.

10. The resulting map shall recognize the co-operation of the State Board of Geological Survey of Michigan.

11. When the work is completed, the Board of Geological Survey of the State of Michigan shall be furnished by the United States Geological Survey with photographic copies of the manuscript sheets; and when the engraving is completed, and at all times thereafter when desired, it shall be furnished by the said Survey with transfers from the copper plates of the map for use in printing editions of said maps.

12. Field parties shall expend their own money and take duplicate receipted vouchers. These to be examined and approved by the director of the United States Geological Survey, and those provided by section 8 to be forwarded to the State Geologist and paid by the Auditor General by draft upon Detroit. The director of the United States Geological Survey is to make a monthly statement of account to the State Geologist showing expenses by United States, as well as vouchers furnished to the State. Expenses by both sides to be finally balanced not later than September 1, 1902.

ALFRED C. LANE,
State Geologist.

Lansing, Mich., August, 1901.

C. D. WALCOTT,
Director of the U. S. Geological Survey.

Washington, D. C., August, 1901.

RECOMMENDATIONS.

DISTRIBUTION.

The bulletins of the Agricultural experiment station, and county newspapers within the county are distributed by the postoffice gratis, and also those of the U. S. Geological Survey. One can hardly see any reason for treating differently the publications of your Board. These have exactly the same object, the spreading of an intelligent appreciation of, and ability to develop properly, the natural resources. The franking privilege would not only relieve us of a burden distinctly felt in so small an appropriation but would very greatly simplify the work of sending out the reports, and correspondence covering the same, so that we should gain a good deal more than the postoffice department would lose in postage. I would therefore recommend that you urge upon your representatives in Congress the wisdom of extending the franking privilege to State Geological Surveys under substantially the same restrictions as apply to agricultural experiment station bulletins, which might perhaps be done by making the State Geologist an officer of the U. S. Survey.

FILING OF MINE MAPS.

During the year two coal mines at St. Charles have stopped operations, and the Pere Marquette No. 2 at Saginaw. There are two abandoned coal mines at Saginaw, and numerous ones in Corunna district, and at Jackson, Grand Ledge, and Williamston. It will be following a precedent set in other states, and be a protection to the interests of fee owners where coal is mined on a royalty (as it almost always is), and make the exploitations of the district adjacent to an abandoned mine in the future much safer, and will undoubtedly avoid a terrible accident some time, if all mines are compelled to file maps showing the area taken out, not too frequently, but always upon shutting down. Blueprints or photographs should be accepted, so that mine operators should be subject to no unreasonable expense. It has occurred that a mine operator was found to be operating outside his own lands, but I think that almost all of them would accept cordially legislation such as is here proposed, if not intended to be harassing in its nature.

TOPOGRAPHIC SURVEY.

It will not ordinarily be possible to spare from our annual appropriation even $2,000 for topographic work, but it would probably not take more than $3,000 to continue the work so as to cover Wayne county and the neighborhood of Detroit, which would serve the interests of a large population, and be of great and direct value to our work as a basis for Prof. Sherzer's work in Wayne county to which I shall in a moment refer. A sheet also to the west to include Jackson would also enable us to have a complete map of Washtenaw county. If possible I should recommend that a special appropriation for this purpose be provided.

WORK.

Upon the completion of Vol. VIII, and the Annual Report, some county reports should be ready for publication as Vol. IX. I should like to have a group of counties about Saginaw bay included. Until we are better caught up with the preparation and publication of reports on counties of which the field work is done, I doubt the wisdom of pushing county work much with this one exception, that Prof. Sherzer has returned and will be unusually able to take up field work the next few months. In connection with his very successful and valuable Monroe county report he has already done part of Wayne county. The sinking of the shaft of the Michigan Rock Salt Co. will give an unique opportunity, and it is time that we rounded up the numerous well records which we have collected along the Detroit river. Therefore I would recommend that Prof. Sherzer be employed to prepare a report on Wayne county similar to that which he has prepared on Monroe county.

Peat has excited considerable interest of late and I have had numerous inquiries regarding it. It seems to me that where we have so much bituminous coal it is not likely to be so important an industry as in Canada. But the resources of the State are very great, and especially in the Upper Peninsula, where there is a dearth of fuel, it might be that the use of peat which was tried years ago, would not only find a domestic market, but be the means of utilizing vast quantities of low grade ores. I would recommend that a report on peat be prepared.

The production of gypsum in the State is not keeping pace with that in other states, nor is it commensurate with the wealth of our natural materials. The industry is in a few hands which are perhaps not anxious to see it grow beyond their grasp. We have had an opportunity to have a report prepared by an exceptionally competent man, and I would like to see one undertaken if we can afford it.

We ought also to prepare a general geological map of the Upper Peninsula on such a scale as to show the sections and in corresponding geological detail. And we ought really also now to take up a general review of the iron country, filling up various gaps left by the U. S. Survey, adapting their work more closely to the property lines, putting it into more portable and economic shape, and extending the surveys of lines of magnetic variation and the study of the structure as far as they can be extended beneath the mantle of the Potsdam sandstone. But in order to do anything worth while in this direction we must have more money. My friend and classmate, Prof. Smyth, head of the Mining Department of Harvard University, would be an admirable man to take charge of this work for us, as he has already conducted important private geological surveys for some of the larger corporations and I think I could persuade him to do it, if there were enough money available to do anything worth while in any reasonable time.

I see no reason for large expenditure in gathering up, correlating and tieing the records of the recent surveys in the copper country. By another year, however, we ought to do much more work in the northern peninsula.

FINANCIAL.

Owing to the confusion existing in the Houghton office which is not yet plastered it is not possible to give as usual just the exact statistics of distribution of our reports. Of Vol. VI there are very few left. Of Vols. V and VII there is just a comfortable supply. The main demand in Vol. VII has been for the Monroe county report.

The expenses up to July 1 were as follows:

	Salary.	Field.	Office.	Total.
July	$634 87	$112 85	$57 82	$805 54
August	667 73	155 80	68 54	892 07
September	656 68	127 23	37 96	821 87
October	563 49	215 57	102 94	882 00
November	426 02	82 53	133 60	642 15
December	458 50	79 59	15 95	554 04
January	462 20	20 15	64 16	546 51
February	445 60	65 29	24 00	534 89
March	454 80	30 38	37 48	530 06
April	460 40	4 85	51 36	511 01
May	442 30	42 48	27 81	530 69
June	.....	32 18	114 06	588 54
Belated vouchers	.....	58 98	40 76	99 74
	.....	50 00	10 29	60 29
Total	$6,134 79	$1,077 88	$786 73	$7,999 40

Of our appropriation for the current fiscal year $4,338.57 has been spent, of which $1,012.65 has been spent through the U. S. Survey for the topographic survey about Ann Arbor. The balance of the year there will be little chance to do anything but regular routine work, getting out the annual report, Vol. VIII, part III on Marl and Cement materials, paying for our share of the work around Ann Arbor, and preparing the county report for the ordinary office and salary list cannot fall below $425 a month.

The appropriation for next year beginning July 1 may be divided as follows provisionally:

Fixed salaries and office expenses	$5,300	
Continuance of work—		
Report of borings	60	
Expenses on reports and sundries	250	
Co-operation in topographic survey	200	
Arenac county work continued	200	
Bay county work continued	320	
Tuscola county	300	
Field expenses of State Geologist	270	
Limestone work continued (Grabau)	200	
U. P. field work	300	
New work—		
Wayne county (Sherzer)	600	
		$8,000
Desirable but apparently not feasible—		
Peat	$200	
Gypsum report	550	
Co-operation in topographic survey	3,000	
Iron country surveys, not less than	4,784	
		$8,534

APPENDIX.

REPORTS OF C. H. GORDON ON THE PORT HURON OIL FIELD, AND THE EROSION OF THE SHORE NORTH OF PORT HURON.

THE PORT HURON OIL FIELD.

C. H. GORDON.

INTRODUCTION.

The special investigations upon which this report is based were made under the direction of State Geologist, A. C. Lane, during the summer of 1901. A considerable amount of data, however, relative to the stratigraphical relations of the region had been obtained by the author while prosecuting field work for the report on Sanilac county in 1896.

The presence of oil in rocks underlying Port Huron has been known many years but until recently it has not been obtained in sufficient quantity to be of commercial importance. The occurrence of oil in Western Canada was described in the reports of the Geological Survey of Canada nearly sixty years ago and "although at that time no use for the substance was known in Canada, except as a supposed remedy for rheumatism and for spavin for horses, Sir William Logan, the director of the Survey, with characteristic sagacity, foresaw that it might some day become of value in this country, as it had long ago proved to be in the East."[1]

In 1860, following the introduction into the province of illuminating oils distilled from coal and shale, interest in the subject was renewed and attention was again called to the existence of natural oil and "gum-beds" in the county of Lambton in the west and Gaspè in the east. In the winter of 1860 and 1861 several great flowing wells were struck at a place in Enniskillen township to which the name of Oil Springs was given. "The oil escaped so rapidly that many thousands of barrels were lost before it could be controlled, or the means provided for saving it." In these wells the oil was found in the upper part of the Corniferous limestone beds at a depth of 260 feet from the surface. As development went on some additional flowing wells were obtained but one by one they were all reduced to pumping wells and some gave out altogether.

