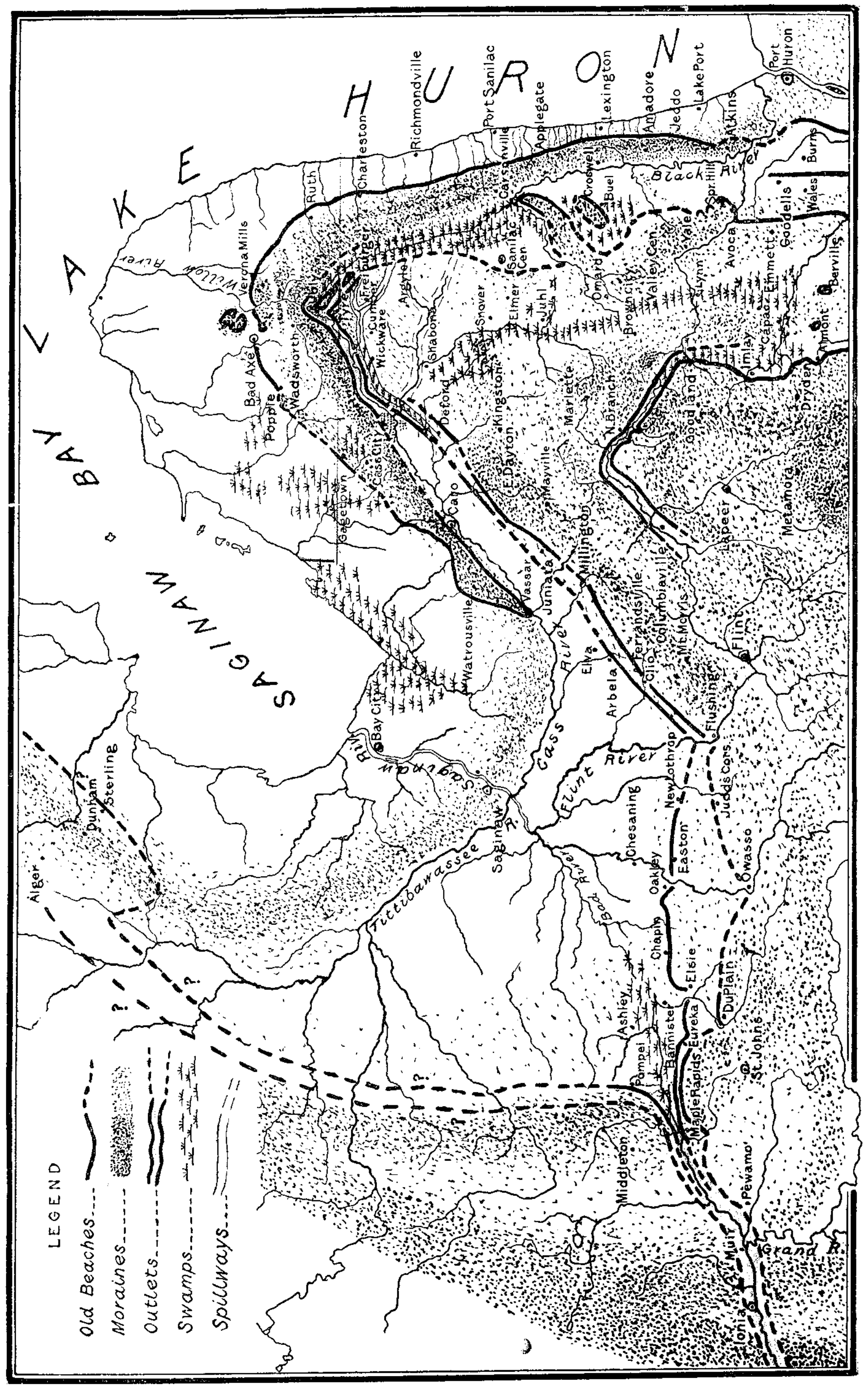
between Ashley and Bannister (according to Spencer quoted by Taylor, not over 100 feet above Lake Huron), about 647 feet above tide. Adding about 100 feet for the depth of water in the channel, will bring the altitude to that of Lake Saginaw as above given. The Lower Forest Beach is given by Taylor as only about 700 ft. above tide around Chapin and the outlet, in which case the correlation with the terraces in the Pewamo channel would not hold. But as we shall later see, there are a number of marked water levels, below the Forest Beach, especially the Grassmere Beaches, and it is possible that Taylor has lost track and jumped over to the Grassmere Beaches in going between Gagetown and Chapin, as he could not follow the beach continuously. The high beaches of the Pewamo channel may correspond with some stage of Lake Saginaw during which the ice had not melted back as far as to Huron county. This subject will be considered later.

On the east side of the Hill district, Taylor saw no signs of lake level above 775 feet above tide, but he will remember that the character of the topography changes at some distance above the Forest beaches, later to be described. It is probable that the ice retreated rapidly from the heavy moraine which has its apex in the northeast corner of Bingham, that the water extended on the east side only for a short time as a long narrow sound in front of and between the ice and its recently deserted moraine, so that there was no pronounced beach line, and the gravels would be hard to distinguish from overwash gravels. I frankly confess myself unable always to discriminate between the two. On Sec. 34, Bingham, i. e., on the old channel connecting the two lakes, there is a hill (267 feet above lake) 849 feet above tide on which is a well marked spit 809 feet above tide. This is quite certain. According to Taylor the earlier stage of Lake Maumee was about 795 feet above tide, while the later Lake Whittlesey, at the time when it reached nearly to Huron county was 800 feet plus on the Tyre Ubly outlet, while other beaches were found at 817 feet near Berville, 825 feet near Almont, 849 feet near Imlay (p. 36). Taylor leaves the question of the exact correlation of these beaches open, and owing to the fact that the beach lines of these old lakes cannot be supposed exactly even, and that the Port Huron and Northwestern R. R. levels are, as above mentioned (Chapter II, § 5), not as accurate as could be wished, it will probably be some time before the exact correla-



ERIE—HURON BEACHES IN SOUTHEASTERN MICHIGAN AND THEIR RELATED OUTLETS AND MORAINES. BULL. GEOL. SOC. AM. VOL. 8, PL. 2.

tion of these beaches can be established with any certainty. Taking the observations on Sec. 34, Bingham, in connection with that on Sec. 31, Paris, and those further south quoted by Taylor, there seems but little doubt that while the water level on the eastern side was still considerably above 800 feet, the ice front had melted back to the southern verge of Huron county. Then we may suppose Taylor's Arkona Beach to be a faint subsequent stage, probably marking a time when the channels across the point south of Verona Mills had lowered the waters of the lake on the east, Lake Whittlesey, so much that their own capacity for discharge was cut down and a state of equilibrium was temporarily established. The level of the lower lake, Lake Saginaw during all this time, like that of most lakes with large inflowing and outflowing stream, would fluctuate according to the climate from month to month and from year to year, without much changing its general level. Hence there would be a tendency for the waters to find their way across the "Thumb" from the waters on the east to those on the west. That was exactly what happened. The waters found their way along the valley now occupied by Black River in Sanilac county (see Plate VI) and across the divide by various shifting channels in Sanilac county, described by Taylor, and more fully noticed in Gordon's report on Sanilac county,* which we need not therefore mention further. They are shown in part on Plate VI. The first channel that particularly interests us is one of the strongest and most permanent of all and just enters Huron county. The rush of waters came up past Palms and Tyre, scouring away the surface "till" down to the sandstone floor, up through sections 34 and 35, Bingham, cutting a bench on the sharp hill on section 34 on the west side of the channel, and drawing it out in a long spit with an altitude of about 809 feet. The water level of the lakes at those times undoubtedly varied from year to year, and from month to month as it does now, probably in even more marked degree, as the cold of winter would have even more effect in checking the flow of water from the ice sheet. But we may safely take the average stage of water in the river between the two lakes at this point as somewhere about 810 feet. But since the stream had had to flow 30 miles or more up north, following the Black River valley, the level of the lake corresponding to this outlet, may have been a couple of feet

*Part III of this volume.

higher, if the grade was the same as that of the present Saint Clair River. The waters thus running north probably met on Sec. 22 a large stream issuing from the melting ice sheet at the angle between the Saginaw and the Huron lobes, and were deflected south so as to follow along the margin of the Saginaw lobe down the present valley of the Cass River. Any one standing on any one of the hills overlooking this valley, will recognize at once that it is a great stream valley, vastly too large for the little Cass. In the mean time the ice front remained nearly stationary long enough to pile up on the Huron side the ridge of gravelly clay and boulders, called a terminal moraine, which runs up in Bingham township from the south part of Sec. 36, into Sec. 22; on the side of the Saginaw lobe it piled up a similar ridge from the south part of Sec. 31 into Sec. 21. These moraines do not meet, and the presumption is that the gap was in the first place occupied by the stream from the ice sheet, though at a later stage in the ice retreat a channel was found in this direction also for the waters of the eastern lake. The height of the moraine (about 844 ft. above tide) and the pronounced character of the Tyre channel, shows that this line was held for some time, but at length the ice of the Huron lobe retreated some four miles and took up a new position, extending from Sec. 33, Paris, into Sec. 2, Bingham. It does not seem as though the Saginaw lobe retreated at the same time nearly so much, as on that side the morainal ridges are piled close behind one another (Plate VIII). On the east side there are also numerous isolated rounded hills between the two main lines, which may be remnants of moraines overriden in a temporary advance.

It may be that there was no general marked retreat of the ice, but that some temporary retreat was just enough to let the water work back of the moraine near Tyre, and once having opened a channel for itself through the southeast part of Paris Township it would hold it pertinaceously, even against any temporary tendency for the ice front to re-advance. To the Tyre outlet was now added a new channel well shown on the map (Plate VIII). It extends from Sec. 32, Paris, to Secs. 14 and 15, Bingham, connecting the head waters of the Cass River and the Black River.

The swamp lying in the old channel is now drained by a county drain. The swamp level is now about (213) 795 feet above tide, or somewhat higher than the Tyre channel (782 feet A. T.), and the

water level was at least 801 feet A. T. and probably more.* It may have caused slight drop from the level when the south or Tyre channel alone was working, but it is within the range of error of our barometric observations. The water still had to find its way up by way of the Black River, and a heavy moraine ridge was built along this line,† rising to about 864 feet above sea level. But finally the ice front was withdrawn from this line. The ridge of till or gravelly clay strewn with boulders was‡ more or less covered, "aproned," with gravels washed on to it from the ice, and the water either gathered in pools, like the Merjelen See of Switzerland, between the ice sheet and the moraine ridge, or worked in from Lake Whittlesey on the south. At this time the ridges marking the stages of retreat of the ice seem to have been out of water to the northwest and to have passed under water to the southeast, for these ridges seem much sharper when laid down in the air than when laid down under water, and we have for example a hill on the south line of Sec. 6, Paris, which is continued to the southeast only in a very gentle undulation. When the ice sheet, with its front thus in the water, and its flank just out of water, forming land-made ridges near the corner of Verona, Sigel, Paris and Bingham townships, retired a little farther, there was left open a channel through Sec. 6, Paris, and Sec. 1, Bingham, around to Sec. 35, Verona. This is not, however, much lower than previous outlets (780 feet A. T.), and as we find it in distinct sand and gravel deposits on Sec. 35, Verona, about 800 feet above tide (219, 216, 217 feet above lake, according to different readings), the opening of the channel could have made no material change in the lake level. It could hardly have led the water off down the Cass valley, for the lowest point on the channel on the south side of Sec. 2, Bingham, appears to be at least 805 feet above tide and I think that any discharge directly west was blocked by the Saginaw moraine and the ice. The channel on Sec. 35, above mentioned, might even have been an outlet

*The midchannel bar of Taylor, if it is the one on the south line of Sec. 24, is about 801 feet above tide. Compare also gravel, at 800 feet A. T. at the southeast corner of Sec. 23, Bingham. The county drain enables us to check levels along here.

†Of fairly uniform height, as the following observations show:
E. line of Sec. 33, Paris, 294 feet above Lake Huron.
N. line of Sec. 33, 268 feet above Lake Huron.
N. line of Sec. 28 slightly later, 295 feet above Lake Huron.
N. line of Sec. 20, 295 feet above Lake Huron.
N. line of Sec. 18, 272 ft. above Lake Huron.
E. line of Sec. 12, Bingham, 274 feet above Lake Huron.
N. line of Sec. 12, 280 feet above Lake Huron.
E. line of Sec. 2, 280 feet above Lake Huron.

‡So on the north line of Sec. 18, Paris.

westward of the great glacial river from the north, already mentioned, into the eastern lake, Lake Whittlesey, though we have not supposed so. Can it be shown that the current was that way?

Even the retreat of the Huron lobe of the glacier two miles farther north, so that its flank emerged from the water near Verona Mills on Sec. 24, Verona, seems to have left the ice front at first at much the same level, for near the southwest corner of Sec. 25, Verona, there are extensive sand deposits and gravel ridges at an altitude of about 801 feet above tide, and a gravel ridge or spit near the center of Sec. 24 at a corresponding elevation. The bottom of a channel in Sec. 24, which is followed by a county drain is at much the same elevation as previous channels (789 feet A. T.). I think I can trace signs of a water level in a faint terrace along the valley of the Willow, a discontinuous bench visible in a series of spurs from the ridge east, which thus gives us some idea of the size of the glacial stream from the north at this time, filling a valley about half a mile wide, to a depth of perhaps (218—182) 36 feet.

In fact on the back side of the moraine of the Saginaw lobe which extends through Secs. 27 and 22, Verona, I have noted a bench and a change in the topography at the same level.* Finally, as indicated on the map, there are a number of kame-like gravel hills on Secs. 29 and 28, Verona, which reach nearly up to an altitude of 800 feet above tide, though the continuous benches are lower.

It is probable, therefore, that so long as the whole current had finally to pass down the valley of the Cass through Sec. 32, Bingham, the level of the eastern lake, Lake Whittlesey, remained practically constant, no matter how many different channels there were by which it started to leave the lake. This level so many observations point to as being between 800 and 810 feet above tide that we may be reasonably confident of those figures, the latter figure being probably the maximum. But when the lobe of the Saginaw moraine melted back so as to let the waters around behind the very heavy series of ridges which run north northeast from the southwest corner of Bingham the lake discharge found its way across the northwest corner of Bingham, half burying the clay ridge on the north side of Sec. 4, Bingham, in sand on the east side, and making heavy gravel deposits along the north side of Sec. 3, Bingham, then as the ice retired sweeping sand and gravel over numerous places in Colfax, Bingham and Sheridan, and passing southward out of the county in some well marked channels,* the new and independent outlets probably lowered the waters rapidly.† The first gravels on the back of the moraine are not very much lower than those previously mentioned, but as we go northwest in Sheridan the gravels appear at lower levels, down to 770 feet, in a long ridge on Secs. 9, 10, 11, and 12.

*799 ft. A. T. on center line of Sec. 22, 0.36 miles east of west quarter post.

We infer thus that as the Saginaw lobe retired from Bingham and Sheridan, the water level lowered rapidly in Lake Whittlesey. We have already seen that this appears to have been not before the Huron lobe had retreated to Verona Mills, and we must indeed almost imagine that at the same time that the Saginaw lobe withdrew across Sheridan township to the neighborhood of Popple, Sec. 6, Sheridan, the Huron lobe would withdraw from Verona Mills a little way. A withdrawal of a mile or so leaves, as is obvious from the map, a clear connection around the end of the rough and irregular agglomeration of conical hills which mark the junction of the two lobes. Gravels are found on these hills clear to the top (855 feet A. T.), but they seem to be largely overwash gravels from the surface of the ice, very likely intermixed at lower levels with material brought down by the glacial stream from the north.

Along north of Verona Mills on Sec. 18, Sigel, are gravel pits for road mending, which Mr. Taylor takes to be kame gravels. The first well marked and continuous beach which extends around north of these hills is at 774 feet altitude (Taylor 775 feet).‡

This is according to Taylor the Upper Forest Beach, and it can be traced continuously as indicated on the map (Plate VIII), spreading broadly over the uplift of the Marshall sandstone escarpment passing about a mile east of Ruth, and decreasing in altitude at the south line of the county down to about 750 feet above tide (756 A. T. on Sec. 7, Sherman). It may occasion surprise that these old beach lines should not follow contour lines, and remain a constant distance

*Sec. 34, Grant, Sec. 32, Sheridan.

†Compare.
Sec. 8. Bingham, 0 paces N., about 500 paces W., sand 804 feet?
Sec. 7. Bingham, 0 paces N., about 600 paces W., about 808 feet?
Sec. 7, Bingham, 0 paces N., about 1850 paces W., sand ridge at 780 feet A. T.
Sec. 6, Bingham, sand ridge 200 ft. wide, at 771 feet A. T.
Sec. 19, Bingham, 368 paces S. of N. W. corner, bottom of steep bouldery ascent with stratified gravel at 788 feet A. T.
Sheridan, southside of Sec. 21, sand ridge at 788 feet A. T.
Sec. 24, Sheridan, about 200 paces E. of S. W. corner, gravel at 780 feet A. T.
Sec. 19 and Sec. 30, Sheridan, esker and kames at about 785 feet A. T.

‡Just N. of S. W. corner of Sec. 18, Sigel, also close to S. E. corner of Sec. 17 and near the east quarter-post of Sec. 21, and for two miles east a gravelly strip cut through by a drain the altitude of whose bottom is about 765 feet.

above the lake throughout. The general testimony of observers is, however, that this is not the case, and there are a number of possible causes to account for it.* but the gravitative attraction of the ice sheet, which would have its greatest effect on a body of water lying between two lobes of the ice front, seems quite sufficient to account for the rise so far as seen in this Forest Beach in this county. When we trace this beach level off from Verona Mills to the southwest we find it again falling slightly. We can trace it quite well, as shown on the map, through Sec. 12, Verona, and across the northwest corner of Sec. 14, faintly up the valley of the Willow, very well marked in a little bay on Sec. 21 and clearly marked on a slope well sprinkled with boulders across Sec. 20, to the southeast corner of Sec. 19, near Badaxe. Here there seems to have been an opening into a large lagoon or sound in which marl was deposited, shallow and not over fifteen or sixteen feet deep for the most part. The altitude of its bottom is 754 feet above tide. A low island with marked dune sand ridges rose above the lagoon in the northeast corner of section 34, Colfax, and from Badaxe to Popple, followed by the old State Road, runs a moraine ridge, which rises somewhat above the Forest Beach level in the northern part and is flanked by well marked terrace gravels at the level of the Upper Forest Beach (765 feet A. T.), and often buried by them. The level of Webber's gravel pit near the southwest corner of Sec. 13, Colfax, gives a good opportunity to obtain the level of the beach here quite

*The following are some of the causes:

(1) The ice sheet may have attracted the water toward it, just as a plumb line is deflected by a mountain near by. This would give a slope relative to the present level increasing to a maximum at the margin of the ice front, and not over 1.8 ft. per mile for a sheet 10,000 feet thick (the Greenland ice sheet is about 9,000 feet thick) while the average slope for 69 miles from the border might easily be 0.4 feet per mile. See Woodward in sixth Report U. S. Geol. Sur., 1884-1885, p. 295-296. also U. S. G. S., Bull. 48, p. 66. It is found generally true that the slope of the old shore lines rises toward the ice. It is to be observed that in the case just before us of water lying between two lobes of the ice, we have a case of maximum effect something like that discussed by Woodward of a canal in the ice sheet near the margin, where the equipotential surface within the ice sheet is to be considered.

(2) The shifting of the volume of the ice sheet, if not symmetrical to the pole would displace the earth's axis of rotation, relative to the solid crust, but a rough investigation shows that this would have a negligibly small effect.

(3) The weight of the ice cap may have bent down the crust upon which it lay during the ice period, which may be supposed to have been uplifted again when the ice retired. But here it is to be noted that we cannot compute this effect as independent of effect No. 1. If the ice sheet depressed the earth beneath it it would have a correspondingly less effect in drawing the water up toward it. In a certain sense the first and third agencies might be inferred from the same phenomenon, by two different ways of looking at it, for the raising of the water surface by ice attraction, would produce an apparent subsidence of the land. The test between the first and third effects would apparently be the rapidity of the apparent uplift of the land. If it continued after the ice sheet had disappeared, it must be really a land uplift. Cf. Upham (23d Annual Report, Minn. Geol. Sur., 1895, p. 162) on Epeirogenic Uplifts. So far as the difference in level of the old water levels and the later water levels is concerned, this effect would be practically the same, to the order of approximation of Woodward's solutions.

exactly with reference to the Saginaw, Tuscola and Huron R. R.* Down near Popple we find a number of hills, which appear to have protruded above water, and the bench marks of the first beach are scored upon their flanks.† Thence the Upper Forest Beach can be traced through Secs. 11, 14 and 13, Grant, down to another sound, a remnant of which is Mud Lake. It reappears again on Secs. 28, 29 and 31, where the moraine once more was above lake level, and where it is at an altitude, as previously stated, of about 744 feet above tide.

North of Badaxe, running from the southwest corner of Sec. 7, Verona, through Secs. 8, 9 and 10 to 11 is a low clay ridge, heavily aproned with gravel on the south side, which rises a little above the Forest Beach level, and seems to mark the line of the ice front at one stage in the time of the Forest Beach. This seems to be practically the same moraine which passes north and west of Popple and northwest of Mud Lake. At the beginning of the time of the Upper Forest Beach this moraine was probably largely under water and kame gravels were extensively formed in a broad shallow sound which faced it and was later resolved into a series of lakes (indicated by shell marls under the present swamp) of which Mud Lake is the only surviving representative. By the end of this time the connection between the two sides of the "Thumb" was so open that the water level was practically identical in both, as is shown by the fact that the gravels at the foot of the ridge north of Mud Lake are at practically the same height on each side. Hence the retirement from this ridge, the last place in the county where the ice front kept above the water, made no material difference in the lake level. I was at one time inclined to think that the retirement from this point might have caused the slight drop to the Lower Forest Beach level, but the double beach line appears well marked on the northwest flank of the Mud Lake ridge.

This Lower Forest Beach is at times somewhat more than ten feet below the other, and can be followed around with it very well, and the two beaches may mark merely two high water stages easily due to climatic variations. Through Sigel township the lower follows

*The level of the surface of the pit is about 180 feet above lake. The average of eight observations on the gravel bench not far from Badaxe gives 182¾ feet above lake.

†S. line of Sec. 31, Colfax, and Sec. 36, Oliver, also on S. line of Sec. 1, Grant, where they can be followed some distance with the eye. Altitude, average of four observations, 172 feet above lake or 754 feet A. T.

the upper beach quite closely, but extends out over the flat lands of Lincoln township much farther in long sand spits or barrier beaches at an altitude of about 757 feet above tide (on the south side of Secs. 20, 21 and 29 and 35, Lincoln, on the east side of Sec. 31, with a spur also, and on the east side of Sec. 33, Lincoln). Through Colfax township there is a broad sandy terrace whose upper margin is at about 749 feet above tide. This second terrace is clearly marked in the north corner of Grant township at 739 feet above tide, and about 6 to 18 feet above the general broad sandy level over which it looks.

The lake thus formed by the running together of Lake Saginaw and Lake Whittlesey has been called by Taylor, following Spencer, Lake Warren. In all probability for quite a while after communication was opened around the end of the "Thumb" the ice front remained not so very far off, and possibly streams issuing from it may have laid down some of the ridges which we find especially in Lincoln. There seems, indeed, to be one ridge in particular which begins on Sec. 11, Verona, opposite the head of the Willow Creek valley, which, as we have said, was probably filled by a river from the ice. This ridge passes thence through sections 2, Verona, and 34 Lincoln, and thence northwest to Secs. 32 and 33 Lincoln, and thence at first north then northwest to Sec. 25, Hume, which, though it has not been traced continuously, seems to be continuous and to be running down hill. It must, if so, mark the successive dumping grounds of a stream issuing from the ice sheet as the latter retired beneath the lake surface.*

Of course such a ridge would be more or less washed over by the waves as the lake level gradually settled. It may, however, be merely a sand spit out in an eddy at the end of the point. Whether this particular line of sand and gravel is rightly explained or not, such streams must have brought down much sand and gravel for the waves to dispose of, and we have evidence of that and also of a strong westward current in the accumulation of such sand and gravel deposits quite extensively all along the westward face of the emerging plain.

*Such a ridge is called an esker and it may be noticed that the supposed esker is in continuation with the line and curves of the upper Willow Valley, and may be due to the same river. It is in a general way at right angles to the ice front and in the direction of the ice retreat. Another somewhat similar ridge appears on Sec. 30, Sheridan.

These deposits of sand were also supplemented by the deltas of the streams which drained the lagoons of Verona, Colfax, Sheridan and Grant, later converted into a series of lakes. Under the swamps which now fill the places of these lakes we find shell marls which may be referred to this epoch, and plainly indicate a colder climate than the present (see Chapter X, Sec. 2). The most noticeable delta of this kind is that of the upper Pinnebog on the north side of Sec. 31, Colfax. Westerly winds may have aided the waves in piling up the ridges on shore. At any rate we find a broad sandy belt extending practically from Robinson's hill in Sec. 13, Dwight, down to Brookfield township, and lying about 710 feet above tide, in which sand and strips of country covered with boulders are abundant. The indications of a northward rise in beach levels rapidly disappear.*

§ 4. Lake retreat. Later terrace or recent epoch.

A temporary halt in the subsidence of Lake Warren seems to be indicated at about 725 feet above tide, after which the lake seems to have sunk more rapidly than before down to about 700 feet above tide. Then the subsidence must have been slower and sand ridges are numerous down to 680 feet above tide. It must have been held at this general level for quite a while, for we find in front of the 680 foot beach line that the drift has been scoured away in many places down nearly to the rock, so that the 670 foot to 690 foot contours are crowded together and a series of terrace benches have been cut on the east side of Robinson's hill on Sec. 13, Dwight. Sand ridges at about this level, i. e. 98-108 feet above the lake were found almost invariably where these contours were crossed, also delta sands near the rivers on both sides of the county. Most of the outcrops, except those immediately adjacent to the shore, are connected with this level. Frequently there are numerous boulders covering the surface of the lower land immediately to the west like the boulder pavement figured by Spencer.†

*The sand ridges are, however, so near together in altitude that they are within the range of our errors in determining altitude, so that nothing can be said very definitely. Still in Lincoln numerous ridges fall within 145 to 134 feet above lake, in Meade within 153 to 133, in Colfax within 152 to 144 and one at 128 feet. In the north part of Grant the soil is sandy about 150 to 130 feet above lake, and in the south part of the township it is gravelly pretty continuously down to 125 feet above the lake; these facts may be accounted for by supposing that the upward grade toward the ice had largely disappeared before the lake had sunk more than thirty feet.

†Loc. cit. in Pop. Sci. Monthly.

Fig. 3 illustrates the boulder bench which lay just below low water and the series of ridges, the highest of which was, of course, somewhat above highwater, of Lake Warren at this level. The fact that the lake was thus held for quite a while from 672 to 692 feet above tide may be connected with the fact that that is about the lower limit for the Pewamo outlet. After free connection was established, it is natural to suppose that the lake would wear down the outlet, and its own level fall until the outlet had shrunk so as to be only sufficient to carry off the annual supply of water, after which the lake would remain relatively permanent. We call these beaches the Grassmere beaches since this general level is most accurately determined where it crosses the Saginaw, Tuscola and Huron R. R. near Grassmere, but it seems to be quite horizontal in its course around the thumb. From this level Lake Warren

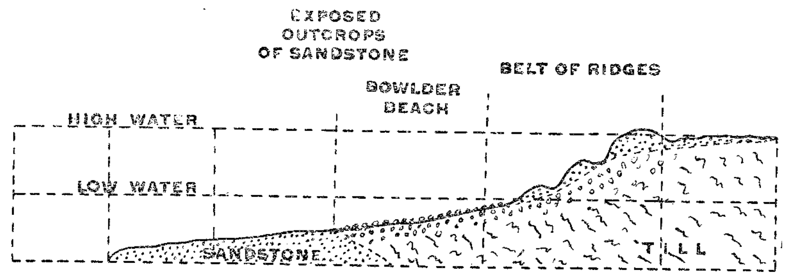


Fig. 3. Illustrates the relation of sand and gravel ridges, boulder benches and flat sandstone exposures to ancient water levels. South line of Sec. 3, Meade Tp.

dropped rather suddenly to an altitude of 647 feet above tide.* What caused this drop, whether the opening of a channel around by Mackinaw into Lake Chicago, or some outlet across central New York down the Mohawk I would not dare to say definitely,† but the subsequent pause in the fall of the waters is well marked and we may follow it, from the swamps of Brookfield township past Elkton, where the beach gravel wraps around a low waterlaid moraine ridge of till, which runs from the northwest of Oliver to the northeast and is the last relic of the ice front that we notice, on to Port Austin where the beach skirts the hill on Sec. 31. This level is also visible on Sec. 3, Dwight, and probably the prolonged lake action during

*Levels back of Port Austin; also the S. T. and H. R. K. near Elkton. There are also delta sands and gravels on the Pigeon River near Sec. 23, Winsor, and on New River in Huron Township, and in Huron Township the 640 foot contour is crowded up to the 650-foot contour.

†Cf. Fairchild's recent announcement of beaches in Lake Warren at low levels. Bull. Geol. Soc., Am. Vol. VIII, p. 271.

this pause had something to do with exposing the outcrops on Sec. 1 of the same town. In Huron township a well marked bar at this level connects the hills on Sec. 3, and it is apparently a prominent sand and gravel beach below the Forest beaches on the eastern side, being traceable quite continuously down to the southeast, until near White Rock it is only three-fourths of a mile from the Lake.

As the streams on the west side of the county come down to this level they emerge from rather deeply cut valleys to quite shallow ones, and are deflected to the north. The contrast between the valley of the Pinnebog where it crosses the Saginaw, Tuscola and Huron R. R. near Elkton, with its valley either above or below,—a change from a valley 20 or more feet deep to one only 3 to 10 feet deep and broad and vague, is striking,—and the same phenomenon is noticeable in the Pigeon on Sec. 36, Winsor, and other streams. This fact indicates that the water stood between 700 feet and 650 feet so long as to give the streams a chance to cut pretty well down to that base level, after which time the water level sank so suddenly that the streams in deepening their valleys had to work back from a mouth quite a distance off.

The next halt of the water below this level is probably a short one indicated by the bench on the Port Austin hill at 635 feet above tide, and by some sands and gravels in the south part of Winsor (T. 16 N., R. 10 E.), and the waves probably just broke on the top of the limestone ridge in Sec. 5 of the same township, and cleaned off the till therefrom.

There is no other marked halt until we reach the most pronounced one in the whole series, correlated by Taylor as belonging to Lake Algonquin, a large lake which stretched from Lake Superior to Lake Erie and discharged over Niagara, though the land was so much lower to the north at that time that the water of Lake Algonquin would have discharged by North Bay down the Mattawa valley (Canada), had not that valley been still occupied by the rear guard of the retiring ice sheet. Like the present lakes it may have had its changes of level from season to season and decade to decade, which seem to be confined within a range from 20 to 25 feet above the present lake level, say 607 feet above tide.*

*Compare the ridge roads of the R. R. Surveys, Chapter III, Sec. 5. The tops of the ridges of sand are evidently piled above what was then the water level, and observations on the highest beach line at Bayport agree with that at Port Austin and with the general altitude of the marshes behind the dune lines, in fixing the highest water line of Lake Algonquin at 25 feet above the 582 foot base

This level is marked on the west side of the county by an almost continuous line of dunes, whose crests commonly rise above 30 feet, and on the other side of the county by cliffs. Only in a few cases, as just south of the lighthouse on Sec. 12, Huron, T. 18 N., R. 14 E., and again north and south of White Rock have the cliffs of the present lake been cut back so far as to overtake the cliffs cut at this higher level, while the dunes of the higher level quite hold their own in comparison with the dunes of the present area. Back of the dunes are extensive marshes lying near the 25 foot level, through which the streams meander. All these are signs of a length of halt much longer than anything that we find above.* Between this and the present lake level it is not uncommon to find four beach crests among the most noteworthy of which is the one followed by a "ridge road" about 14 feet above lake level.† The water line probably lay a little lower, at 10 to 11 feet above the 582 foot datum, at a time perhaps within the range of tradition, as I hear from Dr. W. C. Wright, of Unionville, that the Indians had a tradition of rowing over Pine Island, now 11 to 13 feet above the lake. The high water line of 1886 is well marked in a crest from four to seven feet above the present lake level, and so we come down to the level of 1896. Since that time the water has been rising again somewhat, but the last report of the U. S. Engineers states that since 1886 the St. Clair outlet has been rapidly cut down.

It should be said that Taylor thinks that at the close of the era of Lake Algonquin the Mattawa valley channel was opened and the water of the lakes was for an extensive period (the period of Lake Nipissing) lower, and here and farther south has recently readvanced. This I believe to be true farther south, but as Taylor's paper shows, Huron county lies near his nodal line, where there has been no such readvance for Lake Huron. According to his theory, which in general I accept, during the time of the lake that

(A. T.). There is frequently a second crest a little lower. On the east side of the county the boulder bench or terrace, which must have been below the water line and faces cut cliffs which frequently rise 40 feet and more above the lake, is from 17 (Harbor Beach R. R. station) to 20 feet above the lake. Occasionally above this main bench we can see small benches, old beach crests, at 23 and at 28 feet, respectively, above lake. The streams broaden out and meander in their valleys at this level also.

*Taylor, priv. com., Feb. 11, 1897, correlates this with the Algonquin beach, but leaves open the possibility that it may also represent the Lake mentioned next, Lake Nipissing.

†Beside R. R. levels in Chap. III., Sec. 5, we noted also on the center line of Sec. 18, T. 15 N., R. 9 E., beach ridges 11, 14, 17 and 20 feet, respectively, above lake, and correspondingly, on Sebewaing river, terraces 2, 5, 13 and 18 feet, respectively, above the river bed. Around Harbor Beach the bench appears to be nearly continuous from 18 feet down to 14.

he calls Nipissing, since the present Lake Nipissing (northeast of Georgian Bay, Lake Huron) was at that time part of the Great Lake system, the land was so depressed to the north that the lakes drained to the sea through North Bay and the Mattawa valley, and owing to the tilting necessarily implied deserted the southern part of their basins. Huron county lies near the dividing line between the region where the old level of Lake Nipissing extended less far on the land, and the region where the level of Lake Nipissing was above the present level. If the lake level during the period of Lake Nipissing was lowered in Huron county it could have been but slightly lower, for if there had been a long lower stage we should find the rivers near their mouths had cut down to it, and then the rise of the coast would flood their valleys, producing such a type of coast as we have in Chesapeake Bay, or on the southern shore of Lake Michigan or in Monroe county on Lake Erie. See Part I of this volume. Of such a shore there is no evidence. On the contrary many of the streams, the Shebeon, Willow, Diamond, Allen and others flow on rock bottom close to their mouths. In fact this is the rule rather than the exception, and at other points, as at Caseville, dredging has shown that rock is close beneath, and had the streams been flowing down to a much lower level any length of time, they would have cut back rock channels farther inland. On the contrary the geological evidence is that the latest movement is what Prof. Gilbert has recently shown by measurement, to be still in progress,* viz.: an uptilting of the lake shores to the north-northwest. By carefully comparing the elevation of certain fixed points with the mean water level for the season in the summer of 1897, with the elevations of the same points above mean lake level determined by the Lake Survey years ago, he found the northeastern points relatively higher now than then in a way that indicated a rising of the earth's crust in a direction N. 27° E. about 0.42 of a foot per hundred miles per hundred years.† For instance, "Between 1876 and 1896, a point at Port Austin, Michigan," i. e., in Huron county which we are studying, "on the shore of Lake Huron as compared to a point in Milwaukee, on the shore of Lake Michigan" rose 0.127 of a foot or one and a half inches."‡ The distance between these two points is 259 miles, or,

*Modification of the Great Lakes by Earth Movement, National Geographic Magazine, Sept. 1897, viii, No. 9, pp. 233-247.

†See Chapter III, Sec. 5 (a), for correction of these figures.

‡Loc. cit. p. 244.

in the direction N. 27° E., 176 miles. Huron county is distant fifty miles more or less in the direction north-northeast from the outlet of Lake Huron at the Saint Clair River, so that such tilting would produce along the shores of Huron county a rise of the land upon the lake of about 0.2 of a foot per century. We do not know how long this rate of tilting has continued, nor whether it is increasing or decreasing, but the fact above cited that so many of the streams have rock ledges close to their mouths seems to confirm the belief that the latest motion of land relative to lake in Huron county has been an uplift. Possibly more detailed study may lead Mr. Taylor to shift the nodal line for Lake Nipissing a little to the southwest.

§ 5. Time estimates.

We have now finished our account of the various stages in the retirement of the lake. By comparing amount of cutting on the one side, and amount and volume of beaches and dunes on the other at the different levels we can form some estimate of the relative time during which the water lingered (Fig. 4). Of course no accuracy can be claimed for such estimates. They are only the first rough approximations. Still it seems quite clear that the work below the 40 foot level is more than equal, measured either by cut or fill, to all that which preceded it. To get some idea of the unit of the time scale one way would be to survey Mud Lake and see how much it had shrunk, and been filled since the meanders of the original Linear Survey, and then if possible find its original extent. Rush Lake is also obviously shrinking, but is much younger.

Another way would be to find the amount and the rate of erosion on the eastern shore. The Wisconsin Survey carefully resurveyed the meander lines along Racine and Milwaukee counties, and found an average rate of erosion of 3.33 to 2.77 feet a year from 1836 to 1874. Dr. Andrews found, even rejecting erosion of extraordinary rapidity, erosions from 17 feet a year down to 0 averaging about 5 feet per annum around Chicago.*

For the eastern shore of Huron county we have no such close estimates. In fact the general impression is that the shore has been gaining upon the water. But as Plate V shows, for the ten years before 1896, the waters had been lowering rapidly. Again opposite Harbor (Sand) Beach the shore is protected by the great artificial breakwater erected by the government at a cost of $2,000,000 and a filling in has

*Leverett, Bull. No. II, Chicago Acad. of Sciences; see also Crossman's chart.

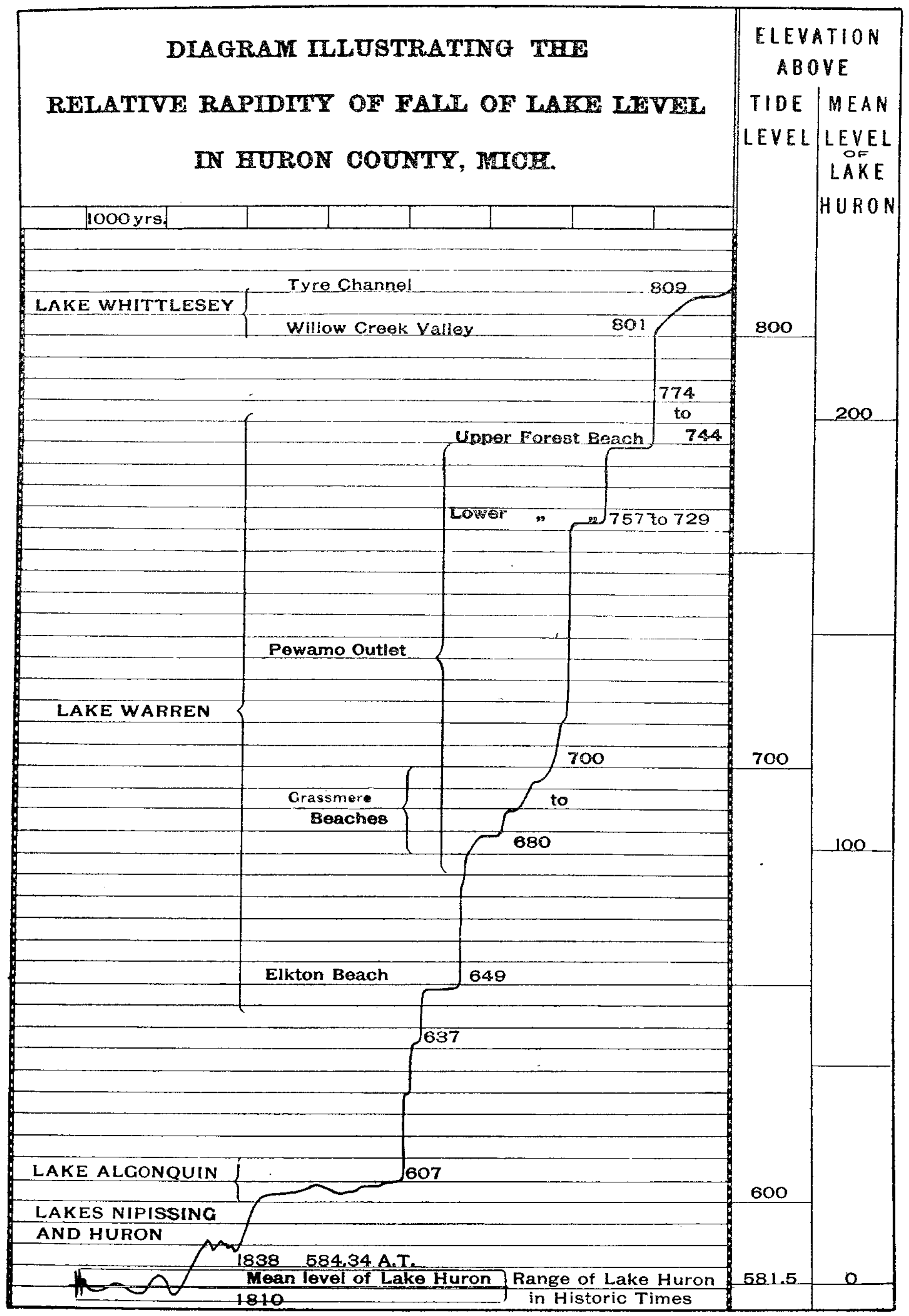


Fig. 4. Illustrates the relative strength of the water lines at various levels in Huron county, Michigan. The altitudes given at various parts of the curve are above tide, lake level being 582 feet above tide, according to Gannet. The altitudes are indicated on the vertical scale while the horizontal scale represents the relative strength of, respectively, the time required to produce the various shore lines. Names of lakes and water levels, etc., with the exception of Grassmere and Willow valley, are after Taylor.

been caused. Mr. Geo. W. Jenks says that a strip of an average width of 50 to 100 feet has been added in his recollection,—the last twenty years or so. A large double tree, which in his boyhood was on the crest of the beach not over fifty feet from the water, is now 140 feet from the limit of vegetation or 145 feet from the water's edge according to measurements that I made in Sept., 1897. The old Land Office notes make the distance along the north line of Sec. 12, T. 16 N., R. 15 E., 50.25 chains, i. e., 3316.5 feet. The county atlas gives by scale 3560 feet, and the careful plan of Sand Beach harbor prepared in 1889 by the U. S. Engineers from work between 1885 and 1888 makes the same distance 3600 feet, showing a decided gain of land over lake, especially as the lake was highest in 1885. But this line is close to the mouth of a stream, and perhaps influenced by its delta. The various successive blue prints by the United States Engineers show plainly the accretions year by year. But when we come to compare with more distant times and especially with the records of the first Land Office surveys, which are not very accurate, however, in 1834 and 1835, when the water was as low as in 1896, we find a very different state of affairs. The indications are of greater or less erosion not of gain. Let us cite a few facts. Mr. J. H. Tucker, one of the oldest surveyors of the county, reports a general erosion of the land; that to the north on the town line where the quarter post originally stood on the land the shore now comes 40 rods this side of it.* The elder Mr. Jenks bought a lot which, according to the government notes, contained 65.50 acres. By 1880 this lot (3, Sec. 36, T. 17 N., R. 16 E.) had dwindled on resurvey to 54 acres, implying if both surveys were accurate and took the shore line in the same way a retreat of 380 feet or 8.43 feet per annum. To the south of the breakwater near the summer resort, on the west line of Sec. 7, T. 16 N., R. 16 E., the line from the corner to the water was in February, 1896, 1730 feet to the edge of the bluff plus about 30 feet to water, a loss from the original survey of 50 links. On the south line of the same section, 7, the line was 20 to 30 links short. This loss in spite of the low water of 1896 and the recent accretion due to the protection of the breakwater shows that there must have been considerable cutting before, amounting to between 100 and 200 feet, i. e., for the fifty years, 1835-1885, from 2 to 4 feet a year.

*But the government notes, April 14,1835, show 34 chains to Lake Huron.