The Oil Spring area is said, by Robert Bell, acting Director of the Canadian Geological Survey, to whom we are indebted for information concerning the Canadian field, to be of small extent. It lies between the village of the same name and the south line of Enniskillen township. The oil field of Petrolia begins a little to the southeast of the center of Enniskillen and extends in a west-northwesterly course parallel with that of Oil Springs nearly to the center of Sarnia township, a distance of twelve

[1] R. Bell, Transactions Royal Society, Canada, 1887.

or thirteen miles. It has a breadth of two to three miles, the center third being most productive.

Oil operations went on in this region with varying activity until 1886 when renewed impetus was given to the enterprise by the discovery of a third oil bearing area in Euphemia township parallel with the longer axes of the Petrolia and Oil Springs areas.

The interest excited by the Euphemia discovery led to the sinking of several wells at Port Huron in 1886 and 1887. Prior to this some wells had been put down along the river with the expectation of finding gas. While nearly all of these were successful in finding gas in the upper part of the Dundee limestone at about 500 feet from the surface the pressure was too weak to make them of commercial importance and none ever went beyond the "burning well" stage. In 1886, C. A. Bailey undertook a determined search for oil, putting down a number of wells. Well No. 1 was located 500 N., 1000 W., Sec. 9, T. 6 N., R. 17 E., and the two others are supposed to have been in close proximity to these. The records of these wells are published in Vol. V, Michigan Geological Reports. These records show that the oil rock (Dundee) was reached at 543, 545 and 572 feet respectively. A small amount of both oil and gas was obtained from these wells but the further attempt to develop the area was abandoned. The surface elevation of this locality is about 605 feet A. T. or 25 feet above the level of Lake Huron.

In 1887, F. L. Wells sunk a well to a depth of 1,685 feet stopping in the Salina formation. This well is located on the bank of Black River, opposite Kern's Brewery, about five feet above the level of the lake (585 A. T.). The oil formation (Dundee) was reached at a depth of 515 feet with "show of oil and gas."*

Following this period of activity, interest in the oil question subsided until 1898 when G. B. Stock, who had formerly operated in the Canadian field organized the Michigan Development Company and began operations on the Goodrich property in close proximity to the Bailey wells. The amount of oil obtained was considered sufficient to pay for operating and additional wells were sunk until now sixteen wells are scattered over that area, most of which are pumping. In addition to these wells, Mr. Stock put down several wells in other places north and west of Port Huron in the hopes of finding a greater supply of the fluid. His example has inspired other prospectors with the hope of successful ventures and several other attempts have been made though as yet with little success.

L. W. Holt representing outside capitalists began operations on the Sweitzer property about three miles north of the Stock wells, and a local company began on a well at Valley Center, thirty miles northwest of Port Huron during the winter of 1898 and 1899.

Sources of Oil.—The presence of oil in a formation depends rather upon the structure and attitude than upon the nature of the rocks. No geological horizon can be regarded as distinctively an oil horizon. In northwestern Ohio and Indiana the Trenton is the source of supply of the oil and gas of that region while in Pennsylvania, West Virginia, New York and Canada the Devonian is the great oil bearing horizon. In Texas, while both oil and gas are known to exist in the Carboniferous and in the Cretaceous, in a few localities of the latter only is there sufficient quantities to be of commercial value. Of these the Corsicana field is the

* See Vol. V and p. 254 of this report.

most important. In the Beaumont field where the richest oil strikes of the last quarter century have been made the oil is found in the middle of the Tertiary, probably in Miocene rocks. In California the oil comes from rocks ranging from Neocene to Miocene, and in Galicia (Austria-Hungary) the oil bearing rocks range in age from Cretaceous to Miocene. The Russian oil is obtained from Lower Miocene.

According to R. Bell[2] the anticlinal theory in connection with the accumulation of gas and petroleum originated with Dr. T. Sterry Hunt, who announced it in a lecture published in 1861. According to this theory these lighter fluids following the upward slopes of strata accumulate in largest quantity under the summit of the dome. Naturally the gas being lightest takes the highest place, the oil next while the water below presses hard upon them. When the summit of the dome is tapped gas, if present, will escape first followed by the oil then water. The more extensive the anticlinal as to breadth or depth the greater will be the accumulation of gas and oil and hence anticlinals of small extent are not likely to prove profitable sources of supply of these products. Other necessary conditions for the accumulation of oil are, (1) deeply seated petroleum bearing rocks of considerable volume, (2) a stratum of porous, fissured or channelled rock for storing the accumulated oil and (3) an impervious layer of argillaceous rock overlying the petroleum bed to prevent the escape of the oil.

It is obvious that the oil is not likely to be found at all points along the crest of an anticlinal but will be concentrated in the domes or elevations caused by secondary upheavals.

Origin of Petroleum.[3]—Much diversity of opinion exists among those who have written upon the origin of petroleum. Two principal views are held, the first being that it has arisen from chemical and physical changes in inorganic material and hence termed the *inorganic theory.* This view is advocated by Berthelot, Humboldt, Mendelejeff, Moquenne, Byasson, Cloez, Russ, Sololoff, Coquand, Grabowski, Hitchcock and others. The second is termed the *organic theory* and holds that the oil has arisen through the spontaneous distillation of animal and vegetable remains at low temperature, with or without pressure. This view is supported by such men as T. Sterry Hunt, Lesley, Orton, Dana, Leconte, Hoefer, Wall, Daubree, Ochsenius,[4] Newberry, Wall, Peckham, Credner, Warren, Storer, Engler, Zoloziecki, Sickenberger, Von Kobell, Watson, Smith, Von Buch, Bertels, Zincken, Paul, Tietze, C. Phillips, Redwood, White, Whitney, Binney, Hatchett, etc.

The inorganic origin of petroleum is receiving less and less support as the field of chemical investigation is extended while the weight of opinion inclines more and more to the view that this substance is derived from the decomposition of animal and vegetable remains. W. B. Phillips[5] in his recently published bulletin on Texas petroleum reports the results of an investigation tending to show the connection of diatoms with oil production and suggests that these low forms of life may have played an important part in the formation of oil deposits.[6]

[2] Petroleum Field of Ontario, Transaction Royal Society of Canada, Vol. V., p. 103.
[3] See Vol. V, Part II, introduction by L. L. Hubbard.
[4] Chemiker Zeitung, 1887, 11, No. 56; 1891, 15, No. 53.
[5] W. B. Phillips. Texas Petroleum, Bulletin University of Texas, 5.
[6] For fuller discussion of this subject see above Bulletin, also Vol. V, Michigan Geological Survey, Part II, p. xix.

GEOLOGICAL RELATIONS OF THE NORTHERN OIL FIELD.

Investigations have shown that the Ohio and Canadian gas and oil deposits occur on the course of the great Cincinnati anticlinal which extends northward from Kentucky through Ohio and western Ontario bearing north-northeastward, from about Point Pelee on Lake Erie, through the counties of Essex, Bothwell and Lambton. It reaches Lake Huron at about Kettle Point and continues under the lake parallel with the eastern shore to a point opposite Southampton, when, turning a little more to the northeast, it crosses the Indian peninsula parallel to another anticlinal that seems to run through Saginaw bay and the gap between the extremity of this peninsula and Grand Manitoulin island.[7] Prof. Edward Orton's investigations on the gas and oil discoveries in Ohio led him to the conclusion that the Trenton limestone received its low arched form along the Cincinnati anticline in that region before the succeeding formation was deposited upon it, while the stratigraphical relations in the Petrolia and Port Huron fields indicates either that a further upward movement took place after the formation of the Dundee limestone and before the deposition of the Traverse shales upon it, or that in this region there was an extensive coral island formation. It is quite possible that both of these agencies combined to give these beds the structure and attitude necessary to constitute them a reservoir for the petroleum originating in lower lying formations.

While the Cincinnati anticlinal is, in general, a gentle swell of great breadth there occur within its area many minor folds and undulations running both parallel with, and transverse to, the general direction of the main axis.

The investigations in western Ontario have shown the existence of a number of these minor transverse folds having two principal courses one about east and west and the other northwest. The fold in the Dundee, shown on Plate IX, at Port Huron is in direct line with the general trend of the undulations in the Enniskillen field and evidently constitutes a part of the same series, while seemingly another branching off from the main axis farther south passes through Mount Clemens.

THE CANADIAN OIL FIELD.

The obvious connection of the Port Huron field with the Lambton county oil area makes it desirable to preface a description of the former with a brief account of some of the wells adjoining Port Huron on the Canadian side.[8]

"The oil of Lambton county is, in the main, obtained from two distinct pools known as the Oil Springs and Petrolia fields, both in the township of Enniskillen. The larger of the two—the Petrolia field—with an approximate area of twenty-six square miles, extends west-northwest about nine miles and east-southeast about four miles from the village of Petrolia; while the Oil Springs field covers two square miles and includes the southeastern part of the village of Oil Springs. The pools are divided by a very distinct synclinal structure, the upper beds of the Hamilton

[7] R. Bell. Transaction Royal Society, Canada. Vol. V, p. 105.
[8] For this information we are indebted to H. P. H. Brummell's Report on Natural Gas and Petroleum in Ontario. Geological Survey of Canada, 1892.

"(Traverse)" being overlain by the black pyroschists of the Portage "(Antrim)" formation; these black shales have at Oil City, between Petrolia and Oil Springs a thickness of forty feet immediately beneath which is found the upper limestones of the Hamilton (Traverse) series.

"The black shale is absent at Petrolia and Oil Springs, the surface rock underneath the drift at both places being the upper limestone of the Traverse series. To the north of Petrolia the black Antrim shales again appear overlying the Traverse, at Wyoming, where they have a thickness of four feet and at Kingston's Mills, where they are fifty feet thick."