As we approach White Rock, just before we come to the high 35 foot bluffs I saw a large pine stub standing erect in the midst of the waters, evidently left from the land waste. The 35 foot bluffs are evidently being attacked vigorously by the waves. Some of the residents attribute the wasting away of the cliffs to the frost's action in splitting them off in the spring. In their observation they are doubtless right, but inasmuch as the cliffs are about as steep as they can be now, it is obvious that the waves break up and carry away the debris of the slips as fast as the frost feeds it down, so that the frost merely acts as assistant to the water. The most detailed information gathered concerns the lot of Mrs. Mary Van Wormer (south part of lot 3, Sec. 20, T. 15 N., R. 16 E.), where a whole barn and barnyard have disappeared in the last ten years. As they cannot plow too close to the edge of the cliff all along here for fear of slipping over, it is easy to note each year that the tracks for the previous season are from 3 to 6 feet farther out than they dare plow. A lot of two acres which lay in triangular shape below the higher bluffs at their northern limit and at the Algonquin 18-20 foot levels is practically gone, the width from the road being not more than 50 feet. This would indicate an erosion of 6 feet a year, or if we take the two acres as a strip from the full width of the Van Wormer property (6 chains) it will still mean an erosion of not less than 220 feet or over 3 feet a year. In September, 1897, the distance of the brink of the bluff from a basswood tree on the east side of the road where it first mounts from the Algonquin level was 76 feet. South of White Rock, on B. Hiduler's property (Sec. 32, T. 15 W., R. 16 E.), we find similar erosion and the rates stated are similar, 3 to 6 feet a year.

Up in Huron township, Sec. 12, T. 18 N., R. 14 E., Mr. Tucker reports that a resurvey ordered by the supervisors showed that a man was paying an undue amount of taxes, owing to the great retreat of the arable land. This is in the neighborhood of the Point aux Barques lighthouse and is another place where the present cliffs have cut back beyond the Algonquin, and it may be noted in this connection that whereas the Lake Survey report them as 40 to 60 feet high, in 1896 by tape line they were but 32 to 35 feet high. *A propos* of the tree stubs left standing in the water as witnesses of land waste, Mr. Jos. Grice who was employed under the United States Engineers reports that such stumps were found in water near the Harbor Beach pier, and also just north of the town line, apparently off Mr. Jenks' lot above mentioned, at a point known as Drowned Point from the stumps thus left. These may, however, be the relics of an island known as Elm Island on the old maps, on which a number of islands now no more are put down. He says moreover that the building of the breakwater caused an extra cut of 15 to 35 feet along the shore to the north of its end for the first few years, until it was checked by the fall in lake level, 1885-1896.

Thus, as the general situation of the eastern shore of Huron county is not unlike that of the eastern shore of Wisconsin, so the rate of erosion, judging from the scattering and not very reliable figures above given, seems not dissimilar, perhaps three feet a year as an average, and almost certainly more at exposed points. If now we extend the general slope of the land from Ruth to the White Rock bluffs, a slope of about 20 to 25 feet per mile, out to the lake level, we find that it will strike the same about a mile and a half out. We also find, just as Andrews found, about four miles out a bulge in the lake bottom, and then a comparatively sudden drop, the bulge being nearly hit by the grade line aforesaid. The cliffs near White Rock were not all cut at the present lake level, but a slice was taken off at a level about 20 feet above the present nearly as far back as the present bluffs, and then successive slices farther down, but the erosion has been much faster at the present level, or the time so much longer that the action has overtaken all previous cuts. If we assume the cut to have been at a uniform rate and to have been from the grade line of the general country the cut we have would have taken about 2,800 years, at a rate of 3 feet a year. But as the recent erosion is extra deep at White Rock, it may be fairer to assume an erosion somewhat higher. If we call the time an even 2,000 years the average erosion would be only about 4 feet per year.

If we look at the Lake Survey chart of Saginaw Bay and part of Lake Huron, or at the field sheets of Sanilac county, we shall see the Algonquin 25 foot bench well indicated and running from half to three-quarters of a mile back of the present shore line. But as it is so much higher than the present bench, it would cut the grade line perhaps a mile nearer the shore, so that the total breadth of the notch cut at this level may have averaged a mile or less, not far, perhaps, from the average breadth of the notch cut at the present level, as the notch at White Rock is probably extra deep. We may

also compare the breadth from the present shore line out to the three fathom line. If an equal amount of erosion has been done at each of these levels, and the mean rate of erosion was the same, and we see no reason why it should have been materially different, say 3 feet a year, each notch of a mile or less at a rate of 3 feet a year would have taken somewhat less than 1,760 years. This would imply a rate of 4½ feet at White Rock to produce strict accordance.

Taylor's estimate for the duration of the present lake system from the rate of erosion of Niagara is 2,700 years. In order to bring our figures into any accordance with his (the factor of safety which he introduces by increasing 2,700 to 5,000 to 10,000 seems to be unnecessary), we must assume that the Nipissing erosion was at a slightly lower level and has been hidden by the debris from the later cut at a higher level, so that the time of the Nipissing Lake is not accounted for in our study, just as it is omitted in the work of Dr. Andrews who gets for the duration of the present Lake Michigan at various levels, from 13,000 to 3,000 years, or in another way, using the rate of erosion determined by the Wisconsin Survey, some 4,700 years. I must confess that the character of the stream valleys and the frequent rock exposures near their mouths leads me to believe that in Huron county, Lake Nipissing and Lake Huron were at nearly the same level, and that the cut at White Rock includes the efficiency of them both. In that case the total time since the fall below the 40 foot level in Huron county could be confined within 4,000 years in accordance with all we yet know. A certain check on our results may also be derived from Gilbert's measurements of fluctuation of relative level aforesaid. From the relative strength of the beach lines, we may feel sure that the lake level has remained more than ordinarily constant within the range through which it has fluctuated in the century. Therefore the rate of change of land level must have been below the average. Thus, unless the rate of change found by Gilbert is abnormally high for the century (which of course it may be) it must be below the average rate of change during the emergence of Huron county from under water,* and then supposing that no oscillations of lake level which have occurred have checked its efficiency as a cutting agent, according to the figures at the end of the preceding section the emergence of the last 25

*All the above expressions are applicable to Huron County only, and do not apply to other counties.

feet must be confined within the past 12,500 years (25 ÷ .2 feet per century). We may note that Gilbert's rate of tilting would, if uniformly continued back into the past, change the present lake level into that of Lake Nipissing (7 in. per mile rise N.) in about 14,000 years. In the same way the apparent rate of lowering of the water at the mouth of French River would point to 14,400 years since the water stood at the level of the Nipissing Beach there, and that was the outlet of Lake Nipissing.

In Fig. 4 I have constructed a curve giving my impression of the relative importance, i. e., duration of the shore lines at different levels, taking into account not only the beaches, but the cutting on the east side, and the character of the river valleys. Perhaps it is too daring to attempt such a line which must of necessity indicate more than the facts warrant, though Mr. Taylor agrees with me in the general proposition that there has been more cutting and more time indicated below the 40 feet level than above, but it gives to the eye at a glance my general estimate of the strength of the several shore lines. It may in a rough way, too, suggest, though it was not drawn for that purpose, the relative duration of the several stages of retreat. We see from it that if we assume the time since the fall below 40 feet above present lake level to be 4,000 years, it will be easy to crowd the remaining fall into an equally long interval.*

We see thus that with the scale of time as above suggested, it would be only some 8,000 years since the ice sheet left Huron County. We may double this time and still be in the dawn of history, so that it is not too much to say that the departure of the ice sheet may have been coeval with the great tide of migration of the human race, which in these latter days is just completing the circuit of the globe.†

*Dr. Andrews also finds that around Chicago the combined bulk of the beaches of Lake Chicago, which, in our diagram, correspond to all above the 40 foot level, and a little more, are about equal to those of the present shore line taking it out to where the water reaches a depth of 24 to 36 feet. Here, however, again according to Taylor the Nipissing is far below present lake level at Chicago, and hence the time of its work should be deducted.

†Estimates of the time since the departure of the ice sheet vary widely, but the present estimate, which has little value, agrees with the shorter estimates of time. Compare Upham's discussion of the whole subject, with references to others in the 23d Annual Report Geol. and N. H. Survey of Minn., 1895, and Taylor in Bull. G. S. A., 1898, IX, pp. 59-64, also Moraines of Recession, Jour. Geol. (1895), July, August), V, p. 422, from which paper at least 20,000 years can be inferred for the Terrace epoch in Huron County.

The most uncertain factors in the discussion above are:

(1) The assumption that all the erosion of the lake in the time in question is above present lake level.

(2) The assumption that the rate of erosion of the past sixty years is a measure for that in the more distant past. Now we know that it makes a great difference in the activity of the lake, whether it is rising or falling, and generally, as Taylor remarks, the action is most energetic when the lake is rising. But the period we have studied is long enough to have admitted of several rises and falls due to climatic variations, while according to Gilbert the movement of the earth crust and the erosion of the St. Clair River now tend to produce a slow fall of the lake such as might easily be supposed to have continued since Algonquin time. The more remote we suppose that time, the slower the mean fall must have been than the present rate, so that the erosion would be likely to be quicker. I cannot see that our rate of erosion assumed is more likely to be in error one way than the other.

Of course there have been times when instead of erosion there has been building, and we have made no allowance for them. But there have been such times in the last 60 years, notably the last ten, and climatic variations have undoubtedly produced these alternations all along.

Such considerations only warn us to what a range of error all figures are liable without enabling us to improve those we have given by any change derived from data wholly within the county.

CHAPTER V.

STRATIGRAPHY, DISTRIBUTION AND STRUCTURE OF THE ROCKS.

§ 1. The Cuyahoga or Coldwater shales.

We have in a previous chapter described the character of the rock column. It now remains for us to consider how these rocks are distributed through the county, what modifications they undergo, and what the indications are of their geological history, and, without trespassing too much on the material of a later chapter, what are their characteristics from a practical point of view. In this history we begin with the underlying oldest exposed beds, the blue shales of the eastern coast. Occasionally thin seams of sideritic grit are intercalated, which grow thicker and more abundant near the top. They are at present exposed only near the eastern shore and in the Willow Creek section. Under the cover of drift or in deep wells they are characterized by the lack of good water from the rock. Speaking generally, it may be said that within the region colored on the map (Plate VII) as of this formation, wells in the rock do not yield a satisfactory supply of water, either in quantity or quality, for it is often brackish. The dip* of this formation estimating from the correlations of the deeper wells, is not far from 40 feet per mile and is in a general way on the west, but the line of strike shows a veering from about S. 31° E., which is the strike of the *Romingerina julia* beds from near Point aux Barques, down to the Willow Creek

*Dips: From New River to Grindstone City (1010 — 900 or 1080 — 1000 to 1029), is 47 ft. per mile. From White Rock, which is 560 + 505 feet below the top of the Napoleon, to Sec. 35. Sebewaing, is 39 miles; altitude of the top of the Napoleon in the well there 502 A. T.; altitude of the well at White Rock, 592 (?). Whence (560 + 505) × (592 — 502) ÷ 39 is 29.6 feet per mile dip from White Rock to Sebewaing. From Sebewaing to Ruth, taking the top of the ridge or rock escarpment near Ruth to be the grindstone or the Point aux Barques sandstone, 70 feet above the bottom of the Marshall, we have 505 perhaps + 70 — (592 — 740) ÷ 6 = 59.5 to 71 feet per mile. If we take the bottom of the Marshall series in the flowing Badaxe well, Sec. 19, Verona to be at 320 feet down, i. e. 437 feet A. T., subtracting this from 592 + 396, since the Harbor Beach well begins about 396 lower, we have 551 feet in 16.8 miles, or about 32 feet per mile. Similarly to the edge of the rock escarpment at Sigel or Allen Creek would be (750 — 437) ÷ 11 = 29 feet per mile. The strikes are indicated on the map, Plate VII, with the dip assumed in finding them in feet per mile.

to the south. The dip seems to be greater toward the east. The character of the sediments is quite uniform, as mentioned above, and with what is known of similar deposits elsewhere, we may infer that they are composed of the finer detritus brought down by sediment-laden rivers from the Laurentian highlands of Canada, and from regions which contained much iron, i. e., region of hornblendic rocks. The sea was not very deep and the shore was either not very steep or was yet quite a distance from the present limits of Huron county.

The indications are that the rock surface in this region is nearly a plain, or rather a gentle slope from the ridge or watershed made by the more resistant rocks of the next overlying series. The more important wells that strike this formation, are those at White Rock,

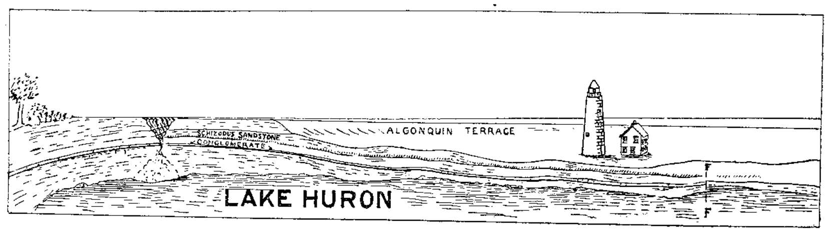


Fig. 5. Ideal view of Point aux Barques lighthouse, showing the conglomerate and the fault. The lighthouse stands on the Algonquin terrace, but to the left, south, the present lake has cut back farther than Lake Algonquin.

Harbor Beach, New River, Grindstone City, Port Austin, Port Crescent, Caseville, Bayport, and Badaxe. The more important outcrops are already partly described in the geological column; additional notes are as follows:

(1) The lower Willow Creek valley gives a nearly continuous exposure largely described in the geological column.

(2) The Point aux Barques section (see geological column, Plate I, and Fig. 5. Specimens No. 19044-19083). In this section we see as we go north and northwest that the beds run downwards from 15 feet at the south end of the bluffs to 6 feet above lake, near the lighthouse. Just beyond the lighthouse the calcareous conglomerate disappears, and is replaced by another layer farther down, the exact and critical point not being exposed when we were there. But this is probably the point spoken of by Winchell where there is a fault, the most extensive dislocation seen south of Mackinac," as he says. The neighborhood of the fault would account for the abnormal dip of 1°

to 1½° to the northeast. The general relations are illustrated by the perspective diagram, Fig. 5, which is not drawn rigidly to scale. There are some errors in Winchell's account, as where he speaks of the lighthouse being one mile east of Willow Creek, instead of 2, and of the dip of the sandstone being southwest instead of northerly, which it is in reality. Southwest is of course the general direction of dip in this region. Rominger's description is more accurate (Geol. Sur. Mich., Vol. III, p. 73). The palæontology of this very important section is given at length in Chapter X, § 3. The shales of this section are also visible farther south in a number of ravines in Secs. 12 and 13, Huron, cutting the bluffs which are at an altitude of 30 to 39 feet above lake and overlook the Algonquin terraces.

(3) Port Hope. A sandy shale occurs along shore and 50 paces south of mill at the water's edge, also in the bed of Diamond Creek for a few feet above its mouth. According to Rominger it also occurs one mile and a half north of the town and in the lake bottom close to the dock. These beds appear to be palæontologically equivalent to those at Harbor Beach.

(4) Near Harbor Beach are frequent outcrops for two miles south practically continuous with the exposures at Rock Falls. Then again north of the town in trenches and ditches up to the town line (N. line of § 1, T. 16 N., R. 15 E.), the shales and bands of arenaceous shales heavily charged with carbonate of iron are exposed. The most widespread form in all this section from Port Hope to an exposure in a wayside ditch on the line between Secs. 30 and 31, T. 16 N., R. 16 E., is *Chonetes* (*pulchella* Win? =) *scitulus*, Pl. X, Figs. 1 and 2; other forms are *Productus lævicosta* and *Conularia gracilis*.

(5) Rock Falls. "The same beds with Chonetes and impressions of Goniatites are well exposed at Rock Falls, the ripple-marked surface of the ledges * * * being covered with Caudagalli fucoids in relief, as well as other singularly-shaped prominences of organic origin."* At the mouth of the stream (N. E. quarter Sec. 19, T. 16 N., R. 16 E.) the water flows over a ledge of shale, and shaly sandstone in alternating beds, with a fall of three feet. The full section exposed was about ten feet. A similar exposure was observed about a mile below this. (Gordon.) The fossils from this locality are Nos. 19146-19150, and palæontologically it is said by Mr. Cooper to be equivalent to the Moot's Run section in Ohio. These same beds occur obscurely at the base of the Algonquin bluffs on and near the north line of Sec. 31, T. 16 N., R. 16 E.

*Rominger, loc. cit., p. 76.

(6) South of White Rock for about a mile occur arenaceous shale beds in steep bluffs of 25 feet elevation above the lake. The same beds are beautifully exposed for about an eighth of a mile in the creek near the center line of Sec. 32, T. 15 N., R. 16 E., and are finely jointed; one set strike S. 52° W. dip to N. N. W., a poorer set S. 70° E. Indistinct cast of fossils, among them Goniatites, are found on the surface of the arenaceous flags. (Rominger loc. cit., p. 76.) These shale bluffs are illustrated and results of tests of them described in Vol. VIII, Part I on Clays and Shales by H. Ries. See also Ch. VII.

§ 2. The Marshall sandstones.

By the time of the next series above, that great elevation of the American continent, which marked the close of the Palæozoic era, had advanced so that the shore line was immediately adjacent to Huron county, and sandstones and coarse rocks prevail. These rocks are far more porous than those which preceded them. The figures of the following table (II) gives some idea of the physical properties of these rocks in this respect. The rocks of this series can be readily traced, at least so far as the upper part is concerned, since they are the most prominent source of water in the county and have been pierced by numerous wells. The water derived from them is much freer from mineral matter than the water from the beds above and below, being so characteristic that Prof. Davis said he could recognize "sandstone water" almost by the taste. Within the area covered by this formation, therefore, one can be almost sure of obtaining good water soon after passing the line between surface and rock. As it passes under cover to the southwest it grows more salty, which is not surprising since the salt of the Saginaw valley is largely obtained from this very formation. But it is nowhere in the county undrinkable and the salt in the deeper wells is probably largely from imperfect casing out of the overlying waters. In Sec. 19, Verona, around Elkton, and almost anywhere near the shore level, i. e., not over 14 feet above it, it furnishes flowing wells, and in many cases where the wells do not flow, as around Owendale and Soule, they once flowed, but now the drain on the formation has lowered the head. It is rarely that the wells are cased deep enough. They should be cased at least down to the top of the Marshall to obtain the best results.

Table II. Physical properties of sandstones, etc. All weights are in avoirdupois ounces (16 to the lb.) per cubic foot and we have assumed that 1000 oz. of water = 1 cu. ft. (which is true nearer than the limits of error).

A. Character of rock.	B. Number of survey specimen.	C. Sp. Wt.	D. Weight wet.	E. Weight dry.	F. Porosity.
Napoleon sandstone: Babbit quarry	19161	2.8	2,339 ±27	2,067 ±57	27.2 ±3.0
Hat Point	19087	2.8	2,718 ±300	2,615 ±300	10.3 ±2.5
Do	19102	2.8	2,308 ±52	2,040	26.8 ±5.2
Grindstone (scythestone of the Huron Grindstone Co., volume computed from dimensions)	19017	2.61	2,420 ±50	2,280 ±20	14.0
Cass river grindstone	19152	2.57 ±.04	2,290 ±40	2,070 ±20	22.0
Arenaceous shale	19092	2.64	2,500 ±120	2,360 ±90	14.0
Fine grained conglomerate of Willow Creek	19108	2.59	2,520 ±240	2,480	4.0
Sandstone near Point aux Barques lighthouse	19046	3.18	2,850 ±50	2,700 ±50	15.0
Bayport limestone	19006	2.69±	2,690 ±350	2,690 ±350	....
Bayport limestone	Report Vol. V.	2.72	....	2,720 170 bbls.	....

The physical characters and subdivisions as they are shown along the north coast between Oak Point and Grindstone City are quite fully described in connection with the geological column. The Badaxe well affords the most detailed account to the southeast on Sec. 19, Verona. As we go southwest the lower part of the series seems to become less sandy, showing that we are going away from a shore line to the northeast, along which this formation was deposited, and the whole Marshall appears in the drillers' records as a hundred

feet or so of white sandstone at top, very full of water, representing the Napoleon, or some part of it, and below this, "red rock," "paint rock," "iron ore" and similar expressions are used in describing it. We can trace this red rock so continuously along* that there can be but little doubt that it represents the Lower Marshall of the north coast. Red rock also occurs so constantly (separated by about 18 feet of blue shale), under the salt rock of the Saginaw River, that as I am informed by Mr. J. Coreyell, it is often referred to in contracts for boring wells. That the Marshall should be represented by red shales as we pass from the shore is quite natural, when we consider the very ferruginous character of this lower Marshall, due as I have suggested it may be to the fact that there were large areas of basic greenstones, hornblende schists, and similar ferruginous rocks in the region from which it was derived. In Winchell's 1861 report (p. 91) he was in doubt as to how the Saginaw well section should be correlated with the coast, and at that time he was inclined to regard the shale reached in the Saginaw well immediately under the brine sandstone as the "thickened separating shale lying between the Napoleon and Marshall Groups." In this I believe he was right. Later and very likely properly, in view of the evidence then before him, perhaps also influenced by Rominger's erroneous views as to the Huron county stratigraphy he seems to have swung to the other conclusion, and to have thrown together the Napoleon and Marshall, as one group under the name of Marshall. With the evidence before us I believe that the other alternative must be taken that the whole Marshall of Huron county is not represented by a hundred feet of sandstone beneath Bay City and Saginaw, but that the lower part becomes shaly, and not distinguishable from the formation beneath. In my report, Volume V, I followed Winchell's later view, but I would now draw the line, for example, in the Bay City well (Pl. VI) of that volume for the base of the lower Marshall as we have defined it in Huron county somewhere near 1285 feet.

Though the dip of the Marshall is in a general way like that of the underlying formation, it has several minor undulations at least in the top of the formation (see Fig. 6), and it is probable that these are, like those at Point aux Barques lighthouse and

*See Sovereign's well, Sec. 30, Lake; Sec. 35, Caseville; Sec. 18, T. 16 N., R. 10 E.; Meredith's well in Oliver; 200—300 ft.; Elkton, Sec. 10, T. 16 N., R. 11 E., Pigeon, Sec. 11, T. 16 N., R. 10 E.; Mason's well at Bayport, Sec. 36, T. 17 N., R. 9 E.; at the bottom of Voltz's well 350 feet deep, Sec. 10, T. 15 N., R. 9 E., and in Beck's well, 490 feet deep, Sec. 16, T. 15 N., R. 9 E., both near Sebewaing.

the Sebewaing coal mines associated with faults of small throw. The capping of Learned's hill on Sec. 31, Port Austin, seems to be left as a small synclinal, since we find on Sec. 35, 800 paces N. and 135 paces W., that the Leiopteria beds exposed in the bluffs of the Algonquin level, to the east of the road dip as much as 5° to northeast and along the shore we find between Hardwood Point and Flat Rock Point a blue shale which seems to be mixed with a breccia of angular pieces of the sandstones with which it is associated. It, too, seems to dip about 4° E.