Petrolia.—A well sunk near the Imperial refinery at Petrolia and known as the "Test Well" as published by Mr. Brummell (Mr. E. Rawlings, driller) shows the following record:[9]

Test Well, Petrolia.—Elevation 667 feet A. T.

		Thickness.	Depth.	El. A. T.
Surface		104	104	563
Traverse	1. Limestone (upper)	40	144	523
	2. Shale	130	274	393
	3. Limestone (middle)	15	289	378
	4. Shale	43	332	335
Dundee	5. Limestone (lower)	68	400	267
	6. Limestone, soft	40	440	227
	7. Limestone, gray	160	600	67
Monroe	8. Limestone, hard, white with hard streaks of sandstone from two to five feet in thickness	500	1100	*433
	9. Gypsum	80	1180	*513
	10. Salt and shale	105	1285	*618
	11. Gypsum	80	1365	*698
	12. Salt and shale	140	1505	*838

* Below sea level.

No. 5 is regarded by the Canadian geologists as constituting the base of the Traverse (Hamilton) series and 6 and 7 the Corniferous.

As the upper portion of these limestones are known only as they appear in well sections in Eastern Michigan and Western Canada it is evident that the attempt to draw a dividing line between the two divisions within the limits of a limestone formation, as represented by 5, 6 and 7, meets with insurmountable difficulties. The Michigan geologists have, therefore, very properly abandoned the attempt at exact correlation of these limestones with the Corniferous and have given to them the local name of Dundee which is defined to include all limestone beds extending down from the shales represented in No. 4, the "lower soapstone" to the dolomite or gypsiferous shales of the next or Monroe formation. The division between Dundee and the overlying Hamilton beds, which are likewise given a local name—the Traverse, is one of the sharpest lines we have and can be easily recognized in well borings. The oil is found at a depth of from 45 to 135 feet below the top of No. 5, which here has an elevation of 335 feet A. T.

Sarnia.—The productive oil territory extends northwest from Petrolia into the southeastern corner of Sarnia township where a number of wells have been sunk, the records of which, however, are not available.

[9] Compare record of Vol. V, part II, p. 46, showing Dundee at 345 to 375 feet.

At Sarnia, which lies in line with the extension of the longer diameter of the Petrolia field, several wells have been sunk in which gas in small quantities was obtained but no oil. Following is a record of Dickens well located in the southern part of the town near the corner of Rose and Tecumseh streets.[10]

Dickens Well, Sarnia.—Elevation about 590 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface deposit. Sand and clay 130. Hard pan 55. Gravel 15	200	200	390
Traverse	2. Limestone	90	290	300
	3. Shale	100	390	200
	4. Limestone	5	395	195
	5. Shale	68	463	127
Dundee	6. Limestone	77	540	50

This well is remarkable in showing the absence of the Antrim shales which at Port Huron, just across the river, are 82 feet thick in Wells bore hole (No. 12 in Vol. V of the Michigan Reports) and thicken rapidly westward to 183 feet at the Junction well.

Evidently the Dickens well marks the location of an extensive pre-glacial channel possibly representing the ancient Huronian river. The top of the Dundee limestone has here an elevation of 127 feet thus showing a westward pitch of the fold of 208 feet between this point and Petrolia.

Another well at King's gristmill, drilled in 1875 by M. E. Rawlings, gave the following record:

King's Gristmill well, Sarnia.—Elevation 589 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface deposit. Sand 9. Blue clay 109. Hard pan 2.	120	120	469
Antrim	2. Shale, black	36	156	433
Traverse	3. Limestone	30	186	403
	4. Shale	263	449	140
	5. Limestone	5	454	135
	6. Shale	40	494	95
Dundee	7. Limestone	60	554	35
	8. Limestone, grey	100	654	*65
Monroe	9. Limestone, hard	546	1200	*611
	10. Limestone, hard and flinty	200	1400	*811
	11. Limestone with gypsum	105	1505	*916

* Below sea level.

[10] As given by Mr. Brummell (H. Mitchell, driller.)

Oil was not observed, but gas in small quantities was found at 400 feet and cased off.

This well is located about one and one-half or two miles north of the Dickens well and shows the presence of 36 feet of Antrim shales. The surface of the Dundee has an elevation of 95 feet or 32 feet lower than in the other well.

Courtwright.—A well at Courtwright, about 10 miles south of Sarnia, gave the following record as furnished by Mr. E. Rawlings, driller, and published by Mr. Brummell:

Courtwright well.—Elevation above tide 588 feet.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface sand and clay	132	132	456
	2. Hard pan	28	160	428
Antrim	3. Shale, black	32	192	396
Traverse	4. Limestone	40	232	356
	5. Shale and Limestone	310	542	46
Dundee	6. Limestone, white	50	592	*4
	7. Limestone, grey	100	692	*104
Monroe	8. Limestone, hard, white	370	1062	*474
	9. Sandstone†	32	1094	*506
	10. Limestone	400	1494	*906
	11. Limestone and gypsum	136	1630	*1042
	12. Salt	22	1652	*1064
	13. Gypsum	13	1665	*1077

* Below sea level.
† Probably dolomite (B). Sylvania (L).

In this well the top of the Dundee is found at 46 A. T. or 81 feet below its position at the Dickens well. It is evident that the fold passes through the south part of Sarnia, its summit being at or a little south of the corner of Rose and Tecumseh streets.

THE PORT HURON FIELD.

The only wells that have yielded oil in the Port Huron area are located on what is known as the Goodrich property in the western part of the city. They belong to the Michigan Development Company, of which Mr. G. B. Stock is the manager. Sixteen wells have been sunk, the larger part of which are pumped, yielding altogether about forty barrels a week. Those interested in the question are firm in the conviction that a larger pool exists somewhere in this region and are persistent in their attempts to locate it.

The Bailey and Stock wells are located near together and correspond closely in their records. The following, furnished by Mr. G. B. Stock, is a typical record of the wells in the Goodrich field:

The Stock wells.—Port Huron.

Location, S. ½, N. W. ¼, Sec. 9, T. 6 N., R. 17. Elevation 605 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Blue clay	100	100	505
Antrim	2. Black shale	87	187	418
Traverse	3. Limestone (top)	43	230	375
	4. Soapstone, soft	70	300	305
	5. Limestone (middle)	15	315	290
	6. Slate or shale, dark	85	400	205
	7. Soapstone	120	520	185
Dundee	8. Limestone, sandy	47	567	38
	9. Limestone	33	600	05

The limestone No. 8 is the oil bearing stratum. The surface of the Dundee here has an elevation of 85 feet A. T. From this point the beds slope toward the northeast and to the west and south. Toward the south and west the slope is apparently pronounced, as shown by the following wells which are evidently located on the southwestern limb of the anticline.

Bailey well No. 1.—Port Huron.

Location 500 N., 1000 W., Sec. 9, T. 6 N., R. 17. About ½ mile southwest of the Stock wells. Elevation about 605 A. T.

(Plate 48, Vol. 5, Mich. Geol. Survey.)

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface	100	100	505
Antrim	2. Black shale	100	200	405
Traverse	3. Streak hard argillaceous limestone with Fes...	2	202	403
	4. Soapstone (argillaceous marl)	15	217	388
	5. Limestone (top) blow of odorless gas at 280	80	297	308
	6. Soapstone (argillaceous marl)	147	444	161
	7. Limestone (middle)	9	453	152
	8. Soapstone with streaks of limestone at 518 and 525	90	543	62
Dundee	9. Limestone (lower)	125	668	*63

* Below sea level.

Grand Trunk Junction well.—Port Huron.

Location at Grand Trunk Junction, near the N. E. corner, Sec. 18, T. 6 N., R. 17 E. Elevation 618 feet A. T.

(Plate 54, Vol. 5, Mich. Geol. Survey.)

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface	124	124	494
Antrim	2. Black shale, small amount of gas at 300	183	307	311
Traverse	3. Limestone (top)	128	435	183
	4. Soapstone	77	512	106
	5. Limestone (middle)	8	520	98
	6. Soapstone	105	625	*7
Dundee	7. Limestone (lower)	147	772	*154

* Below sea level.

Black water was encountered at 680-685 and salt water at bottom. A show of oil appeared at 710.

Marysville well.

Location four miles south of Port Huron, on the Bunch farm, put down by Church & Co. Elevation about 600 feet A. T.

(Plate 40, Vol. 5, Mich. Geol. Survey.)

		Thickness.	Depth.	El. A. T.
Glacial	1. Clay	107	107	493
	2. Gravel (dry)	3	110	490
Antrim	3. Dark blue shale, streaks of black	188	298	302
Traverse	4. Gray limestone	97	398	205
	5. Argillaceous marl thinly laminated and fissile.	193	588	12
Dundee	6. Sandy limestone, porous, indications of gas	37	625	*25
	7. Limestone, grey	390	1015	*415
Monroe	8. Limestone, sandy	80	1095	*495
	9. Limestone, dark grey, hard in places	55	1150	*550

* Below sea level.

Salt water was encountered in No. 7 at 745 and mineral water at 817, 970 and 985. The upper part of these limestones probably belongs to the Dundee.

About ¾ of a mile southeast of Wadham's station, on the farm of Mr. Fair near the railroad track, a well was sunk by Mr. G. B. Stock who furnished the following record:

The Fair well.—Wadham's Station.