Connected with this synclinal fold (from which Rominger may have derived his idea of the correlation of the Flat Rock, Hat Point, and Point aux Barques sandstones), may be the phenomena on Sec. 5, Bloomfield, along Willow River. As we follow this stream up from the section exposed at the bridge (p. 24), on Sec. 4, Huron, toward the south we find blue clay shales and arenaceous flags, undulating and more or less ripple marked but in general with southerly dips. As we pass into Sec. 9, Huron, thicker and coarser beds begin to appear above and gradually extend down to the water line, and sandstone balls (cemented with kidney iron ore), are common. By the time we come to the south line of Sec. 8 there is an overhanging conglomerate with thinner slabby sandstone underneath, and some 300 feet farther south, there is 12 feet of sandstone which might at first sight be correlated with the Point aux Barques sandstone. This it is not, however, but a coarser facies of the grits of the grindstone quarries, for south of and above it we find the well marked zone of *Camarotoechia camerifera*, and *Romingerina julia*, just as it occurs above the grindstone quarries, on Sec. 26, Port Austin. Besides we can trace the Point aux Barques sandstone along continuously by well records and by outcrops on Secs. 22 and 35, Port Austin, and Sec. 1, Dwight, and we find it succeeding the *R. julia* zone farther south in Sec. 20—appearing first at the top of the bank and gradually working down. The *R. julia* zone can also be plainly recognized in a well sunk near the north quarter-post of Sec. 21, Huron, and gives our opportunity of most accurately determining the general strike for this region, viz., N. 31° W.*

*In Port Austin on the north line of Sec. 26, the *C. camerifera* zone is from 14 to 18 feet above lake; on Sec. 17, Huron, it is from 48 to 58 feet above lake and on Sec. 21, Huron, about 60 feet above lake. Hence we must allow for difference of altitude and for a dip of some 30 to 50 feet per mile in estimating the strike. Also from the Point aux Barques sandstone, which crosses a little north of the north corner of Sec. 27, Port Austin, and also near the south quarter-post of Sec. 26 and the southeast corner of Sec. 35, at about the same altitude, and on Sec. 20, Huron, is at a slightly greater altitude, we have a course of almost precisely two north to one west, or N. 27° W. With that strike the dip from Sec. 27, Port Austin, to Sec. 21 will be (58-18) about 40 feet per mile. The dip from Grindstone City to Port Austin as derived from the wells is (1160-1010 or 1225-1080) i. e., 150 to 145 feet in 5.5 miles, or 27 feet per mile while that from Grindstone City to New River is (1010-900 or 1080-1000 or 1029) more than 47 feet per mile. In the same way, comparing the top of Huron City hill with the sandstones apparently corresponding in Willow Creek, we have (104-20) ÷ 2 = 42 feet per mile. The flattening of the dip as we approach the Port Austin synclinal seems evident.

This sandstone disappears before we come to the south line of Sec. 28, though it is 8 feet high about a quarter of a mile north of the line. Continuing south we soon encounter another sandstone, which we might at first take for a higher bed, say the Port Austin sandstone, which can be traced by wells, etc., from Port Austin to outcrops on Sec. 3, Dwight, and thence close to the surface all the way to Robinson's Hill on Sec. 13, Dwight. But this is rather too far east, especially when we allow for some fifty feet difference in altitude, and moreover we seem to find the sandstone rising as we go up stream, appearing on the eastward turns of the stream, about 3 feet above the water at the south line of Sec. 32, Huron, and last visible in the west bank in Sec. 5, Bloomfield. While it is difficult to distinguish general structural dips from the minor undulations and cross-bedding prevalent through all this series, the appearance is to me certainly as if the Point aux Barques sandstone rose again. This may be one end of a gentle synclinal, of which we find the other end near Port Austin. We have accordingly made the lower boundary of the Marshall swing to the west here, and this brings it into line with the underground escarpment of rock which Gordon found, which in default of any better evidence we follow.*

He describes it as follows: "From a consideration of the well-records it is evident that a concealed rock escarpment representing the eastern limit of the Marshall occurs along a line approximately corresponding to the township line between Sand Beach and Sigel townships. At M. Cowper's, N. W. Cor. Sec. 19, Sand Beach, this sandstone comes within 6 feet of the surface, while R. A. Brown's well, 660 paces east and north, shows 48 feet to rock, which is a shale evidently belonging to the Coldwater shales. Again in Sec. 1, Paris, at Susalla's, the rock is but 6 feet below the surface, while a short distance, ten to fifteen rods, north of this the rock comes within 2 feet of the surface, and at Lock's farther south, it is but 12 feet to rock. Toward the east within about half a mile it is said wells fifty feet deep do not reach rock. In Sec. 12 of Sherman town-

*This escarpment is cut and exposed by Allen Creek in Sec. 25, Sigel, T. 16 N., R. 14 E., about 400 paces N., and 400 paces W. of the southeast corner and is apparently close to the bed of the stream for 100 steps.

ship, at Hoeldke's it is 54 feet to rock. At Parisville it is 90 feet. Wells to rock are not numerous enough to trace the line accurately, but the line drawn on the map approximately represents this concealed escarpment. No indication of this ledge appears in the surface configuration. East of Ruth no wells are found that reach rock. Several wells occur toward the south and west. Those to the southwest show that the eastern limit of the sandstone found at Susalla's, northwest of Ruth, passes to the southward of the latter place, crossing the county line into Sanilac county near the southeast corner of Sec. 31, T. 15 N., R. 15 E."

If we could see this escarpment, we should probably find that like many escarpments it was cut into by little streams that have crossed and cut it back. This might not be so if it were a single bed of sandstone with softer beds on top. It might then be the divide all the way and run with comparative regularity. But we know that to the west are the heavier sandstones of the Upper Marshall which would therefore be the main divide. For a mile or so west of this line, therefore, one is not sure of finding good sandstone water, but the chances are better the farther west of the line one is and the sooner rock is reached, while if the rock is deep, as in the wells on Secs. 20, 26 and 16, Paris township, the chances for good water are poorer.

As we have remarked, and as the map (Pl. VII) shows, there are enough outcrops of the three lower sandstones, the grindstone quarry, the Point aux Barques and the Port Austin, to start them off from the shore and it is not difficult to break up the Badaxe record as we have done into a series of heavy sandstones above the Upper Marshall, and then a triple sandstone series above the bottom in shales, but it may be that the parallelism thus suggested between this triple sandstone and the three sandstones at the north end of the county is purely fanciful, except in the steadily decreasing proportion of sand in the lower part of the series.

If we do assume such a parallelism then in the Badaxe well the Lower Marshall has already shrunk from 260 feet to 177 feet. Some shrinking we should expect, as the beds at the north end of the county show unmistakably in their beachworn fragments that they were immediately adjacent to the shore.

The fossiliferous series on Sec. 35, Port Austin, T. 19 N., R. 13 E., the Marshall *par excellence*, palæontologically speaking, can be

traced down into Sec. 2, Hume, and the isolated outcrop, Sp. No. 19100, which is found on Sec. 10, Hume, at Port Crescent, seems to belong in the same series. The sandstone of Hat Point can be followed some distance south-southeast from the shore in bluffs in Sec. 7, and reappears in Sec. 20, Hume [Sps. Nos. 19096, 19097] thus giving us a good strike similar to that around Point aux Barques, but more to the north [N. 15° W.] The escarpment fronts east and all the indications are that the dip is the normal one to the southwest. But it is obvious that if the marked easterly dips which we had around Hardwood Point were long continued, we should have the Port Austin sandstone, which ran below the water line at Flat Rock reappearing from the waves. As already suggested, there is probably a little fault, enough only to counterbalance the abnormal dips in part, for we find the Port Crescent well only 25 feet deeper than those at Port Austin. The dip from Port Crescent to Caseville is, according to the wells, about (1750-1250÷11.7) 43 feet per mile on an average. This dip is probably a little steeper than that for the middle of the distance.*

Allowing for 40 feet dip or less and a strike not more north than N. 15° W., we find that the Hat Point sandstone should extend to Filion, and in confirmation we find on Sec. 20, Lincoln, a well with abundant water immediately at the top of the rock. It should again appear at the top of the Badaxe well on Sec. 19, Verona, and we find the first hundred feet of rock of that well and the wells on Sec. 24, Colfax, mainly sandstone, so that we should find the bottom of the Upper Marshall according as we use the dip derived from Harbor Beach, or a dip of 40 feet to the mile, some 2½ or 3 miles to the east of Badaxe.

Thus we find it continuing into a ridge in the rock surface, which extends on toward Tyre, a ridge which underlies the higher part of the county, though the rock surface is not anywhere near so irregular as the present surface, since wells upon the ridges of till strike the rock deeper down than those in the valleys. And finally just outside the county we find outcrops of sandstone once more, near Tyre where the old channel between the lakes around the Point has scoured down to rock. But to get the most close parallel

*From Sovereign's well, Sec. 30, Lake to Adams' well at Caseville at about equal elevation. the sandstone sinks from 87 feet to about 120 feet below surface. They are about 2.5 miles apart at right angles to the strike which would make a dip of only 21 feet per mile. Comparing Sovereign's well and Leipprandt's well, Sec. 13, T. 17 N., R. 10 E., we have similarly 228-27—(87-25) ÷ 3.1 = 45 feet per mile.

to these Tyre outcrops, we must retrace our steps, and begin at Little Oak Point where, exposed in the Babbitt sandstone quarry and not at present worked, we have a coarse and porous sandstone. There is also sandstone on the south shore of Rush Lake, and we can trace the sandstone along, very near the surface in Sec. 6, Meade, exposed on the Pinnebog in Sec. 5 adjacent, extensively exposed along the road in the ditch on the north line of Sec. 16, Meade, and making a marked ridge which runs southeast through Sec. 15, Meade. The samples taken here are extremely like those from the Babbitt sandstone quarry. (Sps. No. 19101 and 19102 like Sp. No. 19161.) These sandstones are evidently near the center of the Napoleon sandstone and the summit of the prominent ridge in the rock surface. Hence we may obtain from it some idea of the general course of the strike which evidently veers from southeast to south. We do not know just how far this sandstone horizon lies below the top of the Napoleon sandstone but wells like Sovereign's on Sec. 30, Lake, Lounsberry's on Sec. 3, Chandler and the Badaxe cemetery well on Sec. 24, Colfax, make it obvious that there is a considerable thickness of sandstone and nothing of importance but sandstone between it and the top of the Napoleon. This latter we assume to be near Oak Point where the coarse water-bearing sandstones are overlain by bluish drab-colored limestone ledges of dolomitic or partly arenaceous character, fossiliferous, as described by Rominger (Vol. III, pp. 70, 103), and apparently similar in character to outcrops found on Secs. 18 and 19, Meade (T. 17 N., R. 12 E.). This line seems to be a well defined one in almost all the wells, being generally the one where a flow of water, or a new flow of water was struck. The Napoleon sandstone is much more porous than the overlying beds of the Michigan series. (Cf. Table II.) Tracing the top as best we can in the records of the wells, we have platted the observations in Fig. 6 and sketched in contours accordingly. The numbers of this map are of practical importance, for by subtracting the nearest one from the altitude of any point above tide, as given in Plate VIII one may form an estimate as to how far drilling should be carried for the best results. It will be noticed that the surface of the top of the Marshall as thus delineated is not accordant with, and is much more irregular than, the bottom of the formation in dip and strike. It is thrown into a series of gentle folds pitching toward the northwest and corresponding in a general way to that slight fold which we have

spoken of near Port Austin and also to the fold in the coal mine at Sebewaing. As there may be some hesitation in admitting such a comparatively complex stratigraphy on the somewhat uncertain evidence of drill records, it may be well to mention some confirmatory facts:

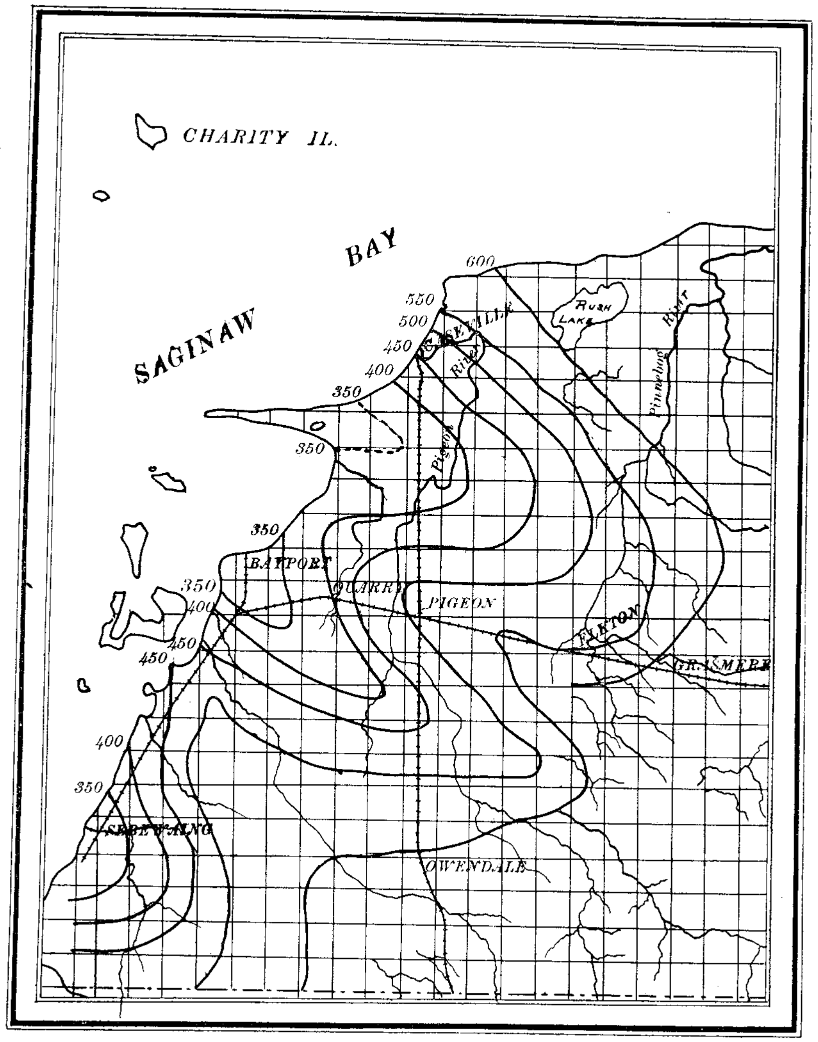


Fig. 6. Contours showing the elevation of the top of the Upper Marshall above sea level.

(1) The dips of the Bayport limestone on North Island, on Big Charity Island and at the quarries are, as indicated on Plate VII, in harmony with the structure assumed.

(2) At a nearly uniform distance above the top thus determined there is a gypsiferous zone, so that the deep rock wells in the area where the top of the Napoleon is less than 550 feet above tide, are pretty apt to be strongly mineralized. In fact the tracing of the gypsum had led me to some such stratigraphy long before the contours of Fig. 6 were drawn.

(3) The records of the Caseville and Bayport deep wells show that there is nowhere near the usual grade per mile between these wells.

(4) The old rock surface as given on Plate VII seems to show that the streams which cut it were adjusted to some such structure as here indicated.

§ 3. Lower Grand Rapids, Michigan series.*

In this the Lower Grand Rapids complex we have a series of considerable interest, both theoretically and practically, but one which taxes all the resources of the geologist to study, as outcrops are very rare. We refer to the series of dolomitic limestones, gypsum beds and shales, which we call the Michigan series. The harder beds of dolomitic limestone are the most likely to be left in ridges on the rock surface, and therefore the most likely to be exposed, and these bluish argillaceous limestones resemble very strongly those used near Milwaukee for the production of Milwaukee cement, which were also formed under similar geological conditions, though not at the same time.

The Marshall was, as we have remarked, a period of uplift and at least for the earlier part of the time a period of rapid degradation of the land, i. e., of wet climate. Toward the end of the time the

*In Volume V, I included this series in the Grand Rapids, rejecting the term Michigan Salt Group as used by Winchell, because there are well founded and generally accepted objections to such terms as Salt Group, as applied to groups of rocks, and especially since we have in Michigan another formation much richer in salt, which material is, so far as yet known, merely a mineralogical curiosity in the "Michigan Salt Group." I then proposed to replace "Michigan Salt" by "Grand Rapids," a place identified with the manufacture of plaster from gypsum, so characteristic of this formation, including also in this term the limestones which were according to Winchell and Rominger equivalent. But I have on farther consideration decided that I ought to have retained the part of Winchell's name which was open to no objection, viz.: Michigan, and especially because during the formation of the series in question Michigan was a separate province to which these rocks were confined. I used the term Grand Rapids group in a more inclusive sense than the "Michigan Salt Group" of Winchell to include also the overlying "Carboniferous limestone" of Winchell, the Bayport or Maxville limestone of this report, which has also been well exposed at Grand Rapids. Since that time, however, the records at Alma and Midland and South Saginaw (Salina) with the samples preserved, together with the older records recorded in Vol. V, have shown that the gypsum beds and the characteristic shales associated are widely persistent and need not be confounded in one group with the limestone above, and at the time of formation of this group Michigan was a separate geological province, through which these rocks were quite uniformly developed in the basin in which they were formed. Their correlation with the Burlington and Keokuk, i. e., Augusta limestones of the Mississippi I have already mentioned (Chapter II, § 4).

climate may have become dryer, for the Napoleon is freer from mud, and more of the nature of a glass sand, with the grains of quartz well rounded and freed from foreign ingredients. I dwell upon this point because it has some bearing upon the coal question. Coal has been reported below the coal measures in a well on Sec. 2, Dwight, T. 18 N., R. 13 E.* and from the Michigan series in Sovereign's well on Sec. 30, Lake, T. 18 N., R. 11 E., also on Sec. 21, T. 15 N., R. 9 E. about 75 feet above the white sandstone of the Napoleon.

While the Marshall very frequently contains coaly bits and fossil rushes, it has never been found to contain workable deposits of coal, and though the conditions during the time of the Marshall and the Michigan were in one way favorable, for the upper part was just about water level and small coal pockets prophetic of the genuine coal measures will probably be found in them, the probabilities are against finding workable coal in the Michigan series. For one thing, the abundant vegetation required to make coal beds requires a moist climate. On the other hand the accumulation of gypsum requires a reasonably dry climate, and we are not therefore likely to find much coal immediately associated with gypsum in the Michigan series. The coal reported from the Michigan series is likely therefore to be slight in quantity, and in most cases reported is likely to turn out black shale.

The conditions of formation of this series seem to have been as follows: The uplift of the Marshall had proceeded so far that not only Canada to the north, but northern Ohio and southern Michigan were out of water, and in the enclosed basin, thus formed, no extensive river entered, capable of keeping up the supply of water against the evaporation of a hot sun. The deposits must have been slow compared with those of the Marshall preceding. Limestone might be directly precipitated, and in that case would be likely to be free from magnesia, or the lime might be deposited in the shells of the animals. Fine mud would slowly form, and one of the most characteristic features of this formation are the beds of exceedingly fine clay, often quite plastic. It is likely that some of these will be valuable, if easily accessible. Finally after a sufficient time to allow of the concentration of the sea-water gypsum was deposited. This would be interrupted of course by variations in the wetness and dry-

*Cf. Winchell's Report, 1860, p. 74.

ness of seasons, and the cycle above mentioned was repeated with variations until a depression let in the waters of the open sea once more.

Just below water level at Oak Point are loose fossiliferous slabs of argillaceous limestone which might well be a good hydraulic cement rock. The limestone near Oak Point we lose sight of upon the surface* unless the limestones around Soule are of the same horizon. But the Soule limestones seem to be about 70 feet above the bottom, somewhat higher in the series, and are underlain by quite a thickness of dark blue shale, often reported as black, or even as coal,† before we come to the Napoleon. We find limestones extensively exposed on Sec. 24, T. 17 N. R. 11 E. and on Sec. 19, T. 17 N., R. 12 E., along the valley of the Pinnebog, and they seem to come close to the surface at a considerably greater altitude on Sec. 18, T. 17 N., R. 12 E. (Specimens Nos. 19103-5, 19009, 19222-23.) Then as the formation swings around in a synclinal following the contour curves of the Napoleon (Fig. 6), we lose sight of these limestone beds, though they are suggested by the record of Klemmer's well, Sec. 7, Colfax and some of the wells in Grant township, until we get down into Tuscola county, where similar beds are exposed above and below Cass City.

The shales with which they are associated are sometimes reported as black, but all the samples seen show only dark blue shales. Like the limestone, however, they are more or less pyritiferous. They are around Sebewaing often very fine grained and sticky, but vary somewhat in physical character from point to point.

Not far above the Soule limestones, near Soule, about 100 feet above the bottom of the formation is a gypsum bed, which grows less and less to the southwest. We may infer this position from the facts reported that gypsum was dredged from the river at Caseville and found in shallow wells and was first encountered in Codey's well in Sec. 24, T. 17 N., R. 11 E., and in shallow wells on Sec. 25, immediately south, whereas in Collison's well, Sec. 15, Fairhaven, the gypsum is probably not so far above the Napoleon sandstone, and in Bauer's well, Sec. 8, Sebewaing, I can find no trace of it, the whole thickness of the formation having dwindled from about 200 feet to 125 feet. Supposing it to be a hundred feet above the Napoleon, and that is about the relative position at Alma and Midland, we may trace its outcrop on the rock surface of Plate VII, by seeing where a surface 100 feet above the surface outlined by the contours on Fig. 6, would cut the surface indicated by the contours of that plate. For example, the surface of the Napoleon is about 500 feet above tide near the southeast corner, Sec. 5, T. 17 N., R. 11 E. and hence the gypsum bed should be about 600 feet above tide there. But the rock surface, cf. Plate VII, is also about 600 feet above tide. Hence the gypsum should strike the rock surface there. Thus we can follow point by point the extension of the gypsum bed. We may control and check this somewhat theoretical location by observations upon the character of the well water. For not only is gypsum somewhat soluble, so as to strongly impregnate the well water of any well which strikes it, but the evaporation went on so far as in some cases probably to throw down a little salt, for from only 100 feet depth Mr. Leipprandt on Sec. 13, T. 17 N., R. 10 E., gets a very strong brine. If rock salt was not formed, the sea water must have been at any rate a concentrated brine, which would be more or less entangled in the pores of the rocks laid down. Hence wells drawing water from this formation, would be strong of sulphates (gypsum is sulphate of lime) and very probably salty.

*Although it is not uncommon to find a limestone just above the Napoleon sandstone in the wells, e. g., Bauer's well on Sec. 8, Sebewaing, and Haffner's well on Sec. 34, Fairhaven, T. 16 N., R. 9 E.

†Sovereign's well on Sec. 30, Lake.

Now we have, to confirm our line of farthest extension of gypsum as drawn upon Plate VII, the following facts:

In Caseville Harbor it appears to have been dredged, and at Mintline's place near by, it is reported to have been struck. To the southeast on Sec. 1, T. 17 N., R. 10 E., Adams' well found salty water at 93 feet depth which was removed by casing to 112 feet. Over on Sec. 2, Libby and Gardner both have wells strong of sulphates, and to the east on Sec. 6, Chandler, near the east line there is a salt spring and Woodworth's well near by on Sec. 5 is quite brackish. In Sec. 8 and also on the north side of Sec. 9 we find wells strong of sulphates, but not so salty (perhaps the salt bed thins out as we approach the edge of the basin).

On Secs. 16, 17, 18, we have wells charged with sulphates. To the east of these sections we have a very different water, very free from mineral matter, and there are no signs of the gypsum, except that on Dufty's place there is a sinkhole which might suggest gypsum. This, however, probably comes from the collapse of some cave in the limestones beneath the gypsum. On Sec. 24 we find in the south part wells and reports which indicate gypsum, and most markedly so in the next section south, Sec. 25. On Sec. 36 we still find records and waters that indicate gypsum, and even over on the southwest corner of Sec. 6, Colfax, then the line of gypsum extension swings north, the Elkton wells not being strongly mineralized, and follows near the north line of Oliver township.

As it advances into Caseville the gypsum seems to be cut into by the old river valley. Otherwise it would cover practically all this corner of the township, though the anticlinal indicated in the Napoleon sandstone by Fig. 6 would carry it clear of Berne.

Then apparently it follows down the old river valley which is quite natural as it would easily be dissolved and eroded, but finally extends over it, as we find highly mineralized wells on Sec. 23, and at Winsor, and finally one on Sec. 10 near Owendale, which only penetrates a short distance into the rock. From a well on Sec. 33, Oliver, a foot of plaster is also reported, but none of the waters in that region indicate any such extension. In fact as to the extension in Sec. 23 and Winsor, it must be remembered that it is by no means necessary that wells strong in sulphates should have their sulphates derived from gypsum, or from sea-water at all. Sulphates may be derived from the oxidation of sulphides of iron pyrites, etc., which are abundant in the rocks of this and the over and underlying series. Hence sulphated water can be used readily only as confirmatory of evidence which in the direction of Owendale is scanty. But turning northward again as is required by the anticlinal indicated by Fig. 6, in the Napoleon, we find in Secs. 28, 29, 30, and in the north part of Secs. 31, 32 and 33, Winsor, T. 16 N., R. 10 E., a group of wells very strong in sulphates and cathartic. This group we can trace on through Secs. 25 and 26, Fairhaven, and here we are quite near to Collison's well on Sec. 16, from which we have seen samples of gypsum. This well is in the midst of a group of wells which all are heavily charged with sulphates.

Over on the southwest side of the anticlinal which runs up here (indicated by the rise in the Napoleon in Fig. 6), in the Sebewaing coal basin, the gypsum does not seem to have been formed, judging from the well records and samples, and hence we have extended this line no farther in that direction. The Michigan series as a whole still occurs, with characteristic, fine, plastic, blue or gray shales, and dark blue or brown, pyritiferous dolomites, and the wells which pass through it are liable to be rather heavily charged with sulphates and salt. The most detailed and accurate record is that of Bauer's well in Sebewaing, Ch. V, § 6. The fact that the gypsum does not extend here may be explained by supposing that at the time of the gypsum formation the sea had dried so much as to have shrunk away from this part.

In some parts of the basin at least there are probably other beds of gypsum above this lowest which we have just followed. Such are indicated by the salt spring charged with sulphates on Sec. 16, Caseville, and by the fact that Leipprandt who makes salt from a well 100 feet deep on Sec. 13, Caseville, also has a well strong in sulphates only 55 feet deep. Schubach's well on Sec. 23, and Lutson's on Sec. 32, Caseville, and a well on Sec. 4, Winsor, all seem to point to a higher bed somewhere about 175 feet above the Napoleon. According to F. Mueller a gypsum bed was struck in wells on Sec. 3, Winsor, and large specimens of a good quality of gypsum were shown me. It was said to have been met about 32 feet down. If in place, which I doubt, it must be at almost the extreme margin. Wells near by show a much greater depth to rock, however, and the gypsum seen may have come from the drift, like blocks of gypsum found on digging a well in Sec. 26, Caseville, T. 17 N., R. 10 E. The upper part of this formation is shown in the deepest well on Sec. 5, Winsor, and is a fine grey shale, somewhat calcareous, with narrow seams of sand, and somewhat pyritic, but in general very fine grained. These upper shales are apparently lighter colored in the northern part of the county than the shales in the lower part of the series. Near Sebewaing no such contrast can be observed.

Concerning the fossils of this formation, see Chapter X.

§ 4. Bayport (Maxville) limestone.

This is one of the best exposed and most fossiliferous of the formations of Huron county. It is the only characteristic representative of the great series of limestones of the Mississippi valley. As I have mentioned in my account of the geological column, in Chapter II, it represents the Maxville limestone of Ohio, and the Upper St. Louis limestone of the Missouri Survey, and probably marks the epoch of depression which admitted the open sea once more into the basin of Michigan (Fig. 2), and put an end to the separation of that basin into a distinct province by itself that characterized the epoch of the Michigan series. The deposition of gypsum might have been terminated in two ways,—either by an increase in the precipitation and supply of fresh water, or by an opening to the sea. The characters of the Bayport deposits, clear limestones and dolomite, and limestones, and white sandstones, crowded with life, and yet comparatively free from mud, indicate that the climate remained dry,—that it was not the former alternative but the latter that took place. This formation is characteristically full of chert, chalcedonic and clay nodules, often a genuine limestone, about 95% Ca CO_3 with little magnesia but generally impregnated with silica, and it abounds in corals, which generally prefer clear water. Signs of vegetation are rare. From all this we may infer that at this time the climate continued dry and hot as in the previous epoch, but that the Michigan basin became an arm of the great interior sea. The thickness of this formation around Bayport is about fifty feet and the indications are that there is a considerable thickness all along that edge of the basin, but as we go southwest it seems to diminish considerably in thickness, until around Sebewaing we cannot safely assign more than 27 feet to this formation. Brown, yellow and white, not blue nor black, are the more characteristic colors for this formation. On Charity Island the formation is quite well exposed, and has been described both by Winchell and Rominger. Winchell gives the section on the north side of the island as follows:* C. Limestone, areno-calcareous, containing Bryozoa, Cyathophyllidæ, and Allorisma 10 inches. B. Limestone with cherty nodules 10 inches. A. Sandstone, calcareous, obliquely laminated 4 feet. "Some portions of A are well characterized sandstone of a whitish or grayish color. The laminæ extend from top to bottom of the mass, dipping northwest at an angle of about 45°. They are quite undulating and even contorted, and the whole mass shows something of a rude concretionary structure." This cross-bedding of the sandstone is like that met with in a sandstone in similar relation to the limestones on the Bayport quarry on Sec. 5, T. 16 N., R. 10 E., at a depth of from 25 1-3 feet to 29 feet [Fig. 9]. It also reminds one of the abnormal dip of the lamination in the type exposure of Winchell's Parma sandstone (Report, 1860, p. 113). The "rudely concretionary structure" is evidently the same as the anticlinal of Rominger's description (Vol. III, p. 119), who describes the section as follows: Upper horizontal

*Report, 1860, p. 102.

beds, a pure lime rock, free of sands, with numerous flint nodules, and interlaminated with thin seams of calcareous shale with *Lithostrotion proliferum*, *Syringopora ramulosa*, *Fenestella*, *Polypora*, *Productus flemmingii*, *Allorisma clavata*, and fish teeth not abundant, 8 feet. Lower beds lying in a discordant stratification beneath the upper in an anticlinal, the higher ledges arenaceous but with lime prevailing, with flint concretions, *Zaphrentis spinulosa*, *Lithostrotion proliferum*, ripple-marked, 5 feet. Lowest beds a light colored ripple-marked calcareous sand rock about one foot above the water level, 1 foot. Rominger sketches this as follows (Fig. 7), and found no outcrops elsewhere on the west side of the island.

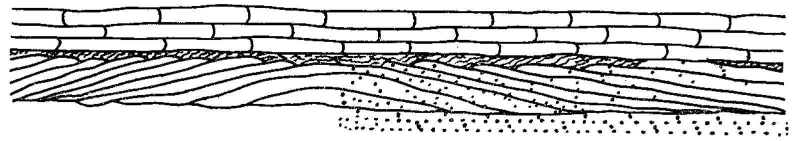


Fig. 7. Illustration of section on Big Charity Island, after Rominger, Vol. III, p. 119, showing discordance in the Bayport limestone. Completed so as to show the lower bands as we observed them, in dots.

Prof. Davis and I visited the island, making farther collections. We added to the above lists a form much like *Athyris trinucleus*. The fauna is in general identical with that of Wild Fowl Bay. The islands had changed considerably from the form given on the Lake Survey chart and there was a long spit northwest from the lighthouse, more as in the outline on the old Walling atlas after the Land Office Survey. There has been considerable growth also toward Little Charity, a broad stretch being left bare, and between the two a small island known as Gull Island was just laid bare.

The point to the north is made up of gravel and boulders, but a short distance southeast of the lighthouse, the outcrops of characteristic layers of limestone with abundant Lithostrotion, chert nodules, and Phillipsia pygidia, begin. On the first little point from the lighthouse in this direction there are 6 feet of bluish shaly limestone with abundant Allorisma, in nodules and geodes, Lithostrotion, etc. (Sp. 19178-19186). About 50 steps farther southeast we find close to the water's edge a three inch bed of hard ringing flaggy gray limestone (Sp. 19187) undulating somewhat, but apparently under the Lithostrotion beds and dipping gently southwest. On top of this bed, *and thus replacing the limestone*, we find an almost pure white sandstone, cross-bedded strongly with a dip to north of west in the cross-bedding (Sp. 19188). About ten steps on in the lower part of the sandstone are large Allorismas (Sp. 19139). Flinty and cherty limestone layers, over-and underlain by sandy ones, continue near the coast to the east point. The bay opening southeast is sandy, but on the long point to the south we find flat outcrops in the broad zone left by the recent water retreat. They frequently contain calcite geodes and weather yellowish brown (19192-19202). They are sparsely fossiliferous, the most interesting form being one that resembles *Athyris subquadrata*, but there are also fragments of Productus, Lithostrotion, Bellerophon?, etc. On the coast facing Little Charity Island there are low paving-slab outcrops of brown brittle dolomite with cavities, and the surface is strewn with chalcedony and other geodes, which have evidently been left by solution of the limestone that enclosed them, as the irregular surface has not been rounded by erosion (19190-19191).

Though, as I have said, the dip appears to be to the southwest, these beds on the southwest side of the island appear more like some of those low down in the section around Bayport. But on the other hand the sandstone there comes under the "firestone" dolomite which most resembles the brown brittle dolomite aforesaid. But as there are undoubtedly alternations and rapid variations in the section, the dip of the strata here can not be regarded as free from doubt. The probability of a southwest dip is strengthened by what Winchell described on Little Charity Island, which he says has similar outcrops, with Syringopora, chert concretions, Bryozoa, and Cyathophyllidæ (i. e. Lithostrotion). He also remarks that the rock may be seen under water for a long distance southwest. The charts indicate rocky bottom and shoal water for some two miles and a half in that direction, while to the northeast of Charity Island the descent to deep water is sharper. Taking the above facts into consideration with the rock exposures along the shore of Arenac county we cannot but think that a rock ridge extends across the mouth of Saginaw Bay, following the beds of this formation, which are relatively resistant to erosion.

According to the contours of Fig. 6, the limestone should appear under Sand Point and it may do so, but I know of no wells nor outcrops that settle the question. We find it next on North Island off Wild Fowl Bay, but there the dip appears to be northeasterly, while at the Bayport quarries and around Bayport it is similar to that on Charity Islands, so that it seems as if North Island might be on the west side of a long, narrow much eroded synclinal running north, and if so it would be the more likely that, if not eroded away (i. e., if the rock is not far below the present surface), we should find the other side of the synclinal under Sand Point. This would be of interest because this formation yields excellent water, and often flowing wells. A well on the end of Sand Point a hundred feet deep would amply test the question for this formation. If this limestone was not found the next thing would be to go down about 300 feet, case off the overlying flows and take water from the Marshall.

On North Island a quarry has been opened and deserted. In it the Lithostrotion, and chert nodules, and carbonates are abundant, and a large Bellerophon occurs like that found by Whitfield in the Maxville limestone* (Sps. 19208-19211). This quarry is on the north side of the island. As we go northeast we find similar strata continued out under the water, with trilobite pygidia, etc., and Allorisma (Sps. 19212-19216). As we go southeast along the shore 100 steps to the cove on the north side of the island, we come to a layer rich in Lithostrotion, which seems to overlie the beds just mentioned, as in the Bayport quarries, and dip gently to the northeast.

Going toward the north end of the island we find that the retreat of the waters had connected it by a goose neck ridge with the small outlying rock of earlier maps, and we come to a dark brown dolomite, ferruginous and not fossiliferous (at least abundantly). The south shore of the island shows a somewhat fossiliferous limestone with Bryozoa, limestone and corals.

Between this island and Heistermann's (Ching-qau-ka, or Stony) next south, the water is very shoal, and according to the Coast Survey charts there is rock almost all the way, and the north end of Heistermann's Island shows thin bedded limestone alternating with sand layers, which would seem to represent lower layers of the Bayport quarry. Some of the layers become on weathering at least, a well marked sandstone. The outcrops are not more than five feet above water, and Winchell speaks of them as much brecciated, a character which I failed to note.

*Ohio Geol. Sur., Vol. VII, p. 479.

On the north side of North Island the limestone drops off in quite a steep bluff but to the southeast between the islands and the shore, it is probably not far from the surface, judging from the shingle, and we find it reappearing again in a low outcrop with characteristic Lithostrotion and Allorisma and other fossils on the main land along the west line of Sec. 36, T. 17 N., R. 9 E. (Sps. 19170-19173). Similar beds with similar fossils we find again at the top of the quarry on Sec. 5, Winsor. Returning to the main land we strike under Bayport village, however, sandstones such are more common in the lower part of the formation, and the beds outcropping, for example, just to the west of the railroad pier, are of a dark flinty dolomite character, and seem also to be lower down.

As we go along shore to the east, the bluffs, now mainly grassed over, seem to be rising, but the dip of the strata to be gently to the west. In other words we have crossed the axis of the synclinal or basin, the uppermost layers exposed being the limestones rich in Lithostrotion. Winchell says, however, that the dip is very slight to the southeast. He makes the following section:

F. Limestone argillaceous, cherty, perforated extensively by a Syringopora, 10 inches.

E. Limestone, compact, bluish, weathering white, 1 foot.

D. Limestone arenaceous, with nodules of chert. Seen dipping into the water 10 rods west. (True, but how does he reconcile this with a southeast dip?)

C. Limestone, dark calcareous, with bituminous (flinty?) streaks and laminae, intersected by broad cracks which have been subsequently filled with material like D, 10 inches.

B. Limestone, yellowish, highly arenaceous, thin-bedded, rather incoherent, the lower one-fourth curiously banded with lighter and darker streaks, 1½ feet.

A. Limestone, arenaceous, highly shattered and recemented. "The flint nodules in the layer D, are bluish, of a fine homogeneous structure and strike fire with steel, with great readiness. They exist in large quantity." The layer E. he recommends for building, and D, E, and F, for making lime. This whole section with the exception perhaps of part of A., for the difference between calcareous sandstone and arenaceous limestone is neither great nor persistent, is in the "firestone" belt of the exploratory borings given among the well records of Secs. 35 and 36, and must cover somewhere from 10 to 16 feet of the quarry section.

Rominger gives a more complete section, as follows: (Geol. Sur. Mich. III, p. 120.)

1. Light colored arenaceous limestones with an alternation of purer calcareous and prevalently sandy seams with many fossils—*Zaphrentis spinulosa*, *Lithostrotion proliferum*, *Syringopora ramulosa*, various forms of Fenestella, Polypora, etc., Productus, *Allorisma clavata*, and fish teeth (Cladodus, Helodus), 10 feet.

2. Dark gray limestone of smooth conchoidal fracture, pervaded by syringopora-like flexuose, anastomosing channels, 1 foot.

3. Similar dark gray limestone of smooth conchoidal fracture, 1 foot.

4. Another similar bed, 1 foot.

5. Blackish thinly laminated calcareous shale, full of scales, teeth, and bones of small fishes, beside a species of Cypris or Cythere, 2 feet.

6. Dark gray bituminous limestone with smooth fracture, 8 in.

7. Arenaceous limestone laminated, 2 feet.

8. Sand rock, few in.

9. Delicately laminated limestone, 6 in.

10. Shale, seam.

11. Gray limestone with cherty nodules, 1 foot.

12. Greenish white calcareous sandrock, 5+ft.

Total, about 25 feet.

Comparing this with exploratory section No. 3, on Sec. 36, T. 17 N., R. 9 E., we can identify the bottom bed 12, with the sandstone of the same and beds 7 to 11 probably with the 3 2-3 feet of limestone; beds 2-6 may be the 4 1-4 feet "firestone," No. 2 being the bed from which our Sp. 18207 is taken—from outcrops near the picnic grounds west of the railroad. The upper ten feet correspond to the outcrops on the west line of Sec. 36, and the first three feet of the quarry, bed No. 1, Fig. 8. The next beds are the building stone beds of the quarry (No. 2 Rominger=F. of Winchell?) and the black shale seems to be represented in the quarry at 8 feet, 6 inches. (Compare Winchell's C.) Rominger's sandstone bed No. 8 may be parallel with the sandstone from 9 feet, 8 inches in Fig. 8. Rominger's beds 9 and 10—the "delicately laminated limerock and shale"—may represent the cement rock of the quarry section, cement rock being generally an argillaceous limestone, and we have as satisfactory a correlation, as can often be got. The dip of the limestone

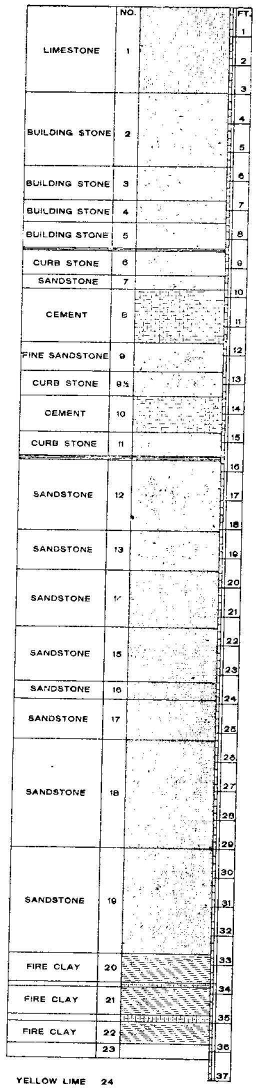


Fig. 8. Beds as given at Bayport quarries.

from hole No. 1 in the quarry to hole No. 4 on Sec. 35 is * about 12 feet to the mile, which is not far from that indicated by the contours in the underlying Napoleon sandstone in Fig. 6, for the same direction. The dip between holes No. 3 and No. 4 would be† 26 feet a mile, which would yield for the three points a dip to W. 39° S., of 27 feet per mile, but the position of the limestones on North Island and their dip forbid us from regarding this as a dip at all widespread and indeed it is not justifiable to join three points on a pitching synclinal to obtain a dip which can be expected to hold generally true. However, it shows plainly enough that the dip is really west and not east. The corresponding strike seems moreover to be almost exactly that of the limestone ridge from Sec. 5, Winsor, to Secs. 9 and 15, where the Lithostrotion beds lie at nearly the same altitude as on Sec. 5, and are very close to the surface. The limestone is exposed in a slabby pavement profusely strewn with weathered out Lithostrotion in the ditch on the north side of Sec. 5 and we find *Lithostrotion proliferum*, and also *mammillare (=canadense)* profusely strewn upon the fields in Sec. 9. The last place in this direction where the limestone lies near the surface is Sec. 22. All the way along it forms a pronounced ridge in the rock surface with bluffs facing an old river valley to the northeast. The sides of this river valley may be even more precipitous than our contour map indicates them, for such a massive cherty limestone overlying a formation of soft shales and gypsum, would be practically sure to outcrop along a river valley in an escarpment of vertical bluffs in which caves would be likely to form. And in fact we find in developing the quarries, and running the adjacent railroad spurs that the northeast wall of the limestone is nearly vertical so that the drop of the limestone is reported to be from 12 to 18 feet. Reports of cavities struck in this formation in sinking wells are also frequent. I happened to be standing by when one was struck in Bauer's well at Sebewaing.

*Either (48.2 — 3)—11.16, i. e., 34, or (48.2 — 16)—(11.2 — 10.5) i. e. 32, or (48.2 — 36)—(11.2 — 34) i e. 35 feet in 2.78 miles.
†(20.43 — 8)—(11.16 — 10.5) i. e. 12 feet in 0.47.

Turning from the Bayport quarries to the southwest on the other hand, we find the limestone falling gently in this direction, according to the quarry authorities about 3 feet per hundred to the west, more than the dip above given, but that was an average taken very nearly to the center of the synclinal. In the quarry the bottom is now in the thinner bedded, bluer limestones and the bituminous shale parting shown in Fig. 8, at 8 feet 5 inches. The Lithostrotion occurs most abundantly above bed No. 1, and the quarry has developed about 3 feet of limestone above layer No. 1 of Fig. 8, which has been analyzed. (Chapter VII, § 7.)* The chert concretions which contain some clay are very often pear shaped, with a pit at one end, not infrequently enclose some shell, and are most abundant immediately below in layer No. 2. Fig. 8. In the lowest bituminous layers I observed a large ammonoid that I was not able to extract. The Producti are not altogether abundant, and are more often perhaps in the lower layers. The Allorismas sometimes occur in the chert concretions. The two valves are commonly together, but frequently flaring, showing the original presence of the ligament, and often not at all parallel to the bedding, in noteworthy contrast with the way the shells occur in the beach deposits of the Marshall.

As we have said, to the southwest the limestone slopes off gradually in sharp characteristic contrast to its behavior to the north and east, and the same contrast is noted on Sec. 9. Wells down to it, give an abundant supply of water, and as soon as the surface of the ground is below the level of the quarry we begin to get flowing wells (Fig. 9). The deepest part of the synclinal seems to be on Sec. 12, Fairhaven, and then the limestone rises to appear again at the surface on Sec. 14, where it is exposed in a slabby pavement in the valley of the Shebeon, and the ditch on the north line of the section. Mr. W. H. Wallace, formerly Superintendent of the quarries, thinks that through Sec. 14 goes a fault, as he finds limestone to the west of the line of the supposed fault, and sandstone to

*Accordingly Benedict in "Stone" Aug. 1898, p. 154, calls No. 1, of Fig. 8, ledge 2.

the east. Such a fault is not in itself unlikely as we have one of the same character in the Sebewaing coal mines, in similar relation to a synclinal, but in view of the way that sandstone replaces limestone in this formation I cannot consider the evidence conclusive, and at any rate such a fault has no great throw. Were there such a fault, however, it might be of importance in concentrating lead ore, but as yet the explorations have shown no concentration.