Location S. E. ¼, Sec. 2, T. 6 N., R. 16 E. Elevation about 655 feet A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface gravel	4	4	651
	2. Blue clay	110	114	541
Antrim	3. Black shale	122	236	419
Traverse	4. Limestone (top)	230	466	189
	5. Soapstone	105	271	84
	6. Limestone (middle)	45	616	39
	7. Soapstone	95	711	*56
Dundee	8. Limestone (lower)	122	833	*178

* Below sea level.

No gas or oil was found in this well.

A well sunk by Mr. G. B. Stock on the farm of F. A. Beard, ten miles northwest of Port Huron, gave a heavy flow of mineral water at 140 feet, another of brine at 587 feet with a slight show of oil at 813. The record of this well, which is located in the valley of Black river at the mouth of Mill creek, was furnished by Mr. Stock.

Beard's well.—Abbottsford.

Location near S. E. Cor. Sec. 8, T. 7 N., R. 16 E. Elevation about 655 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Marly clay	30	30	625
	2. Tough blue clay	86	116	539
	3. Wash gravel	22	138	517
Antrim	4. Black shale	100	238	417
Traverse	5. Limestone (top)	217	455	200
	6. Soapstone	122	577	78
	7. Limestone (middle)	4	581	74
	8. Soapstone	156	737	*82
Dundee	9. Limestone (lower)	96	833	*178

* Below sea level.

A heavy flow of water of excellent quality which came out with considerable force when first struck was found in gravel (No. 3) at the base of the surface formation. This well was still flowing in considerable volume at the time of our visit. Instead of coming up the pipe the water had forced its way up outside and had made a considerable opening all around the pipe. Bubbles of gas were constantly given off by the water as it boiled up from below. The "top limestone" shows unusual thickness in this well and in the Shaw well hereafter described.

The westward descent of the Dundee is well shown here, the surface lying at 82 feet below the sea level while at the Stock wells in Port Huron it is 85 above, a difference of 167 feet. At the Fair well there is a descent of 141 feet, at the Junction well 92 feet, while at Marysville it

is 73 feet. At the Bailey well (No. 1) the surface of the Dundee is 23 feet lower than at the location of the Stock wells though the distance between them cannot exceed one-half mile.

Westward from Beard's well the inclination of the beds evidently continues as shown by the well put down at Valley Centre, in Sanilac county, which stopped in "top limestone" at a depth of 876 feet. This well was put down by a local stock company of which David Murray is manager. The record was furnished by Mr. Lewis Hydorn who assisted in the drilling:

Valley Centre well.

Location S. E. ¼, N. E. ¼, Sec. 27, T. 9 N., R. 13 E. Elevation 805 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Red sand and loam	5	5	800
	2. Quicksand	90	95	710
	3. Clay	22	117	688
	4. Sand and gravel with plenty of pure water	32	149	656
Marshall	5. Sandstone	5	154	651
	6. "Conglomerate"	20	174	631
	7. Sandstone	30	204	601
Coldwater	8. Slate (blue shale)	10	214	591
	9. Soapstone	175	389	416
	10. Slate	150	539	266
Berea	11. Limestone	10	549	256
	12. Sandstone	20	569	236
Antrim	13. Shale changing to soapstone below	272	841	*36
Traverse	14. Limestone	35	876	*71

* Below sea level.

The formations 5, 6, 7 here indicated as belonging to the Marshall group may be the equivalent of the Richmondville sandstone within the Coldwater series. Assuming a thickness of 400 feet for the Traverse here, it is evident the Dundee would be found at a depth of about 1241 feet or 436 feet below sea level. From this it appears that the descent of the Dundee limestone between Port Huron and Beard's is about 16½ feet per mile, while between Port Huron and Valley Centre the top of the Traverse shows a westward descent of 15 feet per mile, a reasonably close correspondence.

Turning now to the wells northeast of the Stock area we find a descent of the beds in that direction, though not so marked, indicating that the few wells put down here are near the broad summit of the anticline.

A well was put down by F. L. Wells some years ago, the record of which was published in Volume V of the Michigan Geological survey. This well is located about a mile east (and a little north) of the Stock wells on the bank of Black river a short distance above Seventh street bridge.

Well's Bore Hole.—Port Huron.

Location, bank of Black river opposite Kern's Brewery.* Elevation 585 A. T.

(No. 12, Plate 57, Vol. V.)

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface, mostly clay	102	102	483
Antrim	2. Black slate and shale	83	185	400
Traverse	3. Limestone (top)	105	290	295
	4. Soapstone with seams of limestones	225	515	70
	5. Limestone (middle)	.....	.....	.....
	6. Soapstone	.....	.....	.....
Dundee	7. Limestone (lower) cherty at top with show of oil and gas	133	648	*63
Monroe	8. Dolomitic limestone with indications of salt and gypsum	68	716	*131
	9. Marl and marly limestone	54	770	*185
	10. Hard dolomitic limestone	75	845	*260
	11. Bluish black marl with gypsum	58	903	*318
	12. Hard dolomitic limestone with show of brine and oil	42	945	*360
	13. Argillaceous marl with streaks of dolomitic limestone and gypsum	205	1150	*565
	14. Hard gray calcareous sandstone. (Oriskany?)	95	1245	*660
	15. Bluish black argillaceous marl	10	1255	*670
	16. Dolomite and gypsum	300	1555	*970
	17. Alternating beds of salt limestone and shale	130	1685	*1100

*Below sea level.

At the top of the Traverse was found a thin bed of shale overlain by a streak of hard argillaceous limestone containing FeS_2.

At the time of our visit a well had just been completed on the Sweitzer property about a mile and a half north of the Stock wells, by L. W. Holt for a stock company. The record of this well as furnished by Mr. Holt follows:

Sweitzer well.—Port Huron.

Location S. W. ¼, Sec. 33, T. 7 N., R. 17 E. Altitude about 610 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Soil and sand	5	5	605
	2. Clay	100	105	505
	3. Hard pan and marl	15	120	490
Antrim	4. Black shale	100	220	390
Traverse	5. Limestone, white with thin strata of soapstone	60	280	330
	6. Soapstone	278	558	52
Dundee	7. Limestone (lower)	62	620	*20

* Below sea level.

There was a show of oil at 558. The well was shot at 568 and a small amount of oil obtained. Another well (No. 2) was in progress a short distance from No. 1. This well, as also the Wells boring, reaches the Dundee at a slightly lower level than the Stock wells but all are evidently not far from the crest line of the fold.

* Where wells have been put down for water.

A little more than four miles north of Sweitzer's on the farm of Mr. Shaw, a boring was made by G. B. Stock who furnished the following record:

Shaw well.—Fort Gratiot township.

Location S. E. ¼, Sec. 8, T. 7 N., R. 17 E. Altitude about 600 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Sand and gravel	5	5	595
	2. Purple clay or mud	30	35	565
	3. Gravel	3	38	562
	4. Blue clay	79	117	483
Antrim	5. Black shale	45	162	438
Traverse	6. Limestone	203	365	235
	7. Soapstone	95	460	140
	8. Limestone (middle)	15	475	125
	9. Soapstone	65	540	90
Dundee	10. Limestone (lower)	115	655	*55

* Below sea level.

This record shows an unusual thickness of the "upper limestone" (No. 6) while the soapstone is proportionately decreased in thickness. A showing of oil was claimed to appear here at 557 but no effort was made to develop it further and the well was abandoned.

Northward from this point the beds descend and other rocks appear overlying the black shale. At Papst's well three miles south of Lexington there are 252 feet of shales including a thin bed of limestone above the black Antrim shale. The record of this well furnished by the driller is of doubtful utility for purposes of correlation, and is not given here.

The accompanying map (not printed, open to the inspection of those interested. L.) shows the configuration of the surface of the Dundee limestone as nearly as it can be determined from the data available. From this it will be seen that the crest of the fold is marked by a line passing northwestward through the southern and western portions of Port Huron then veering northward. The fold plunges steadily in the direction of its course while to the westward it is bordered by a synclinal trough which likewise descends to the north and west. The wells at Mt. Clemens and New Baltimore[11] show another fold coming in from the southeast.

While the information derived from additional well borings will undoubtedly call for modifications of this map in details it is believed that in its essential features the surface of the Dundee limestone will be found as here represented. If correctly represented it is evident that oil must be sought along the crest of the Port Huron fold.

As the fold plunges to the northwest the tendency of the oil would be to seek the highest points and hence would follow the rock toward the southeast unless intercepted by transverse depressions. Thus far no indications of "pools" have been found.

[11] See pp. 221 to 223.

The following paper on the erosion of the shore just north of Port Huron which was taken up by Dr. Gordon incidental to his work on the Port Huron oil field, has interest in a number of ways. In the first place the actual commercial loss of land is not inconsiderable. Much of the fine clay, however, is doubtless swept down the Saint Clair river and reappears in the gain of the Saint Clair flats. Again we have interesting data to be applied elsewhere upon the possibilities of erosion of the till. While the effect of the rise and fall of the lake level is very marked in hastening or retarding erosion, in the period used the lake level was about the same at the beginning and at the ending. It will be noticed that the rate of erosion found is in harmony with that found in the Huron county, so that the estimates as to the length of time that erosion has been taking place at or near the present level will not need to be materially modified. It is, however, quite likely that when the bluffs were thickly wooded the trees, as they were undermined and slid down, would greatly protect the bank from erosion. This is indicated by the greater erosion during the later period.

WAVE CUTTING ON WEST SHORE OF LAKE HURON, SANILAC COUNTY, MICHIGAN.