The calcareous sandstone here exposed is very fossiliferous, and has been noted by previous writers. It should be studied by an able palæontologist on the spot, as it is often very friable, even when charged with fossils. Beside previous forms is one described as *Spirifera Keokuk*, which appears to me to be more likely a Spiriferina. For a fuller list see Chapter X, § 4. These beds must be in

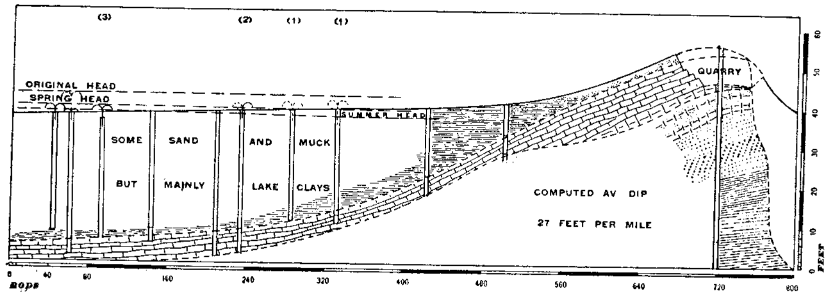
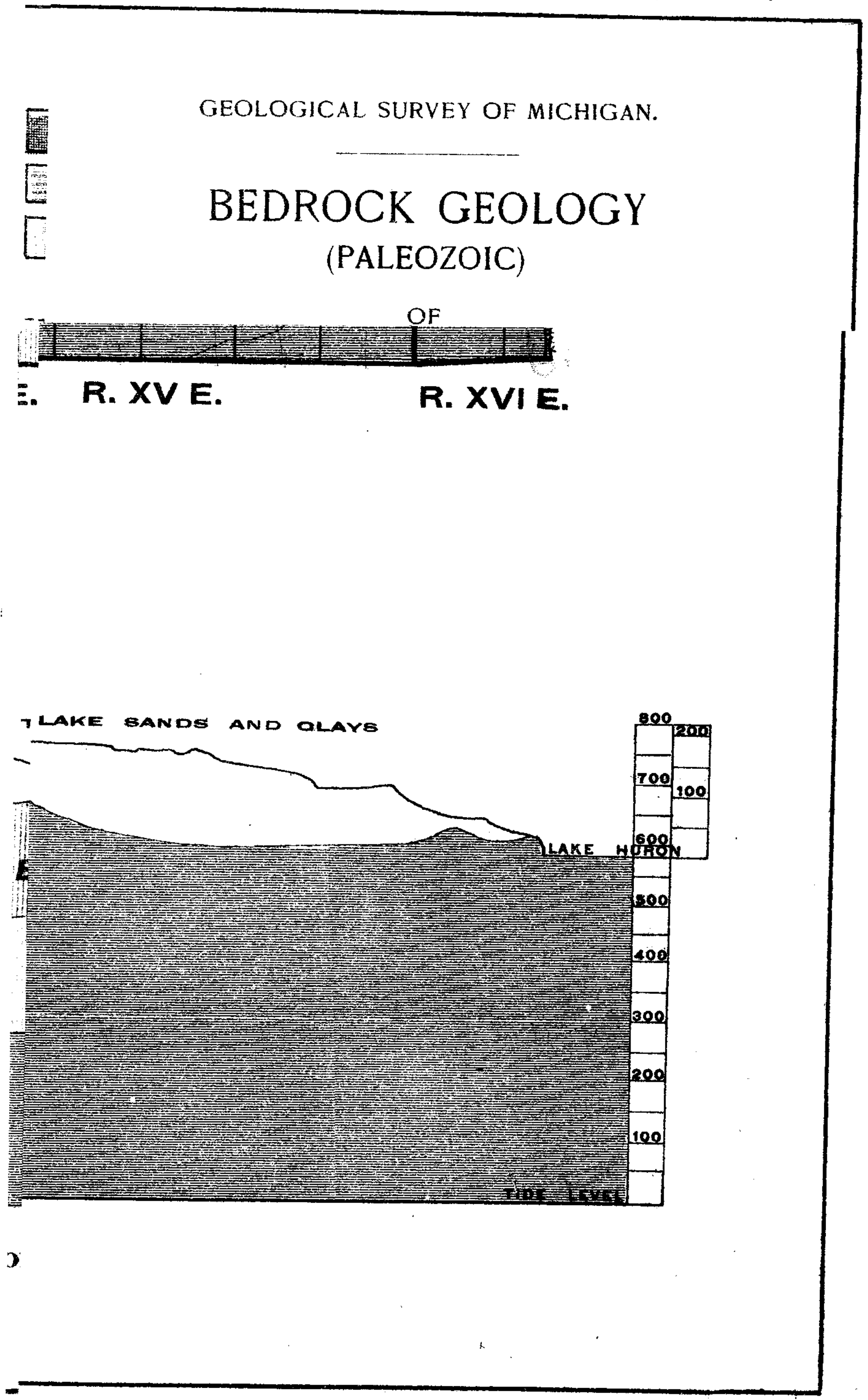


Fig. 9. Cross-section from Bayport quarries, southwest showing the relations of present surface, rock surface, flowing wells, and varying water level at point of intake.

the lower part of the formation, for the wells after passing from the calcareous sandstone, which is the surface rock, into a more massive limestone, which has been developed by some test pits below, in about 12 feet pass into a "blue rock," which appears to belong to the Michigan series, and to be a pyritiferous shale. South of this exposure the limestone is absent for some distance, being lifted up by the anticlinal indicated in Fig. 6, and the depth to rock is greater, but if we may trust the Lake Survey charts, there is a rock bottom almost all along the coast, and in that case the limestone ridge or bluff probably turns to the south almost at the coast line and following it along returns again, as indicated on the map, somewhere north of Sebewaing, to the land.* In its return,

*Between Haffner's in Fairhaven and Sebewaing, is 2⅔ miles. Difference of elevation of Napoleon sandstone is (610 − 132) = 478 — (596 − 252) = 344, i. e. 134 feet; accordingly the dip is 50 feet per mile. Hence the limestone bottom 127 feet down at Sebewaing (596 — 127), 469 feet above tide, will strike the rock surface 540 feet above tide about 1.42 miles north-northeast of Sebewaing.



however, it is much thinner, as shown by the record in Bauer's well in Sebewaing, and in some of the well records in this corner of the county cannot be recognized at all.

§ 5. Coal measures.

The Coal measures occur only in a little basin near Sebewaing. This formation does not anywhere outcrop, and we are therefore dependent entirely on the well records and the shafts for our information. I am obliged to the courtesy of Mr. Chappell for an opportunity to visit the mine of the Sebewaing Coal company. As litigation was in prospect, our notes are in some ways deficient and wanting in numerical accuracy. The following sketch-map (Fig. 10) and section Fig. 11, show the general relations. The two companies to first mine the coal both began in troughs. The main shaft of the Sebewaing Coal company has about 4½ feet of coal at a depth of 125 feet. At the air shaft, 200 feet west, the coal is but 109 feet deep, and at the first shaft which was opened (still farther east), by John T. Russell, it was but 86 feet down through the coal. In this first mine there was much water. One miner* reports having encountered a water channel into which he could stick his whole head, and I myself saw such a channel in the present mine which would easily admit an arm. Turning from the 125 foot shaft to the west we find the coal rising, for the last fifty feet quite sharply, as much as one foot in six, until we come to a fault, which may be from 350 feet to 650 feet west of the shaft. On the line of the fault was this cavity which had a corroded surface, somewhat as if the water had made it by dissolving pyrite from the rock. This cavity is 8 inches by 5 inches and many feet in depth. Slickensides on the coal are well marked and also in the slate. Though the fault was always reported to me as having an upthrow west, it appeared at this point as having a downthrow of about 2 feet, the overlying slate coming in at the roof. The dip of the fault, judging both by the cavity and slickensides aforesaid, was steeply to the west.† The general relations along an east and west line are illustrated by Fig. 11.

I noticed little crystals of gypsum on the surfaces of the coal at this point and as we approach the fault the mine is very wet, and the mine water is somewhat salty, and very strong of sulphates.

*Geo. N. Fleming.

†From the open cavity I should judge the dip to be about 80° or by slickensides 60° to 70°.

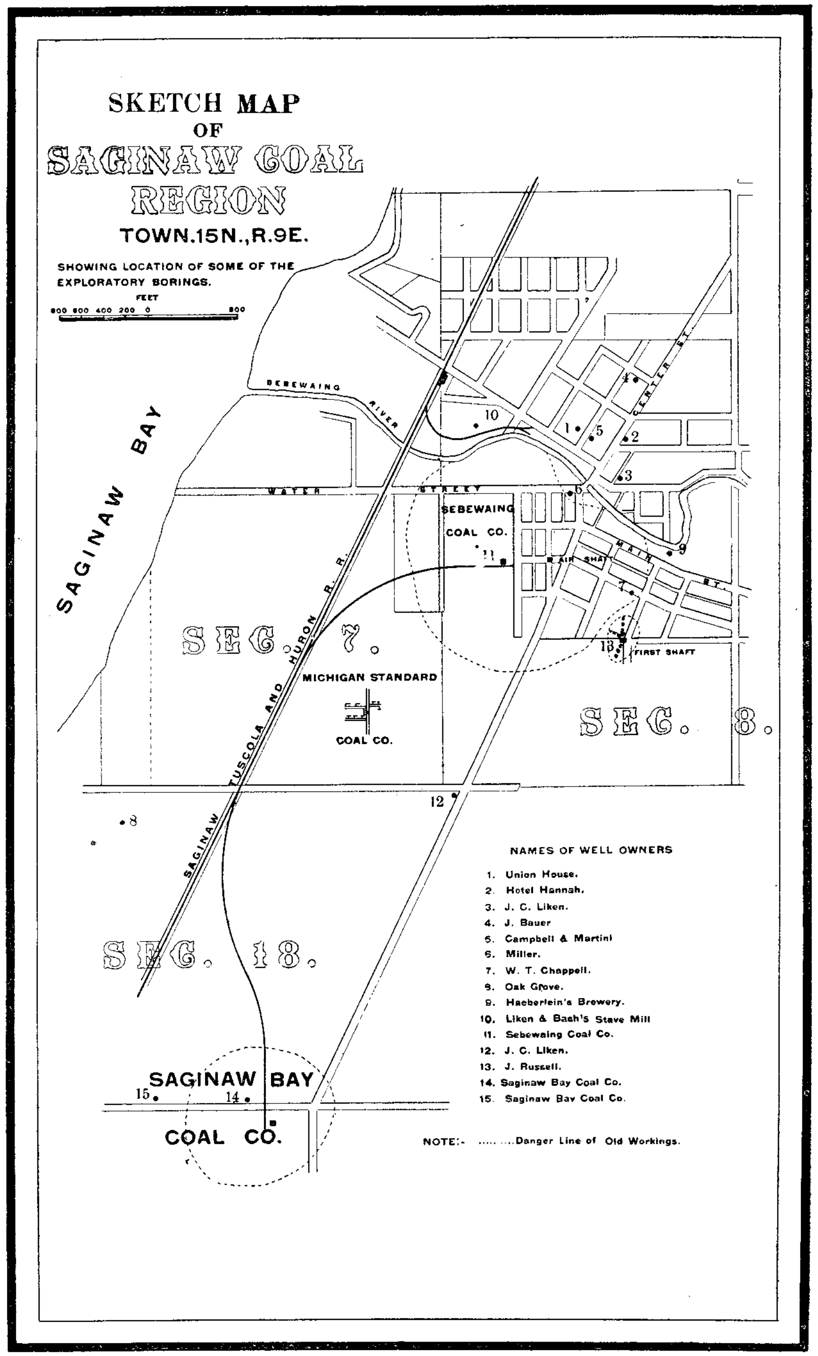


Fig. 10. Sketch map of Saginaw coal region, showing location of some of the exploratory borings. The mines have not been mapped, but the dotted line indicates the danger line or area within which the workings are probably confined.

depositing in the galleries a heavy flocculent precipitate of iron. The water is said and seems to come in from the bottom. It is true, however, in a general way, that the fault throws the formation up, i. e., that the coal to the west and southwest is higher than at the shaft, and as we often find in going toward the center of a coal basin another seam makes its appearance above the first. The section on Sec. 7 is about as follows:

Surface clay, with at times a few feet of bottom hardpan, 40-50 feet.

Sandstone, 15 feet or less.

Bluish shales passing at bottom into black shales and at bottom sometimes a 1-foot bed of coal, 6-13 feet.

Fireclay and lighter shales, 19-6 feet.

Lower coal, sometimes wanting, but often up to 4 feet.

"Fireclay," 0-5 feet.

Sandstone, 12 feet and more.

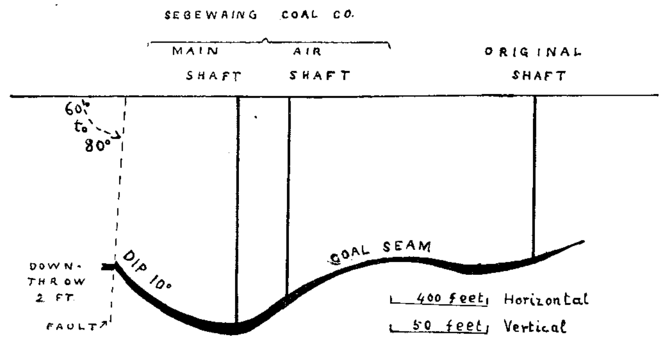


Fig. 11. Illustrating the relations of the coal and the fault at Sebewaing. This is a cross-section in a generally westerly direction, but the shafts and borings shown are not in line.

At the time the coal was formed the land was just about the level of the water, and in the marshes and flats thus formed the coal was deposited. It has been estimated that in the shrinkage from vegetable matter to coal, a loss of volume to about one-fifteenth takes place, so that a four foot bed of coal would mean an original swamp deposit some 60 feet thick. Thicker deposits would generally be formed in the hollows of the surface, and as they subsequently shrank and settled, there would be a tendency for faults to be formed toward the center of the basin and so in settling there might be a basin formed on top where in a subsequent overlying swamp another coal deposit might be formed. We find accordingly as we go from the fault to the south, that the little upper coal seam already mentioned appears. So in Sec. 18, while the section on the north part of Sec. 18, say in Liken's new deep well, is much like that already described, the beds become deeper in the south part of the section so that the lower coal is generally over 90 feet deep. The shaft of the Saginaw Bay Coal Company is said to have struck coal 4 feet thick at 110 feet below surface, and on the south line of the section it is also deep. There are some sudden variations in the recorded strata, however, due to the following cause. These old swamps, lying at or a little above the water level, were extremely likely to be cut through by old river channels, which would form sandstone beds, or they might also abut against old ridges of beach sand skirting the coast. Suppose for example that the present lake should now rise twenty feet. There is a strip of somewhat swampy country from Bayport southward which would again become a swamp. If the rise of water or lowering of the land was slow enough, the surface of the swamp might build up with vegetable matter fast enough to keep pace with it, making a thick bed of muck or peat. Now if the lake rose still farther the dune ridges and the whole country would be buried, and this bed of muck might become coal and might then appear as a bed of coal abutting against, or cut out by the bed of sandstone which would be formed by the ridges of sand upon which the "ridge roads" now run. The change from coal to sandstone would be quite sudden. And so for example we find that Mr. Liken's new well near the northeast corner of Sec. 18, T. 15 N., R. 9 E., only sixteen to thirty feet away from a previous exploration for coal, found a considerable bed of coal which was almost replaced in the older exploration by a thirty foot bed of sandstone. In Sec. 18 these sandstone channels or ridges seem to be prominent, as we find another encountered by the deep well put down by Russell, close to the Saginaw Bay Mine.

On Sec. 17 we find the coal also ranging from 106 to 80 feet in depth. The last doubtful report of coal comes from Sec. 21. Any farther extension in that direction would be cut off by the buried river valley, indicated in Plate VII, but as is indicated in Fig. 6 by the contours of the Napoleon sandstone, the basin probably is opening out and deepening to the west and in fact coal is reported from Fish Point and from Sec. 12 and Sec. 13, T. 16 N., R. 8 E., in considerable quantity and sometimes at greater depths than in Huron county. A tendency is noted, without exceptions, for the coal to be thicker where it is struck at greater depths, which may be explained by the thicker formation of the original muck in the hollows of the surface.

At the mine of the Sebewaing Coal Company the coal is from 4½ to 5 feet thick, about as follows:

4 inches "bone coal," i. e., lean coal that will burn, but without reducing in size, then

1 inch to 1½ inches of pyrite then

4 feet of fair coal somewhat pyritiferous.

There is a good slate roof, and fire clay underneath often in some cases pretty sandy. The bluish gray slate roof shows no fern impressions so far as seen, the only fossil noted being in the coal seam, and mainly small bits of rushes and vegetable matter, Lepidodendon and Calamites. One fragment of Stigmaria, changed largely to pyrite, was picked up by C. G. Maywood of Albion College, and Mrs. W. L. Webber has a similar specimen.

The coal contains at least 3% of pyrite, and the refuse piles effloresce with sulphate of iron, and take fire spontaneously.

CHAPTER VI.

WELLS AND BORINGS.

§ 1. Introduction, utility of the collection of records.

The main part of this chapter is composed of the descriptions as we have gathered them from well-drillers and owners, of the wells of the county, arranged systematically by township, range and section. It is possible that some one may say, "What is the use of this?" So far as the improvement and development of the water supply are concerned the use will be the subject of the next section. But it may be well also to call attention to the fact that without the data furnished by systematic inquiry concerning wells, such contour maps of the rock surface, or of the top of the Napoleon sandstone as given in Plate VII and Fig. 6, would be impossible. Without these maps we could have, from the few outcrops scattered over an almost plane surface, but very vague ideas as to the structure and distribution of the rocks below. And if any one should reply, why not give these maps then alone, and not the raw material, we make answer that in the maps the facts can not be distinguished from the theoretical deductions added, and are to a certain extent inaccurate. As we have seen, even the railroad levels do not agree among themselves, and so even Plate VIII showing the altitudes of the present surface of the county is liable to be in error as much as twenty feet, though we hope that the relative accuracy is generally greater (that is to say, although for example the level of Ubly should prove to be ten feet out, it would not effect the relative altitude of the hills and valleys around the town). But allowing that the contours of Plate VIII are liable to be 20 feet out, Plate VII and Fig. 6 which are constructed from them, and from the well records which are in parts of the county yet but few, must be still less accurate. Now, as new wells are bored and their records collected, if a more accurate contour map of the county is to be constructed with the aid of railroads or levels yet to be run, in

this chapter are recorded all the data which we have toward better maps on the same lines. From our maps alone one cannot tell what part is more, what part less sure, what part observation, what part theory. To make this chapter thus a summary of recorded facts (facts which could not be collected later, as we have found how rapidly details as to the beds encountered or even the depth and casing of wells slip from the minds of owner and driller), we have added records of borings not primarily for water, and some references to outcrops in each section.

§ 2. Practical lessons.

The important things in water supply are quantity, quality and head. Head and quantity are not equivalent, though they often vary together. It sometimes happens, that a well will yield a water which will rise in a tube quite a distance and yet yield a dribbling supply, while another well may not have the water level at the surface of the ground at all, and yet cannot be lowered by pumping. A larger hole will generally give a greater quantity of water, but the diameter of the boring will not affect the initial head. Dynamiting will often improve the quantity of the yield, but will not usually make a permanent improvement in the head. In our review we will take up the question of quantity first.

(a). *Quantity.* An ideal well as to quantity will water your own and your neighbor's cattle, and run harvesters ad libitum. Four gallons a minute is generally ample for all farm uses.* The quantity of water which a well will furnish depends, first, on the beds from which it draws water never becoming dry, and second, upon their being porous. The porosity depends upon the proportion of voids, or the difference between the weight of a cubic foot dry and a cubic foot wet. Table II shows the porosity of some rocks and we see that the Napoleon sandstone, 26% of its volume being voids, is therefore an excellent water-bearing bed. Surface wells draw their water from sands and gravels. Sand is less porous than gravel, and clay is least porous of all. Shale is like clay. Limestone and gypsum are not in themselves porous, but being somewhat soluble are liable to have water channels dissolved out in them.

Surface sands and gravels if not covered by clay are apt to be dried out in a hot season, and we notice that many of the surface wells ran short during the hot weather of 1895. Surface wells

* = 1440 gallons a day = 100 gallons each for 10 people and 7½ gallons each for 60 head of stock.

striking sands or gravels under clay are much more likely to be permanent so far as drying out is concerned (and are probably of better quality), and the same thing is true of sandstone or limestone under shale or clay. The boulder clay or till has in this county usually enough clay in it to count as a fairly impervious, that is, not porous bed, the coarser sand, gravel and boulders being embedded in a clayey cement. But the distribution of the sands and gravels under or in streaks within the boulder clays which may be struck by wells is quite erratic, and no general statements can be made that will apply to any large district. Belts near the old beach lines seem to be rather better favored with alternating layers of differing porosities. Very generally there is a porous bed immediately above the rock surface.

As far as rock wells are concerned, however, we can make more positive statements. In the eastern part of the county, colored Coldwater shale on the map, Plate VII, wells into rock are not successful in striking abundant water, and what water there is, is likely to be salty, as is shown in the Grindstone City and other wells. In the central part of the county, colored Upper and Lower Marshall, there is no difficulty in striking a good supply of water within a few feet after striking rock. The only exception that I know of is Wright's well on Sec. 12, Hume, the record of which is very curious. It seems as though water-bearing beds must have been overlooked, but there may be peculiar local conditions. The more westerly part of this area, that of the Upper Marshall or Napoleon sandstone, is the more freely supplied with water. Farther to the west abundant water can invariably be found by going down a few feet into the Napoleon sandstone. How far that will be may be found by subtracting the altitude of the top of the Napoleon sandstone as given on Fig. 6 from the altitudes of the surface of the point where boring is proposed, as derived from Plate VIII. For example, a well on Sec. 3, T. 17 N., R. 10 E., would be expected to have to go (600 — 400) about 200 feet to strike this horizon. *To get the best results the casing should be continued from the top of the ground nearly down to the top of the sandstone as thus indicated, and be tight.* Of course the well itself must go a ways into the sandstone.

Over the area colored as underlain by the Maxville limestone, however, it will not be needful to go down so far (unless the limestone happens to be cut through by the old river valley), for although the limestone itself is not porous, it is soluble, and the calcareous sandstones, when the cement is dissolved out, are very porous, and cavities and water channels are dissolved along the joints and fissures in the purer limestone. Throughout the northern patch of limestone around Bayport wells to rock or a few feet in it get (cf. Fig. 9.) an ample supply of water often flowing above the surface, while in the southern area it is often necessary to go a little deeper, yet not over 150 feet.

(b). *Head.* In beds, not freely porous, the question of head is of no practical importance, because even if the head were such that the water would rise above ground in a closed pipe a little pumping would soon exhaust it. A well in shale or clay may yield a little water quite steadily, even in the dryest times, but will yield but a few bucketfuls at a time.

The general conditions of the head of wells and the circumstances that will produce flowing wells have been quite fully discussed in a valuable paper by T. C. Chamberlin in the Fifth Annual Report of the Director of the U. S. Geological Survey,* so that I shall confine my treatment and practical illustrations to conditions actually observed in Huron county, letting those who wish to study the subject in a broader way refer to the paper mentioned. The county furnishes, however, many suggestive illustrations of most of the important points made by Chamberlin.

By head we mean the pressure under which the water is in any bed. This determines of course how high it will rise and is commonly measured by the height above sea level of that water surface up to which it will rise. If the height to which it will rise is above the surface it will flow. If it is over 30 feet below the surface, a force pump must be used. The head is dependent upon the pressure of water in the bed. In a superficial porous bed, we find that the water sinks down into it and fills it up to a certain level which varies with the condition of the bed and the season. With the warm, dry months of summer this water level falls lower and lower, (Fig. 9) and wells which once penetrated it do so no more. When the well is dry to the bottom, the water level has fallen below it and there is a strong temptation to start boring from there and follow down after it, a course which as we shall soon see has objections. (Cf. Fig. 12). In a porous bed in which there is no outlet, the head is

*Pages 137-173, 1885.

everywhere sufficient to raise the water level to that which exists where the water is taken in. If this porous bed extends off under impervious clays, to a region where the surface of the ground is lower than the water level at the point where it takes in its water, being covered by previous beds only or exposed to the air, wells down to it will find the water rise above the surface. But as the water level at the intake fluctuates the water level in the wells will also tend to fluctuate. An excellent example of this is seen (Fig. 9) in the wells in the Bayport limestone, to the southwest of the quarry ridge along which the limestone outcrops or is covered only with gravels. Here we find wells going down through impervious clays and tills until, upon striking the limestone, they find that the water rises higher than the surface to a water level dependent on that in the limestone. We find, however, than one well that flows in spring ceases to flow later in the summer, that another fails about the Fourth of July, and the others in still lower ground last all the year around. We are thus enabled (Fig. 9) to follow the gradual fall in the water level of the limestone as the summer goes on.

Again, draining swamps lowers the water level. The water runs off instead of sinking in and remaining on the land. This is the general effect of bringing land under cultivation. Thus the drainage of the swamps which cover Lincoln, Colfax, and Sheridan, will tend to lower the water level, and the head in the underlying beds of the Marshall. The head in these beds is not solely dependent upon this factor, but yet it is one of the causes that we have to take into account in explaining the recent lowering of the head in all the wells of the Napoleon sandstone to the west.

If now the porous bed from which the supply of water is obtained has outcrops at different levels, and especially if it has points of discharge, either natural, as by springs, or artificial, through artesian wells and the like; the question what the water level will be for any new point becomes more complex. In general the water level in superficial porous beds slopes gradually toward the lakes and streams and repeats the modelling of the surface, but in less relief. Thus the depth to water is greater under hills than in adjacent valleys, but not quite as much as the difference of elevation would imply.

This remark applies, for example, to the wells in the dune sand

or gravelly regions. The Napoleon sandstones, and in fact all the porous beds of the county so far as we know have outcrops or are only covered by sand near or under the lake. Near the shore therefore their water level approaches lake level and then rises as we go into the interior of the county. The head under cover will depend somewhat upon the relative nearness to the different parts of the outcrop, being most nearly dependent upon that part of the outcrop nearest. For example, the head of the Napoleon sandstone around Elkton will not be higher than somewhere between the water level on Sec. 9, Meade, where the sandstone is exposed, and the water level around Badaxe, i. e., between 660 and 740 feet above tide. Since the level of the surface near Elkton is only 650 feet or so above tide the chance of flowing wells thus indicated is good. But another class of considerations must also be taken into account, viz., the escape through wells or fissures at lower levels. This is a factor which we cannot neglect in the case of the Napoleon sandstone. Practically all the brine of the Saginaw valley is drawn from this formation, and around Sebewaing, at Oak Grove and numerous other places there are strong flowing wells. Now if these wells are, in the aggregate, but a drop in the bucket to the amount which may be rapidly taken in and percolated, then they have no appreciable effect on the head, but if not, then for a wider and wider circle about the point of outflow the head will be lowered toward that maintained at the point of outflow. For example, suppose two holes to be put down side by side where the water rises, at first ten feet above the ground in both. Then let the casing of one of them be untouched but the casing of the other of them be cut off level with the ground. The water will flow from the former and the level in the latter will be lowered. As the holes are farther apart the effect in lowering the level will be less and less marked, the greater the gap and the less porous the beds between the two wells. We have a number of illustrations of this principle in the county. Chappell's deep well at Sebewaing burst its casing and leaked into the coal mine and consequently all similar wells drawing their sources from the same stratum, the Napoleon sandstone 250-300 feet below surface, dropped two or three feet in their head or ceased to flow entirely. So for example at Elkton, when the casing of the deep railroad well was cut off below ground, so that the water was allowed to flow into a basin (whence it could find its way into the surface beds the water surface of which stood at a lower level) the wells around immediately lost their head. Fig. 12 therefore shows a common form of casing not to be recommended for this reason among others, that if the porous beds A have a good head,—more than that of the surface water,—the water will flow out from the lower beds A up and out into the surrounding surface materials C and thus lower the head of A. It is not at all necessary that such a well should be a possible flowing well. Just as soon as we strike a water stream so strong that it will fill up the old basin, in the bottom of which the new boring was put down,

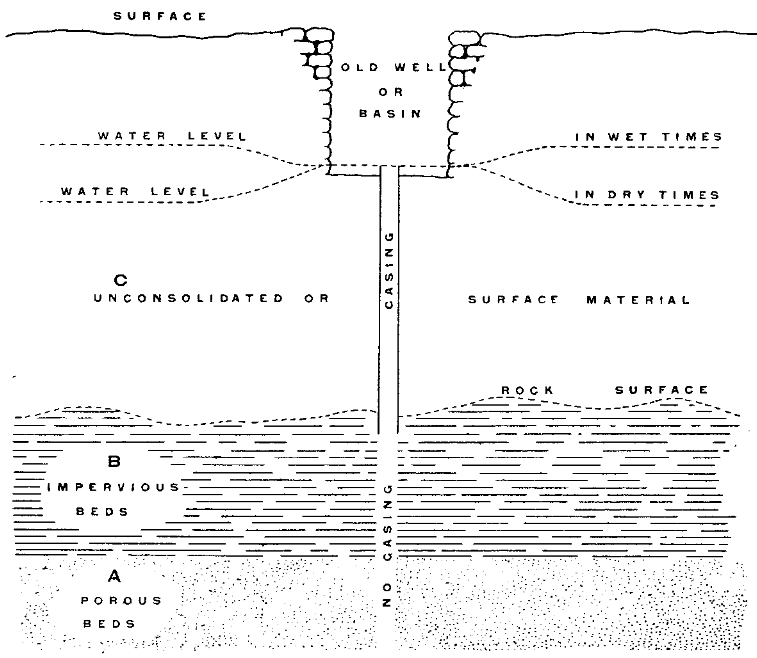


Fig. 12. Illustrates improper boring and casing, involving danger of contamination from surface waters, or of contamination of surface waters by a salty layer with strong head in A. There is also probability of reducing the head in the layer A, by flow of water into the surface layers. There is also danger of the bore hole closing, through clogging from the basin, or caving in of beds above A.

higher than the surface water would, it will tend to spread through the stoning of such basins into the surrounding surface materials, and tend to dissipate the head of the lower beds. An interesting illustration of this action is in the case of abandoned salt wells where the casing has been pulled. These are frequently flowing. The old salt wells at Port Austin and Port Crescent flow, those at Caseville are at least very near the surface and the Bayport well had a head, as I am informed, of 10 to 32 feet above ground. Now

there are a number of the Port Austin wells which are salty, though shallow, whose saltness may readily be accounted for by supposing that the salty water from the flowing wells has had head enough to push its way out into the higher strata.* It might be well to case these old salt wells far enough down to prevent this action. The effect on quality of the arrangement illustrated in Fig. 12 and of insuffìcent casing we shall return to later. It is enough now to notice that a group of such wells large enough to be an appreciable factor in comparison with the amount of water which can freely circulate through a bed may seriously lower its head, perhaps checking its flow in some other district. I dwell on this point because this form of drilling and casing is extremely prevalent. Now although it is difficult to form even an approximate estimate as to how much water can be taken in, say by the Napoleon sandstone, it must be remembered that wherever overlaid by clay or till the flow of water which can be taken in to replace any drain upon it must be slow. Thus although the outcrop (under the surface materials of the Pleistocene) of the Napoleon sandstone is over 200 square miles, and a precipitation of 30 inches each year over that area would give (200 x 43, 560 x 2.5) 21,780,000 cu. ft., i. e. (÷365 x 24 x 60 = 525,600), about 40 cu. ft. per minute, when we consider how much runs off directly, is evaporated, or finds its way into the rivers by way of surface gravel beds, the outcrops where the sandstone is close to the surface being probably much less than ten square miles, if we estimate the amount subtracted, by the thirty or more flowing wells draining upon this formation and the much larger number of wells that draw their supply from it but do not flow, it becomes evident that the draft upon it must be a large fraction of the supply and hence the head will diminish almost uniformly from the highest levels to the points of escape. We must consider also that the Napoleon sandstone is subjected to drain by wells outside the county limits, and that water may escape up the line of fissures like that exposed in the Sebewaing coal mine. The exact drainage by the flowing wells we do not know, though from some observations on some of the flowing wells, and the time required to fill a pail of about 3 gallons (0.4 cu. ft.), I infer that many of them will flow more than a quarter of a cubic foot per minute.

*It is true, however, that the Lower Marshall sandstones are sometimes salty in themselves as we can see by wells on Sec. 12, Dwight, and in Bloomfield township.

Chamberlin in the paper mentioned has suggested that a fluctuating head is a sign that the supply is being drawn on to the point of approaching the limit of supply (loc. cit. pp. 151-165). Judging by this test the supply from the Napoleon sandstone is already in that condition, for almost all the flowing wells report changes in the head from day to day depending on the weather, amounting to stoppage at times. I do not consider any definite law as proven as yet.*

Nor do I mean to say that the water supply from the Napoleon sandstone will fail entirely. Nature has her own methods of enforcing economy, and will simply lower the head, until the water running to waste by the flowing wells or escaping into the upper beds, is sufficiently cut off to restore the balance between demand and supply. But I do mean to say that a higher head could be obtained or retained by more ample and effective casing and greater economy in use.

However, in the immediate future we shall probably have an ampler supply, since the series of dry years culminating in 1895 will probably be succeeded by wetter ones.

The effect of the opening of the Saginaw coal mines should not be overlooked in this connection. As they must be pumped out, the water level for the strata in which they are located must be kept some 120 feet below the present surface or about 470 feet above tide. Now this would have no effect on the water level of other strata separated from them by impervious layers. But, as we noted, there were water channels all along the crack opened by the fault encountered by the mine, and ample indications that such channels were used. Beside this, a deep well into the Napoleon sandstone (7 of Fig. 10) was encountered in mining and the casing burst and it leaked into the mine. Furthermore there may have been other borings and wells with so little casing as to have served as channels of communication between the lower beds and those in which the mining and pumping were done. There seems to be a notion prevalent, that the abundance of water which was

*Among the causes which might affect the flow thus periodically are: (1) A decrease in atmospheric pressure would allow the flow to be more free. (2) If there were points of discharge of the water under the lake, as is likely, then a rise in the lake level would raise the level in the wells, as raising the height of a dam backs the water up stream. (3) Variations of wet and dry seasons, affecting the water level at the outcrop, would slowly make themselves felt. A few of the more important observations on such fluctuations may be of interest, and will be found in connection with the wells on Secs. 8, 15, 18, and 27, Sebewaing, T. 15 N., R. 9 E.; Sec. 22, Fairhaven, T. 16 N., R. 9 E.; Sec. 9, Oliver, T. 16 N., R. 11 E.; and Sec. 13, Caseville, T. 17 N., R. 10 E. See also Sherzer's comments on the same phenomenon in Monroe county, Part I, p. 194.

so large a source of expense to the Saginaw Bay Coal Company was derived in some way from Lake Huron. It is my impression that the lake had nothing appreciable to do with it and that most of it came from below. In most of the wells within a radius of four or five miles the lowering of the water at the time of the opening of the coal mines was marked. It is true, however, that this opening took place during a period of decreasing rainfall and lowering lake level, so that more than one cause was working in the same direction in the same time. But I doubt not that the draining of those mines had a marked effect in lowering the head in all the beds down to and including the Marshall sandstone.

The flowing wells and fluctuating head in the wells that draw their supplies from the Bayport limestone and sandstones, and occur in the northern part of Fairhaven township, have already been noticed. On the extreme southern verge of the county in the southern part of Sebewaing and Brookfield townships we seem to be entering a similar district, which will be more fully understood when Tuscola county has been studied. But before we leave this subject we have still to say a few words upon the sandstone beds of the Lower Marshall. These as we have said are less persistent, and (with possibly one exception) fade out, not being bearers of water either in the Bayport or Caseville wells. In other words they are shore deposits replaced by finer deposits to the southwest. This is a case mentioned by Chamberlin as favorable to flows* and is also illustrated by the cross-section at the foot of Plate VII. Wells in the fine grained extensions of the Lower Marshall sandstone will not affect their head, but as the outcrops of these strata lie on the eastward slope from the highest land of the county, we can expect flowing wells from them only in case they are struck on the western side of this divide at an altitude lower than the water level over their outcrops, and yet not so far to the west as to find them already too impervious to give a free supply of water. In such case, as the water level of the intermediate county stands high, we may expect as Chamberlin has shown, a head almost equivalent to that at the outcrop. The experience of Mr. B. Kreutziger in Sec. 6, Colfax, T. 16 N., R. 12 E., who went through the Napoleon sandstone into the shales below and got no increase of head, is discouraging for such a possibility in general. Three wells, however, seem to have been

*Loc. cit., Figs. 11 and 17.

fortunate enough to lie in this narrow belt and to be at a sufficiently low altitude, to wit: a well at Port Crescent, the well on Sec. 19 T. 16 N., R. 13 E., near Badaxe, and Homer Filion's on Sec. 8, T. 18 N., R. 13 E. I should suppose that a few more flowing wells of this type might be obtained along the valley of Bird Creek, in the southeast corner of Colfax township, and perhaps in the lower part of Sheridan and in the Cass River valley and the valley of the upper Willow. At any rate the water should rise to near the surface at these places.

(c). *Quality.* The quality of the water is generally good, with exceptions that we take up later. Surface wells, especially those in the sand ridges, are liable to contamination, but while wells may be noted in the list whose percentage of chlorine, unusually high for the district, indicates that they are affected by barnyard waters or by sewage, and presence of chlorine (a constituent of common salt, which is sodic chloride) is often used by water chemists as an indication of the presence of sewage contamination; in this district it would be entirely wrong on that account alone to condemn a water, for some of the very best and purest wells of the county show quite a perceptible amount of salt, which is of course not injurious, and up to a certain point only renders the water more palatable. Indeed it is remarkable what an amount of salt the palate can become accustomed to, and not notice. A water free from salt will taste flat and insipid, after using a slightly saline water for awhile. It is hard to say what the limit of drinkable water is. We have found a water with over 4% of salt used, although under protest, and one-half of one per cent of salt is soon quite unnoticed. Cattle and to a less degree horses all enjoy a moderately salty water. A connection between diabetes and mineral water has been suspected, but not at all proven. There is an interesting field of research open here for the physician.

In the area of the Marshall sandstones the percentage of mineral constituents is generally low. This is so markedly the case for the Upper Marshall,—the Napoleon,—that we find it comparatively fresh, even when there is salt water above it. One suggested explanation of this as follows.*

The total amount of salt which Michigan has produced to 1896 is very nearly 75,000,000 barrels. Almost all the salt of Saginaw

*It is also quite possible that the water was very early freshened as it is an emergence sandstone.

Bay, Midland and Gratiot counties was derived from this formation, though not quite all. These counties produced practically nine-tenths of the salt until 1879, since when they have had a less and less share. Though we have not the statistics to separate the production accurately, it seems safe to say that two-thirds of the whole production or 50,000,000 barrels of salt were derived from the Napoleon sandstone. At 280 pounds to the barrel, and allowing an 86° brine which would yield certainly not more than 22.10% solids, or allowing for the other mineral constituents and loss of salt in manufacture, supposing six times as much brine by weight to be used as salt was produced, and this, as the analyses given in Vol. III of these reports show, is too low an estimate of the volume of brine required, we would have 84,000,000,000 pounds of concentrated brine abstracted from the formation. If a cubic foot of the sandstone (See Table II, p. 90) holds 10% voids, it would contain about 100 ounces of pure water or about 116 ounces, or 7.25 pounds of brine. Thus nearly 11,600,000,000 cubic feet of sandstone would have to be drained to furnish this brine, or 42 square miles of a sandstone 10 feet thick. But in addition to the brine made into salt, there has been a great deal wasted and a great deal abstracted by the salty flowing wells, like the Oak Grove well, that reach the formation. Moreover all through the geological ages preceding the ice period while the Marshall existed as a basin with the water level over its outcrop higher than that over the center, there must have been a tendency for the water to work up by every crack and crevice (e. g. such a fault as we find in the Sebewaing coal mine) toward the center of the basin, to be replaced by fresh water working in at the margin. Thus the tendency will have been for the water to become fresher in the more porous layers near the margin of the basin.

This is an important fact, for we have only to compare Mr. Leipprandt's wells on Sec. 13, Caseville, or the Brewery well at Sebewaing with Mosner's near by, to see that in case there is too much mineral matter in the water it is probable that casing down to the top of the Napoleon will help matters (casing off tightly with rubber washers or a seed bag to prevent the heavy brine from working down). Wells traversing the overlying Michigan series have more mineral matter than is necessary or frequently than is healthy or palatable, i. e., many wells to the east of the line which

I have marked as the outcrop of the gypsum beds, or in the lower part of the map the line of the top of the Napoleon sandstone. Of course some beds east of that line are too shallow to be affected by the formation, drawing their supply from the drift, or Bayport limestone and sandstone; others have so strong a current from the Napoleon sandstone as to weaken the water until it is comparatively drinkable, but speaking generally in the district thus marked off and colored on the map, wells in rock are likely to prove unsatisfactory, being highly charged with sulphates, and very likely salt also. Gypsiferous waters, technically called selenitic, our tests have not sharply distinguished from the allied group of more cathartic sulphated waters which also contain sodium and magnesium sulphate, but it is my general impression, from the taste and reported effects that the northern area in Chandler contains more calcium sulphate in proportion than the southern area in Fairhaven and Winsor townships.

Mr. McCoubrie's well on Sec. 7, Chandler, is cased deeply and yet is salt, but as the casing is smaller than the hole, and as the water becomes fresher after pumping, I believe the casing leaks and lets the heavy brine work slowly down to the bottom of the well.

The Burton ale of England is said to owe its peculiar excellence to the gypseous waters from which it is made. Generally speaking brewers find artesian waters satisfactory, but seek as low a percentage of mineral as possible.

Almost all the waters of our list which are graded as more than low in mineral matter are bad boiler waters, in other words, all except the best sandstone waters. The sulphates of lime are especially bad. The best remedies are frequent blowing off, and, for calcium and sulphate the use of salsoda, and using very hot feed water. As regards iron and the carbonates of lime, etc., some help will be obtained by letting the water stand in a tank exposed to the air some time before using, just as in salt manufacture, for the iron and lime will then spontaneously separate out to a large extent. The following well at Grassmere is said to furnish an excellent boiler water. So should the waters of the Napoleon generally, when properly cased. Occasionally there is a well that foams somewhat badly for boiler use.

The next section is written by Prof. Davis and gives his account of the waters of the middle district, which are in general much less charged with mineral matter than those of the other districts.

§ 3. Wells and well waters of the middle townships of Huron county. (By C. A. Davis.)

The territory assigned to the writer for examination was a strip a township and a half wide on either side of the line between ranges XII and XIII east, i. e., the middle north and south road of the county. This area was subsequently changed somewhat by Dr. Lane who added to his own territory the east half of Chandler township and of the township south of it, because of the ease with which they could be reached from his headquarters and by the railroad. After the completion of the survey of this territory parts of Grant and Brookfield townships were assigned to me with headquarters at Owendale.

The wells of these sections may be classed under the following heads:

(a) Dug wells. (1) Springs.
(2) Boarded or planked,
(3) Tiled,
(4) Stoned.
(b) Drilled wells. (1) In the drift,
(2) Through the drift to rock,
(3) In rock.

Springs were comparatively rare, and were found most commonly along stream banks, where the gravel deposited by the stream at some earlier time had been cut through to an underlying clay. Such springs where they were near the house were usually the source of supply for domestic purposes and a reservoir was made by sinking a headless barrel around the spring. The water of such of these springs as were examined was found to contain rather more calcium salts, chiefly carbonates, than deeper wells.

The most common form of curbing for wells in newly settled districts where the wells were comparatively shallow and dug through clay or gravel soil was a box of boards or planks. Such wells were often noticeably foul from the decay of the timber used and from material which had mechanically mixed with the water.

A few wells were noticed in which a large sized drainpipe or ordinary tile or cement was used as curbing. Such wells are free from the objections to which planked ones are liable, and are more permanent. By far the larger number of dug wells visited were stoned up, either with sandstone, drawn from a distance in some cases, or with erratic boulders from the drift. In either case the use of this form of curbing is open to very serious objection, since the spaces between the stones permit the entrance of surface water during storms, and also of that which runs from the surface through cracks and channels, which in clay soil are far from uncommon. During the long continued series of dry seasons which have prevailed for the past years many of the dug wells, partially or entirely failing, have been deepened by boring small holes by hand with augers of various sizes to underlying water-bearing strata. These holes were commonly left without tubing and the water supply was frequently not permanently improved unless the water-bearing stratum which was found, gave a strong up-current, which could keep the opening made by the auger clear. Only one case was noted in which a dug well was flowing over the top.