BY C. H. GORDON.

At various places along the shore in Sanilac and Huron counties the encroachment of the lake upon the land is proceeding at an appreciable rate. In Sanilac county there are a number of reaches where the water breaks fairly against a bank twenty to twenty-five feet high, composed of boulder clay overlain occasionally by the stratified sand and gravel of abandoned beaches. As some of these localities indicate that shore destruction has gone on practically unhindered by artificial means since the settlement of the region it was suggested by State Geologist, A. C. Lane, that a study of a typical locality might afford data from which a quantitative estimate of the encroachment of the lake in recent times could be derived.

LOCALITY.

Accordingly during the summer of 1901 a site was selected 3½ miles south of Lexington which seemed to offer especially favorable opportunities for this investigation. The shore here forms the eastern boundary of the Haywood estate (Figures 5 and 7) comprising the S. ½ of the S. ½ of section 18 and the N. ½ of the N. ½ of section 19, T. 10 N., R. 17 E., where it was evident no effort had been made by cribbing to prevent the cutting away of the land. At this point the direction of the shore line is S. 17° E. with a slight bend to the west. The vertical escarpment is about twenty feet high composed wholly of glacial till. At the southeastern corner (G on Fig. 5) sand and gravel appear over the clay thickening toward the south as the shore line cuts diagonally across the old beach to which it belongs. Behind this beach line a small ravine or dry run comes in from the south while another intersects the bluff 40 rods north of the south boundary line. The land has been cleared and under cultivation for many years.

A distinct impression of recency in lake encroachment is gained by observing in places plow furrows cutting straight out to and across the edge of the bluff. At one point three distinct stages of cultivation were noted. First the oldest plow furrows at right angles to the bank extending clear out to the edge, the corresponding north-south furrow having been removed by the waves. Second, outermost furrows parallel with the cliff and within six feet of the edge, a position it would be impossible to reach by the plow at the present time. Third and last, with the outermost furrow about ten feet from the edge. These stages are all clearly defined and indicate a distinct encroachment of the lake between each

period of cultivation. Opposite the north boundary of this estate at E, Mr. Papst, who owns the property on the north, has placed a crib of logs which has checked shore wash here and inaugurated a stage of land building.

The Shore Line.—The shore line at this point belongs to the type designated by Lane in the Huron county report[1] as the cliff and shingle type. In this case the cliff, with vertical inclination about 20 feet high, is composed of boulder clay. Farther south the shore line intersects an old beach, the Algonquin, the top of which is 20 to 25 feet above the present lake level. This is one of the most pronounced beaches of the series described in the Huron and Sanilac county reports. South from this point it appears as a well developed ridge or belt of sand and gravel. Northward in Sanilac county it appears only in isolated stretches having for the most part been cut away by the encroachment of the lake. Plate XV represents the beach cliff at a point about one-fourth mile south of the Haywood estate. At this point the stratified beach deposits rest upon the boulder clay which to the north constitute the whole cliff section. The plane of contact between the beach deposits and the underlying clay is marked by pieces of coniferous wood in the form of logs and stumps of various sizes. One of these is seen projecting from the bank to the right of the hat in the left foreground of the picture. About a hundred yards south of the place where this view was obtained the surface of the clay descends to near lake level and logs and stumps of considerable size, evidently washed out of the bank, strew the shore.

Stratification of Clay.—Owing to the recent removal of material the face of the cliff is remarkably fresh and offers excellent opportunity to study the character of the deposit. Exclusive of the 18 inch soil horizon on top, there are three well marked divisions in the clay all characterized by more or less clearly marked stratification planes. Following is the section taken here:

		Feet.	In.
1.	Soil—top loam	1	6
2.	Light colored, or drab sandy clay. Rather obscurely but evenly and regularly stratified: pebbles mostly of small size	9	0
	(a) Between this and the underlying clay is a brownish band, in places consisting of yellowish sand, filling irregular depressions in the lower clay. This apparently represents a soil horizon. Thickness	.6 in. to 1 ft.	
3.	Blue clay, darker and more compact than No. 2. The stratification is well marked and fairly regular. It is well shown in Plate XII. The contact between this and the overlying division is marked by a more or less clearly defined unconformity. The clay is distinctly jointed and contains more numerous and larger pebbles, many of which are distinctly striated. Thickness	7	0
4.	Below No. 3 there is exposed four feet of darker blue and still more compact clay, stratified, the layers being decidedly contorted. It is separated from No. 3 by a well marked seam or crack but shows no appearance of a soil horizon. The surface of this lower clay bed is irregular but the layers of		

[1] Lane, A. C.—Geological Report on Huron County, Michigan.—Geological Survey of Michigan, Vol. VII, p. 40.

	Feet.	In.
the overlying bed fit conformably into the depressions. The boulders in this bed are prevailingly of dark crystalline rock and are, for the most part, subangular in outline and often planed and striated. Thickness exposed.....	4	0

The three divisions, 2, 3 and 4, are clearly marked and for the most part can be readily recognized in Plates XI to XIII. They undoubtedly mark three distinct stages in the advance of the ice sheet. The compact contorted condition of the lowermost division shows the effect of the overriding of the ice in its next forward movement. In No. 3 the effect is much less, indicating that the movement was much less pronounced.

FIRST SURVEY.

The land survey notes on file at the county court house, Sanilac Center, show that the original survey was made by Lewis Lyon, deputy surveyor in 1823. Following is a transcript of the field notes of the meander of the east boundary of sections 18 and 19, T. 9 N., R. 17 E., beginning at point where north line of section 18 intersects the lake:

Direction.	Distance chains.	Remarks.
S 16 E	41.00	At 39.50 a stream 25 links wide enters from N. W.
S 10 W	3.50	
S 17 E	11.00	
S 14 E	12.50	
S 33 E	3.00	
S 22 E	5.50	
S 18 E	4.50	
S 2 E	2.90	To corner of fractions 18 and 19.
S 27 E	3.50	
S 13 E	12.00	
S 26 E	15.00	
S 40 E	5.00	
S 15 E	12.00	
S 30 E	8.00	
S 13 E	9.00	
S 12½ E	20.97	To fract. corner of 19 and 30.

Starting from the northwest corner of section 18 the distance to the lake, according to the Lyon's survey, was 24.50 chains. From the southwest corner of section 18 on line between 18 and 19, the distance to the lake was, according to same survey, 46 chains, and along the south line of section 19 it was 73.70. The meander of the shore according to these measurements is shown on the accompanying map.

RESURVEY.

To obtain exact data for an estimate of rate of shore cutting a survey was made by us with the assistance of county surveyor, Thomas Nicol, with the following results:

Starting from the southwest corner of section 18 the distance to the

lake (A B) was found to be 38.60 chains instead of 46 as shown by the survey of 1823. In Lyon's field notes, a hemlock 26 inches through occurred at 15.95 chains from corner. The stump of this tree was found by us at 15.90.

One-fourth mile north along quarter section line bounding the Haywood property on the north (D E) the distance to the lake measures 33.71 chains while that on the south (F G) in like manner measures 46.76 chains.

Starting from the point where the north quarter section line meets the lake the meander of the shore line for the half mile bounding the Haywood farm is as follows:

Direction.	Distance chains.	Remarks.
S 2 W	2.73	
S 12 E	6.85	At 1.76 a small run.
S 17 E	2.28	
S 22 E	3.87	
S 17 E	16.62	To elm tree. A small ravine enters from west at 7.
S 24 E	9.85	Stake set. Bluff 30 links east. Ravine 9 links west. Small stream enters lake from south at 7.85.

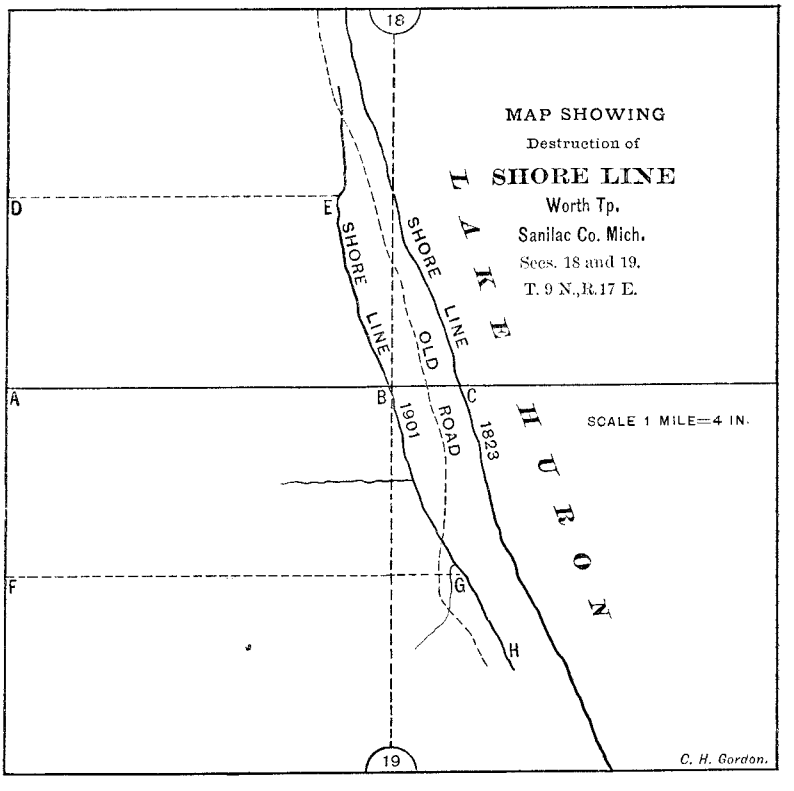


Fig. 5. Sketch map showing the advance of lake Huron, in Worth township, Sanilac county, Mich., at an average rate of 5.7 feet per annum.

The estate of Clark Haywood of Cleveland owns the south part of the south part of Sec. 18 and the north part of the north part of Sec. 19.

RATE OF WASTE.

The shore according to this 1901 survey is shown on the map, Fig. 5, in connection with that of 1823. According to the original survey the Haywood estate contained 184.90 acres and this is the size of the farm as indicated on the county maps. The new survey shows an area of 157.65 acres. It appears therefore that 27.25 acres of land have been removed by the lake in the 79 years intervening since the first survey, or an average of .345 acres per annum. The total average recession of the shore line within the area under consideration is 6.81 chains or 449.46 feet an average recession of 5.7 feet per annum.[2]

Old Government Road.—According to Mr. R. Papst, the old government road from Port Huron to Port Austin followed the lake shore here at a distance of several rods. Well marked traces of this old road can be found on Mr. Papst's farm. This road can be traced to where it crosses the edge of the bank 40 rods north of the north boundary of the Haywood estate and again on the south where it appears following the strand line. Near this point it is said that an orchard existed on the side toward the lake but its site has now entirely disappeared. On the Haywood estate the road lay entirely outside the present shore line as indicated on the accompanying chart.

Material removed.—The cubical contents of the portion of land removed equals the volume of a block 2,640 feet by 449.46 feet by 20 feet, in which the average height of the missing portion is taken to be the same as that of the present bank, a conclusion warranted by the appearance of the ground slopes. This yields 878,944 cubic yards of earth, an amount sufficient to cover an area of 545 acres to a depth of one foot, or an average of 6.9 acres per annum. According to the United States survey charts the area of Lake Huron is 22,322 square miles and the average depth of water about 200 feet. The length of coast line is about 500 miles. Assuming a uniform rate of cutting and filling, corresponding to that found above, it would take about 4,000 years to cover the bottom of the lake to an average depth of one foot or about 800,000 years to complete the filling of the lake. But the rate of cutting here is probably a maximum or at least more than the average and hence, on this assumption, a still longer time of stable conditions would be necessary to bring about the complete filling of the lake. The changes going on in the lake region make it evident that long before that stage is reached the lake will have lost its waters possibly in part through the reopening of drainage down the Illinois valley.

OTHER HISTORICAL DATA.

Old residents at Lexington remember when wave cutting was proceeding along the village shore at a rate approximating nearly a rod per year. The greatest cutting took place during the years of high water, in 1870 and '71 and in 1885 and '86. In the former years the lake was

[2] An estimate by planimeter and scale from the field sheets of the Lake Survey (photographed in Fig. 6) shows that at the time of that survey, August and September, 1859, the south line of Sec. 18 was about 44 chains long, the old road referred to below being shown as continuous on the map. The area of the Haywood estate was then about 176 acres. This implies a waste of 9 acres or 4.18 feet per annum in the 36 years from 1823 to 1859, and about 18 acres or 7.2 feet per annum in the 47 years since from 1859 to 1902, the greater rate of erosion in the later interval, being I suspect due to the removal of the forest protection L.

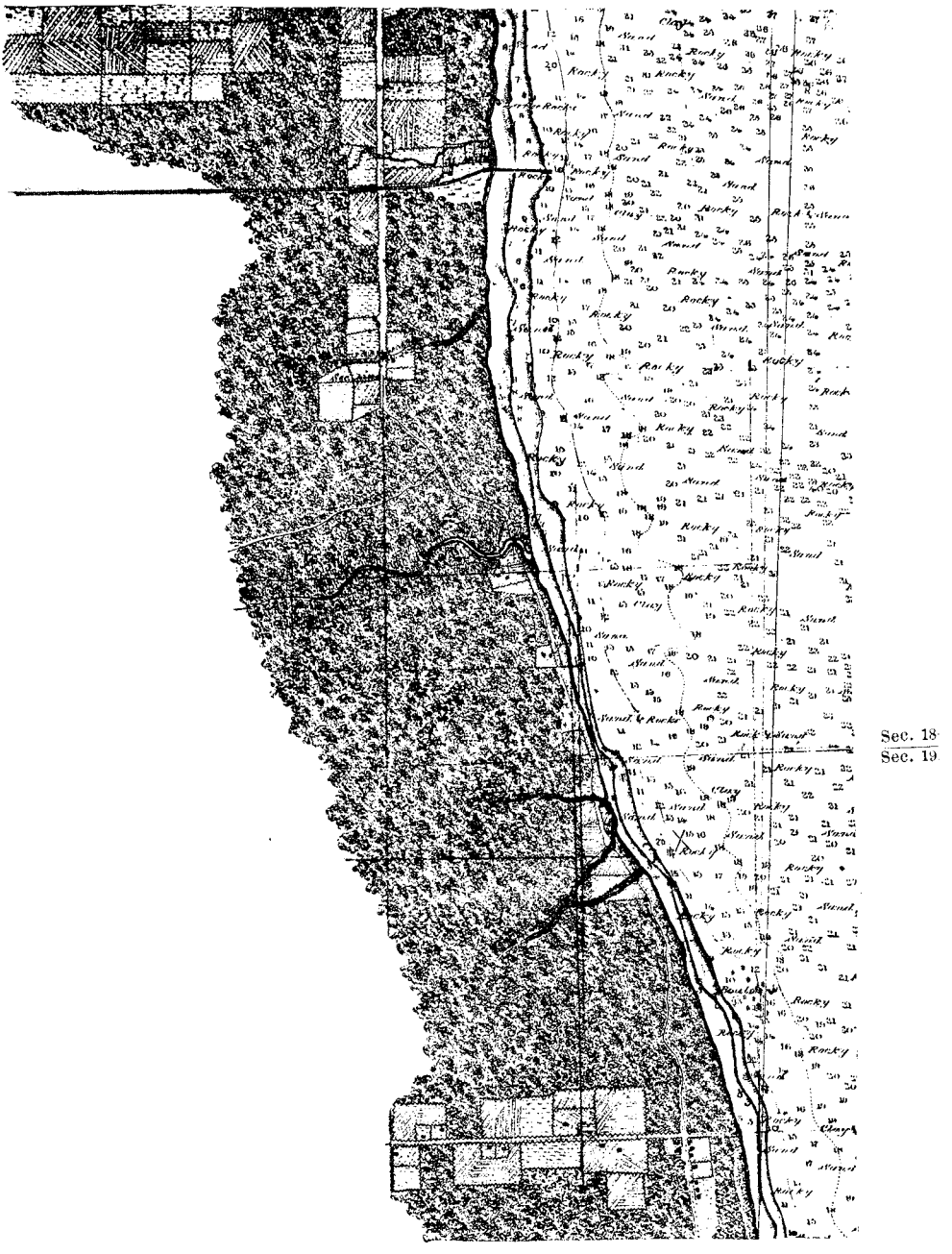


Fig. 6. Photograph from the original sheet (from which the map of Fig. 7 was made), showing the shore in Sections 18 and 19 at the date 1858.

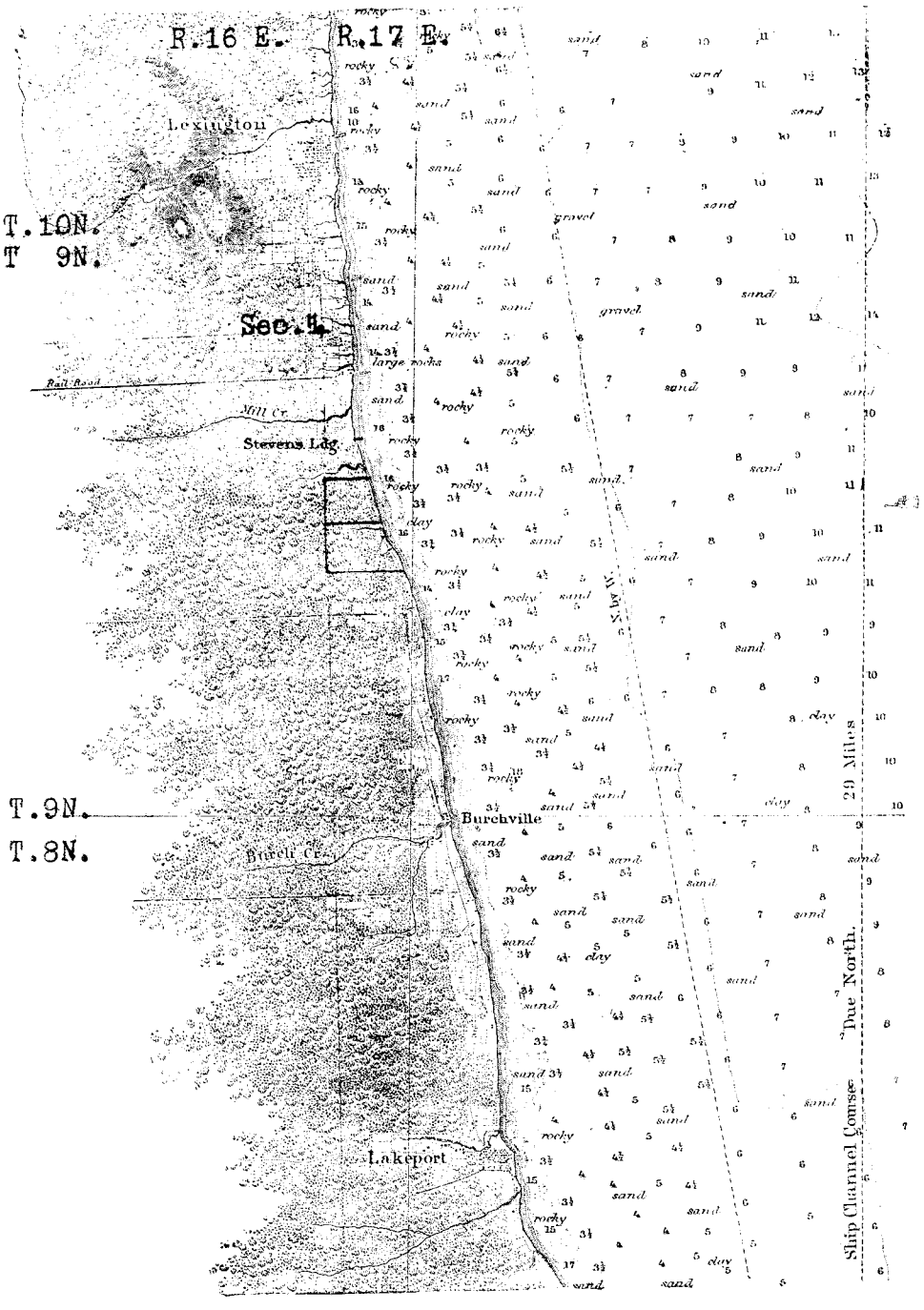


Fig. 7. Extracts from the Lake Survey map of the south end of Lake Huron, showing the location of the maps, Figures 5 and 6.

undercutting the bank south of the mill at the foot of Huron avenue. The most extensive cutting took place opposite the Lucia property just outside the village limits on the south. It is related that during[3] the years of high water, twenty years ago, a coal barge was driven ashore opposite the latter place in such fashion that the nose of the vessel was squarely against the bank with bowsprit extending out over the land. The position where the boat lay is now dry land. Of late years accretion has been going on at a rate of 10 to 30 feet per year. The amount thus gained at the foot of Huron avenue is 244 feet.

Previous to 30 years ago cutting was quite general all along the shore but since that date it has been to a considerable degree checked wherever cribs have been put in.[4]

[3] We are indebted to Judge Beach and R. Papst for the data referring to conditions in former years.
[4] The changes just north of Port Huron have been subject matter for a complicated law suit, the decision upon which we do not yet know.

ILLUSTRATIONS.

PLATE XI.

Clay Cliff and Shingle Shore line.
View looking south from north line of Haywood estate. The threefold character of the section can be recognized. The soil horizon separating the upper and middle divisions can be readily distinguished.

PLATE XII.

View looking north in same locality. The stratification planes in the middle division are plainly shown.

PLATE XIII.

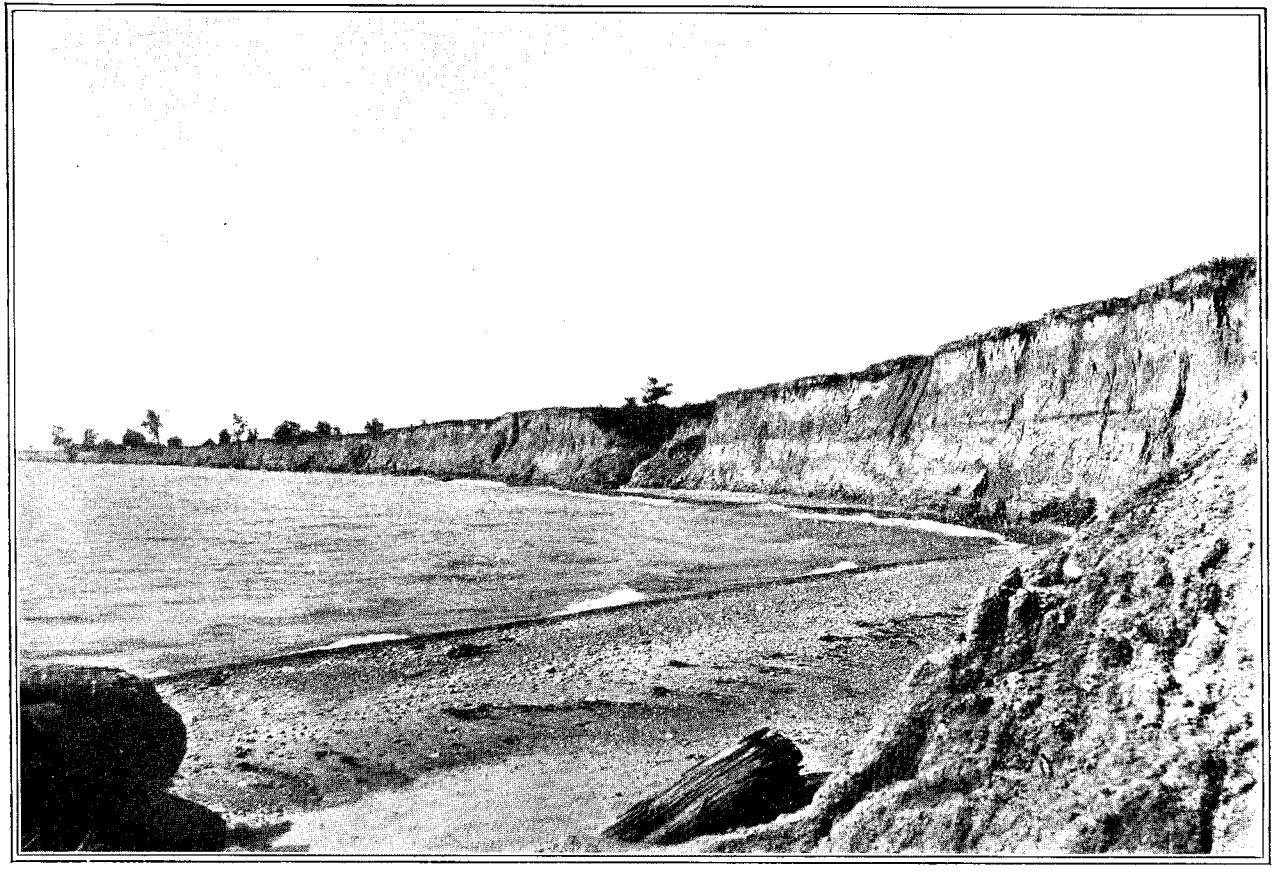
A Cave In. The tumbled masses in the foreground are blocks of clay fallen from the cliff in the time intervening between two visits to the locality. With the coming of a storm the waves will dash upon the shore and soon reduce these masses to a pulverized condition, dropping the boulders and pebbles upon the beach and carrying the finer material away to settle in deep water beyond the action of the waves. Through undercutting by the lake the tree has been thrown from its perpendicular attitude but with noble persistence has sought to regain it.

PLATE XIV.

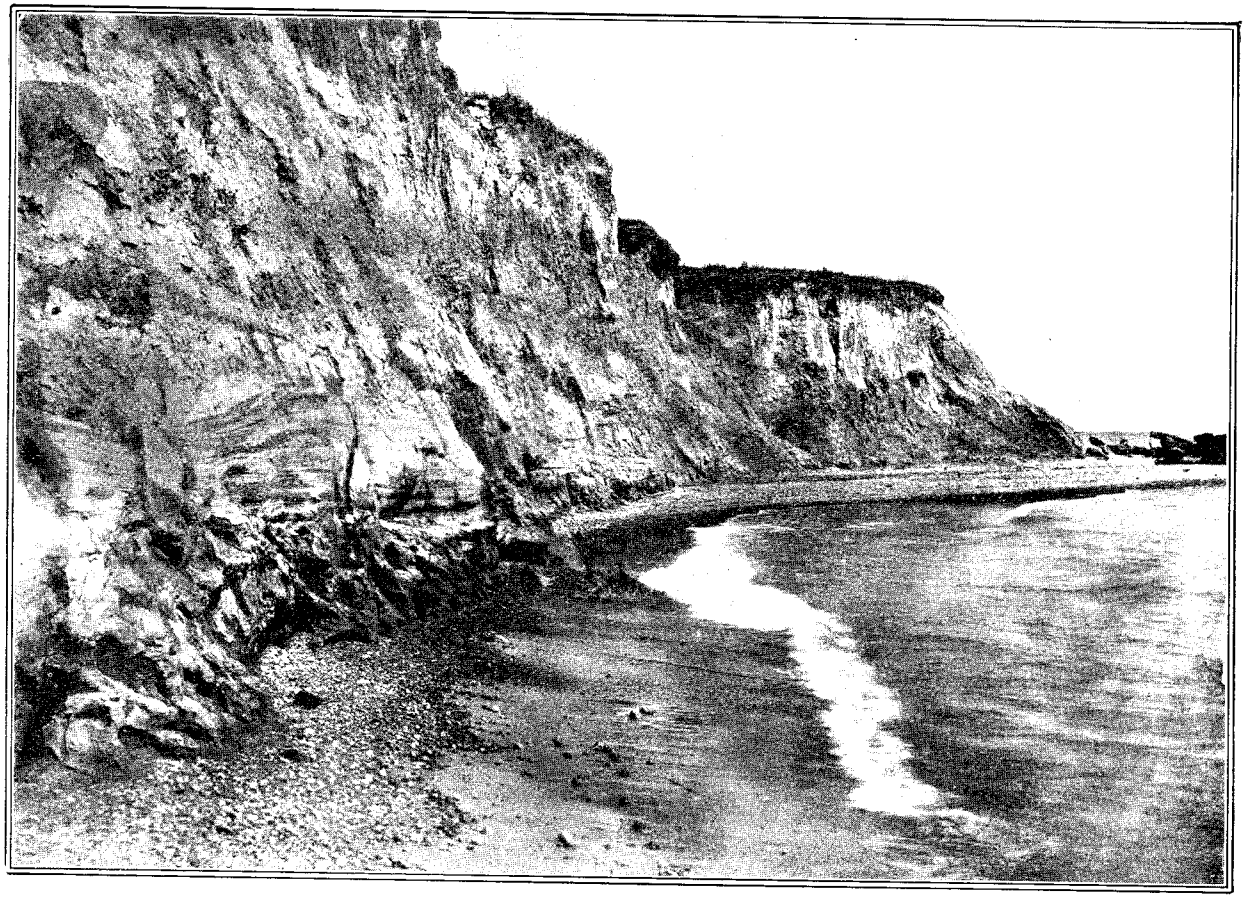
Where the Waves Work. A general view looking northward from the top of the cliff on the farm south of the Haywood estate, showing the nearly flat country behind the cliff.

PLATE XV.

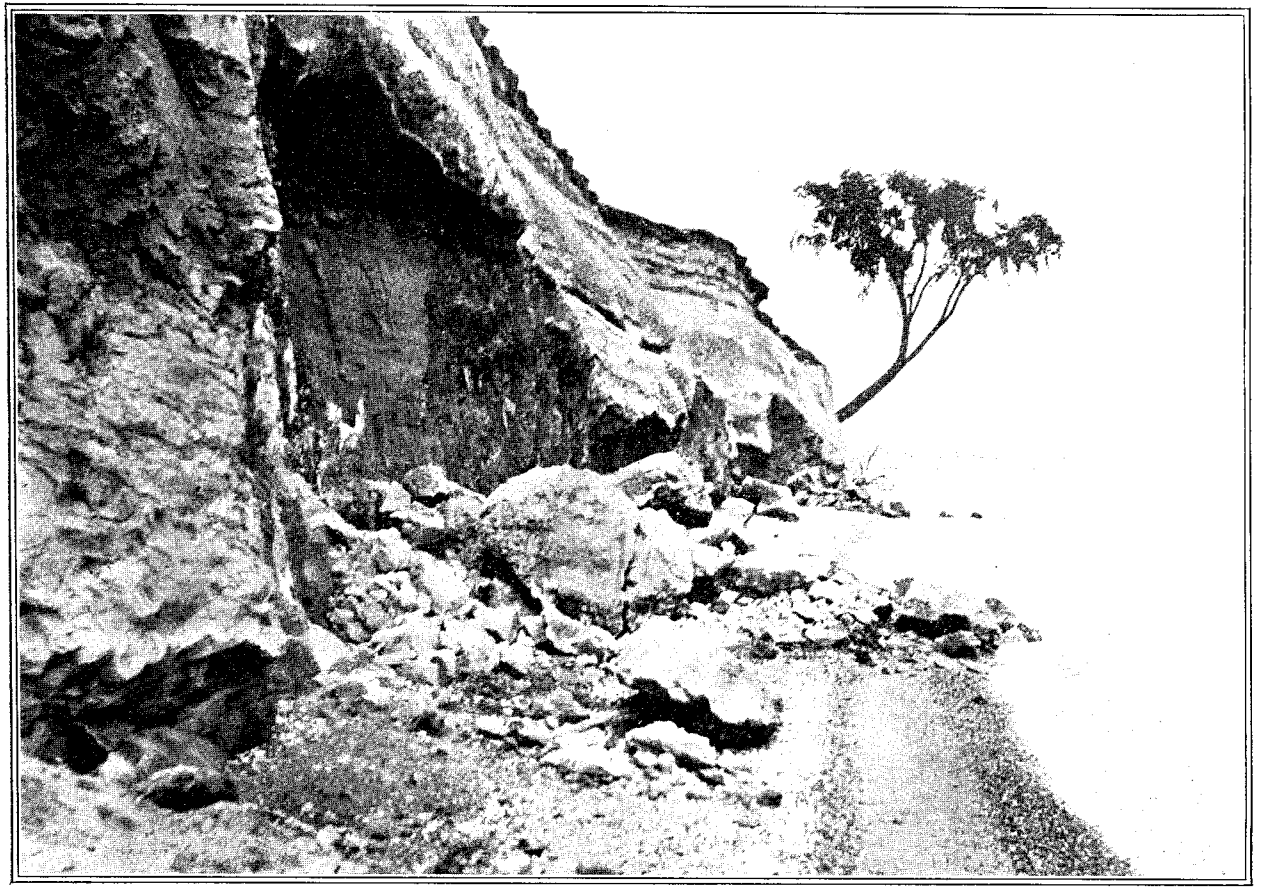
Algonquin Beach and underlying clays. At the contact of the two near the hat at the left of the center of the picture, a small tree trunk may be seen projecting from the bank.



VIEW LOOKING SOUTH FROM NORTH LINE OF HAYWOOD ESTATE.

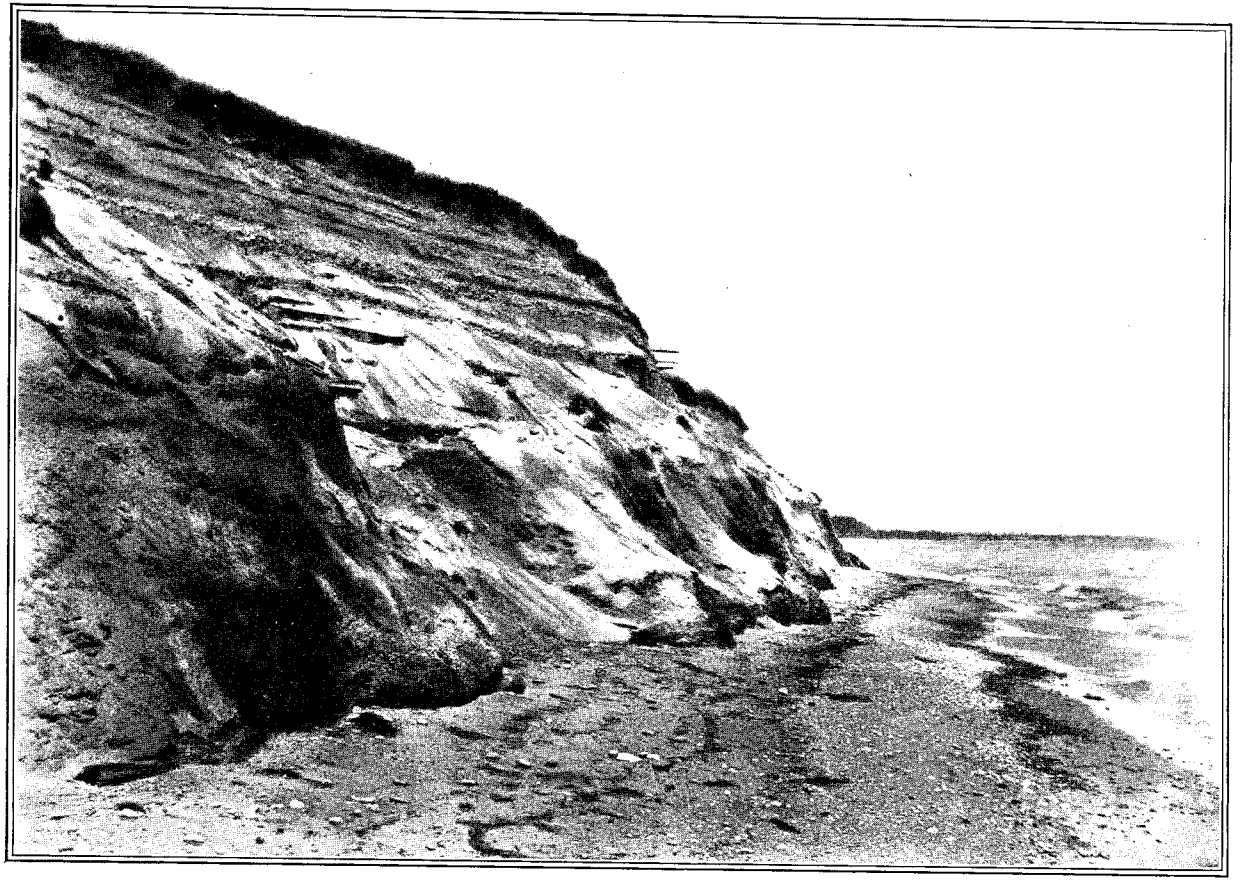


VIEW NORTH FROM NORTH LINE OF HAYWOOD ESTATE, SHOWING BEDDING LINES OF MIDDLE DIVISION.



CAVED MASSES OF CLAY, SANILAC COUNTY BLUFFS, AWAITING WAVE DESINTEGRATION.

GENERAL VIEW, CLIFFS AND FLAT COUNTRY, LOOKING NORTH OVER HAYWOOD ESTATE.



ALGONQUIN BEACH AND UNDERLYING CLAYS EXPOSED IN BLUFFS.

INDEX.

INDEX.

N. B.—The names of shells of the marls on page 138, and of fossils between pages 161 and 210 are not indexed.