The water from such of this type of wells as were chemically tested varies characteristically with the soil, or rather with the form of drift deposits in which they were dug, or from which the water came. The water from "veins" in the clay or clay gravel, generally contained more dissolved mineral matter than that from sand or gravel. The mineral matter was frequently largely calcium carbonate, although the sulphate was not wanting. The presence of iron was frequently shown by the reddish color of the "tea-kettle scale" and in nearly every case the presence of chlorin was strongly indicated by the usual test. The water from sandy layers, as would be expected, was more free from the calcium salts, and in general contained less mineral matter.

The character of the soil also has much to do in determining the kind of wells which are most common in a given district, and in studying the wells of the region traversed this was well shown. In sections where the surface layers were porous and underlain at a depth of several feet by impervious strata, or where the drift materials were clay and sand and gravel intermingled in layers, dug wells as described above were almost exclusively used. Where the surface material was a compact clay without intermixed sand, or where the rock was near the surface, the wells were frequently drilled. If the clay deposit was very deep the drill would sometimes strike a water-bearing stratum before rock was reached, and along the southern border of Grant township the wells were frequently of this character. The water from such wells was practically the same as that from those dug in the clay. In many places, however, the drill would reach rocks before water would be found in any quantity, especially if the overlying clay was compact to the rocks.

An interesting region was found just west of Ubly, where there are many high clay ridges. On these the water was nearly all obtained from deep drilled wells which went a foot or two into the underlying sandstone ninety or a hundred feet below the surface, while the wells in the lower flat land on either side of the ridges were not twenty or thirty feet deep to the same sandstone, showing that the rock surface was in the main nearly uniformly flat underlying the regions. Where the surface material is rather thin and porous and the rock directly below, wells drilled a considerable distance into the rock are the only reliable source of supply. In such cases drilling is continued until a "vein" of water is struck, and, judging from reports, the rock is more or less intersected with small channels in which the water collects, as it is said that the drill drops, at the time water is found, as if a hole had been reached.

The water from this class of wells was so characteristically pure and free from mineral matter (see Anal. Badaxe water p. 137) that it was possible to tell by the taste alone whether water came from the sandstone or from the clay above it. Calcium was usually present in traces in the form of the sulphate, and chlorin was either absent or present in small amounts. With the exception of two drilled wells on the middle line of Sec. 18, Huron township, and two dug wells on the N. E. ¼ of Sec. 12, Dwight township, and one in Paris township, near the quarter line on the north side of Sec. 20, the wells visited by me alone were remarkably uniform in the character of the mineral constituents. The two wells mentioned as exceptional were quite brackish, and contained in addition considerable calcium sulphate. In some neighborhoods the iron dissolved in the water was noticeable to the taste, and one well about 100 feet deep was found at Pinnebog P. O., and was quite strongly impregnated with hydrogen sulphid. One well a half mile west of Owendale P. O. was found which was strongly gypsiferous. In the day's trip to Sand Beach to assist Dr. Gordon, I found the wells about there, in Bloomfield and Sigel townships very brackish or even unpleasantly salt, and to the west of the territory assigned to me the wells contained both salt and gypsum in large quantities.

To sum up the results of the examination, the well waters of the section are remarkably free from mineral matter, except along the northern tier of townships. The water from the sandstone is very pure and more so than from the drift above it. All the waters of the section contain chlorin and in some districts the amount is largely in excess of that normal to well waters of the country as a whole, and in other formations might be looked upon as an indication of bad drainage and contamination, but in this region, the fact that salt-bearing formations are so near, both horizontally and vertically, and that there are many old salt wells in the vicinity, affords a satisfactory explanation of the occurrence of chlorids in such quantities.

No flowing wells were found in the region, except one just east of Badaxe, until the valley of the Pinnebog was reached. South of Elkton, about Owendale, and south and west of that point, a considerable number of such wells were found, and also some that formerly had given good flows, but within a year or two had ceased flowing.

§ 4. Mineral waters.

So much for the waters as drinking water, but, like some other things, what will make a well man sick may often make a sick man well, so that some of the less potable waters may still be useful.

The water from the well of Mr. Raither on Sec. 13, south of Bayport, has been brought to the Bayport resort to be used as a cathartic and southeast of it are a number of wells still more powerful. Most of them that are used regularly are mild and one can quickly become used to them, but in hot weather when one is tempted to drink more, and especially if neighbors come to help in the thirsty work of harvesting, they give their characteristic effects. Some are really too strong to drink at all. Such cathartic wells are low in chlorides but strong in sulphates. The sulphates of magnesia and soda are probably the most efficient agents, but no complete analysis of the waters of these wells has as yet been made. Free sulphuric acid is sometimes to be detected.

Then there are the flows from abandoned salt wells. Port Crescent has quite a local reputation, and it seems to me that for tonic salt baths, such wells, which flow, as we have remarked, at Bayport, Port Crescent, and Port Austin, should be an attractive addition to the resources of a summer resort. The deep well at Harbor Beach, however, has been the most exploited in the county, and its analyses are given in Table III.

The way in which some of the wells rust tinware points to the presence of free acids, probably free sulphuric and carbonic acids, and many of them are slightly chalybeate or iron-bearing, judging from the red coating they throw down. However, the iron may be derived from the casing.

One or two cases have been reported where malarial cases have been greatly benefited by drinking the water from these deep wells. Whether there is any chemical ingredient in the water (one of the wells was Mosner's well in Sebewaing) that was helpful, or whether the change was really due to the leaving off drinking swamp water, the real trouble being bad water and not bad air, I shall not presume to decide.

The amount of iron necessary to make a chalybeate (or ferriferous) water of marked medicinal effect is very small; many of the wells seem to contain some iron, especially those otherwise strong in mineral matter.

TABLE III.—ANALYSIS OF HURON COUNTY WATERS.

Chemical components.	Helderberg brines.			Berea brines.		
	(1)	(2)	(3)	(4)	(5)	(6)
H_2O	....	....	....	776.761	767.197	789.764
$CaSO_4$	0.58	0.9936	0.90	0.129	2.539	2.623
$CaCl_2$	41.07	62.6636	56.89	31.274	3.000	5.373
	....	....	Fe. tr.	....	....	Fe_2O_3 .032
$MgCl_2$	22.44	5.3542	4.85	15.675	1.591	4.106
$MgBr_2$	0.84	24.8400	22.50	....	....	....
KCl	3.07	37.7788	34.22	....	....	....
NaCl	203.29	179.2391	162.64	176.161	225.673	189.134
H_2S	....	0.2271	....	....	....	....
Loss	14.41	0.0004	....	....	....	....
Total solids	285.7	311.6000	282.00	223.239	232 803	201.236
Sp. Gr.	1.187	1.180	....	88°	84°	....

Note.—These analyses are all reduced to parts per thousand, i. e., grams per kilogram or ounces per cubic foot, nearly, from various forms of statements as referred to. It has been assumed that the respective chemists in stating the amount in grains per imperial gallon, etc., have really taken 10 lbs. of the water a gallon, regardless of the specific weight of the brine. It is quite common to neglect the specific weight of mineral waters.

(1) Hetherington & Rasher, analysts; for U. S. Alkali Co., Sp. Wt. 1.187, from grains per imperial gallon divided by 70.

(2) S. P. Duffield, analyst, left unchanged from grammes per litre, but Sp. gr. = 1,180 at 60° F. Harbor Beach.

(3) R. C. Kedzie, analyst, from grains per imperial gallon, dividing by 70, with tr. of Fe., both these analyses from Vol. V, p. 82. These two are earlier than No. 1, but all three are of waters from the same well.

(4) From Vol. III, p. 183, and Vol. V, Part II, p. 75, from percentages, 88° salinometer; Ayers' well, Port Austin.

(5) S. P. Duffield, from percentages, 84° salinometer, Harbor Beach 702 ft. deep. Another report gives 98.7% of the solids NaCl.

(6) From percentages, 78.5° salinometer, Thomson Bros.; White Rock 566 feet deep, Vol. III, p. 184, and Report on Centennial Exhibit.

(7) A. B. Prescott from well about 2000 feet deep, but plugged off at 550 feet, see below; main flow from Napoleon. Sp. Wt. 1.0029. Old Bayport, T. 17 N., R. 10 E.

(8) A. B. Prescott, Oct. 13th, 1891, from well 328 feet deep at Bayport, main flow from Napoleon sandstone, but Michigan series not cased off, well flowing all the time; from grains per gallon by dividing by 700÷12.

(9) Bayport Station, 19 foot well, A. B. Prescott. Residue of half a litre tested for K, Li, and Br. Sp. Wt. = 1.0007. Faintly alkaline, saline solids, 0.5006 per thousand.

(10) Dr. R. C. Kedzie, well 15 feet deep pumped, Bayport, by dividing by 70 from grains per imperial gallon. Hardness 12° temporary, 6.5° permanent.

(11) Is a sanitary analysis of a shallow well at (Sand) Harbor Beach. See Water Supply Paper of the U. S. Geol. Survey, No. 31,

	7	8	9	10
$Ca\ H_2(CO_3)_2$	.451	.038	.344	.148 $Ca\ CO_3$
$Ca\ SO_4$	.360	.440	.019	.000 $Ca\ SO_4$
$Fe\ CO_3$	.....	.044	.009	.....
$Mg\ H_2(CO_3)_2$	.....	.100	.....	.031 $Mg\ CO_3$
$Mg\ Cl_2$	.198	.....	.016	.....
Silicic acid	.015	.144	.010	.....
Na Cl	2.379	.925	.022	.007 Na Cl
$Na\ H\ CO_3$	.....	.201	.078	.014 Organic
Total	*3.403	1.892	.499	.200

* By summation.

p. 47. The above analyses I have all incorporated in that paper, where their statements in other forms will be found.

No. 11 is by Prof. V. C. Vaughan at Ann Arbor.

Nos. 12 and 13 are partial sanitary analyses of the Badaxe water supply by F. S. Kedzie and are from wells 200 feet deep in the Upper and Lower Marshall sandstones. See § 6, under T. 16 N., R. 13 E. No. 12 is from the dead end of the pipe (the references in water supply paper No. 31 are erroneously interchanged, and the increase in organic matter over No. 13 is doubtless due to growth of algæ, while the increase of inorganic matter may probably be iron dissolved by free CO_2 in the water from the pipe.

No.	11.	12.	13.
Number of bacteria in 72 hours	.812	.....	.....
Albuminoid ammonia	.00008	.000072	.000048
Free ammonia	.00002	.0000024	light tr.
Permanganate reduced	.003	.....	.....
Chlorine as NaCl	.002	.....	.....
Organic residue	.020	.100	.090
Inorganic residue	.035	.235	.204
Total residue	.055	.355	.295
Hardness	5°.5	5°.9	5°.2

Of these analyses the most interesting geologically and practically are those of the brine near the bottom of the Harbor Beach well. That the water analysed by Dr. Kedzie is as strong in K and Br as shown there can be no doubt. Some of it is still preserved at the Agricultural College and used for exhibiting tests upon bromine. That the sample was artificially doctored there is no reason to believe, in view of the fact that the well was used and continued to be used only for salt manufacture, and so far as I know there was no attempt made to sell the property.

All parties seemed to be much surprised at the result of the analysis, which was repeated, as shown. The most plausible supposition is that the sample contained an extra large amount of the bitter water struck at 1860 feet, which was later diluted by lower brine of more normal composition at 1875 feet. It will be noticed that these brines are somewhere in the Helderberg dolomites, probably (possibly Hamilton i. e. Traverse) and not in the Berea which as elsewhere in the county was a strong pure brine, the analysis of which is No. 5. Nos. 4, 5 and 6 are from the Berea grit and show clearly the progressive increase in solids with depth. Nos. 12 and

13 show the pure water of the Marshall sandstone. No. 8 shows the same water mixed with the sulphated waters of the gypsiferous Michigan series above. No. 7 penetrates deeper into the lower Marshall and we see that the $CaSO_4$ is relatively reduced while the salt and carbonates increase,—just what might be expected. Nos. 9 and 10 are shallow wells showing the water yielded by the Bayport limestones and sandstones,—a little hard and not as low in mineral matter as the Badaxe, but less mineralized than most of the water in the state. Probably the circulation of water in these beds is quite free, as I have indicated in discussing Fig. 9, and an analysis in sand would not be very different. Such analysis I take No. 11 from a Harbor Beach well to be, for I know that the deeper wells like that at the Dow House are salty.

§ 5. Chemical tests of well waters.

In a county as flat and with as few outcrops as Huron county, any thought of following the stratigraphy was out of the question, unless the wells helped us to do it. Information gathered concerning the beds passed through is valuable so far as it goes, but often the important facts have passed from the memory, and again memories are deceptive. I had the depth of the Port Crescent salt wells reported to me from memory as all the way betwen 900 and 1,500 feet deep. It was therefore very desirable to have as a check something that could be tested as a present fact, and it seemed to me possible from things I had heard about different wells, that something might be made by testing them. Practical tests in a small way were hopeful, and as the proof of the pudding is the eating, I resolved on a systematic testing of the wells. It was obviously necessary that the tests should be of the simplest and most rapid description, and they could be but qualitative.* "A pocket case containing a set of reagents for making the ordinary qualitative tests for the more common metals forming soluble salts was devised and taken into the field, equipped with test tubes, etc., but was abandoned after a few weeks' trial as too cumbersome, and from this time on a discarded bicycle-tool-bag, respectively compass case," containing a few physicians' casevials of reagents and a test tube constituted the laboratory. The brief experience had shown that the waters were practically free from substances easily recognizable, except the sulphates, chlorids, calcium and iron, and search for others was not practicable in the field. Under these circumstances

*All in quotation marks is from Prof. C. A. Davis.

the reagents selected were,—silver nitrate, barium chlorid, ammonium oxalate and tannic acid, the latter not perhaps the best for the purpose, but the only available one at the time it was adopted. A small quantity of the water to be tested was used to rinse out the test tube thoroughly, then not more than one-half inch of the water was taken into the tube and a drop or two of the reagent required was allowed to run into it. If chlorin was the substance sought and after the addition of silver nitrate a mere opalescence appeared, the result was noted as indicating a 'trace' of chlorin. If the silver nitrate gave a milky appearance to the water, up to the point of curdiness it was noted as 'Cl low' or 'low plus;' if a curdy precipitate formed, it was said to be 'medium' or 'medium plus,' according to the promptness with which the curdiness appeared, and if the water had a brackish taste, it was noted as 'Cl strong,' and the curdy precipitate was very marked in such waters.

"After the test was made it was usually repeated, and the tube was very carefully cleaned, before another substance was looked for. In this way the wells were tested quantitatively in a rough way, as well as qualitatively.

"The other mineral constituents could not be graded so accurately as the chlorin, but the density of the precipitate and the rapidity with which it formed gave a fairly good indication of the relative amount of each substance present, and by the aid of these tests we were enabled to determine the mineral impurities of the wells visited, with sufficient accuracy for the purpose."*

I may remark that the chemicals above mentioned have the advantage that they can be carried around in a dry form, and dissolved in rainwater as needed. Citric acid may be used instead of HCl for the same reason.

A few suggestions as to recognition of the substances by the general behavior of the waters, may be also interesting. Lime and to a less extent magnesia and iron make tea kettle scale; a scale of carbonates, will dissolve in hot vinegar quite rapidly with effervescence, but the sulphate of lime dissolves more slowly with no effervescence, and has a fibrous appearance when carefully examined, and is softer. An iron water makes a red scale and turns tea black or a weak yellow solution brown, practically the same re-

*All in quotation marks is from Prof. C. A. Davis.

action as that which we used with tannic acid. Cathartic effects are generally due to sulphate of magnesia or sulphate of soda.

As Prof. Davis remarks above, the testing was qualitative, but we give below a table which he prepared showing roughly the quantitative equivalents of his chlorine tests. As the difference between medium and strong is one of taste it is more uncertain, and I found that as I was in a region, and staying at hotels at Sebewaing and Bayport where there was more salt naturally in the water, than was usual in the district in which Davis worked, my division line between medium and strong was higher than his. In order to grade more accurately these wells with much mineral matter I had recourse to a physician's urinometer, which measures the specific gravities. This consists of an instrument like a salinometer,—a cylindrical vase in which floats a glass bulb with mercury in the lower end, and the upper end prolonged into a stem like a thermometer, which is usually divided into 60 divisions, with the 0 at the top, at the point at which it floats in pure water. The heavier the water is, i. e. the more salt it contains, the higher the bulb floats and the excess of weight of equal volumes measured with reference to the volume of pure water is measured on the urinometer scale and the reading gives about twice the salinometer reading and about eight times the percentage of salt. For example, if the urinometer reads 16 the salinometer will read 9 minus, the percentage of salt will be somewhat over 2%, the specific gravity will be 1.016 or a cubic foot of the water (thirty quarts) will weigh nearly 16 ounces more than a cubic foot of pure water would under similar conditions.*

My tests around Sebewaing indicated that by taste I usually classed a well with a specific gravity of 1.002 as moderate, but anything above that as strong or "medium plus." Hence the range of "medium" in my case would be up to 2.6 parts per thousand of solids, and if as in analysis (8) the salt (NaCl) was about half the solids (and the wells were generally strong of sulphates as well as chlorides), my "medium" would correspond to Davis's "medium plus." The range of meaning in the other components is still less exact, but speaking generally, "SO_4 strong" would correspond to a saturated solution of gypsum, about 178 grains per imperial gallon or 2,170 to 2,540 parts per million.*

*Approximately; the table on pp. 177-179 in Vol. III, of our reports gives more accurate figures, but that is itself not quite accurate, and the varying percentages of different salts prevent great accuracy, so that the rule above is probably practically as accurate as the table. The temperature ought also to be considered. Urinometers are usually graduated for a temperature of 60° F.

The following are Prof. Davis's notes to determine the value of his Cl tests during the summer:

100 milligrams NaCl to litre H_2O	=	no saline taste	Cl low—"
200 " " " " "	=	" " "	Cl low—
300 " " " " "	=	" " "	Cl low—
400 " " " " "	=	very slight saline taste	Cl low—
500 " " " " "	=	slight saline taste	Cl low+
600 " " " " "	=	faintly brackish	Cl low+
700 " " " " "	=	faintly brackish	Cl low+
800 " " " " "	=	brackish	Cl medium
900 " " " " "	=	well marked brackish	Cl medium
1000 " " " " "	=	well marked brackish	Cl medium
1100 " " " " "	=	well marked brackish	Cl medium+
1200 " " " " "	=	well marked brackish	Cl medium+
1300 " " " " "	=	well marked brackish	Cl medium+
1400 " " " " "	=	slightly salt	Cl strong
1500 " " " " "	=	slightly salt	Cl strong
2000 " " " " "	=	well marked salt	Cl strong+

"So our 'Cl low' or 'traces' probably indicate salt present as high as 2 parts to 10,000 of water, 'low' up to 5 parts to 10,000, 'low +' up to 8 parts to 10,000, 'medium' up to 1.1 parts to 1000, 'medium +' up to 1.3 parts to 1000 and strong above 1.3 parts to 1000; in every case, provided the chlorides of calcium and magnesium were not present (which seems likely from the faintly saline tests which are present in nearly all my solutions). The lowest amount of salt I could get to give a reaction was two milligrams to the litre, — 2 parts to 1,000,000, — from which I got a very slight opalescence, forming very slowly. In these experiments I used the same silver nitrate which I used all summer, and the results may have additional interest on that account.†"

The main result of these tests is to show that the Napoleon sandstone has less mineral matter, and especially less of sulphates in proportion to chlorine than the overlying beds, and a parallel phenomenon has long ago been observed by Garrigues, in the brines of the Saginaw River (Vol. III, pp. 182-183). Below the Napoleon the salt reappears, but the sulphates are not so prominent, and the analyses of the deeper wells show a predominance of magnesium and calcium chlorides.‡

*Its solubility varies somewhat with temperature, being greatest at 95° F., and also with the other substances in solution.

†Extract from letter of C. A. Davis, Feb. 12th, 1897.

‡The varying percentage of sulphates on the one hand and of the chlorides of magnesia and lime on the other in association with these brines suggests some interesting questions. How can the gypsum which exists in the sea water be so completely got rid of as in analysis (4) or must we suppose that the sea was then deficient in a sulphate of lime? The latter supposition in view of the beds of gypsum that occur both above and below seems hardly likely, and one is tempted to conceive the sulphate of lime as having been chemically replaced. But the only place where the sulphur can be disposed of is in the sulphides. We find, in fact, brine-bearing sandstones, the top of the Napoleon sandstone, or the sandy layers exposed at the Point aux Barques lighthouse, heavily charged or entirely encrusted with sulphides. But this disposition of the sulphur implies a reducing or

§ 6. Systematic catalogue of wells and borings.

Explanations and Abbreviations.

In so many records taken by different men at different times perfect uniformity in description is not observed. But in general the first thing given is the location of the wells within the section, according to the system which has been for some time adopted by the Survey, i. e., by the number of paces north and west of the southeast corner of the section, assuming ordinarily 2000 paces to the mile, and that wells are ordinarily about 50 steps from the road. Thus locations beginning 1950 N. are on the north side of the section. Occasionally wells are located from some other corner, or by feet, instead of paces, or described by the fraction of the section in which they occur, but it is explicitly stated in such cases. Next generally follows the depth, and the depth of bed rock, or the depth of casing, in feet and then the results of tests for salt (Cl) sulphuric acid H_2 SO_4, sulphates (SO_4), and lime (Ca) and iron (Fe), as above described (§ 5), stating whether they are present in large quantity (strong or str.) in moderate quantity (med. or mod.), in slight quantity (low), or in traces (tr), or absent (0). Next comes the elevation above sea or tide level (A. T.) which sometimes precedes, sometimes follows the altitude in feet. The elevation above Lake Huron is about 581 feet less. When the water tasted markedly of mineral, the specific gravity test with the urinometer was often made (Sp. Gr. or Sp. Wt.).

When the well flowed the temperature was commonly noted with a pocket thermometer. That read by Davis seemed to read about 2° higher than that by Lane. The latter has been compared with Green's thermometer No. 7536 and agrees within a degree. The general division of field work has been given above. In certain cass of doubt the field observer is indicated by initial; (D) Davis, (G) Gordon, (L) Lane.

The records are arranged first by townships then by ranges, beginning at the S. E. and then by sections.

deoxidizing action, and it may be noted that the sulphides tend to form near and replacing fossils or in blue or black shales which owe their color to the organic matter contained, which may serve as a deoxidizing agent. The general reaction would then be that organic carbon in oxidizing would bring into solution the iron as bicarbonate, which would partially then interchange with the lime, forming sulphate of iron (Geol. Sur. Miss. III, 1892, p. 19), which would then in presence of more reducing carbon compounds, be reduced to the sulphide of iron. According to this scheme the sulphides would form near the reducing agents and the sulphates and bicarbonates farther therefrom. In the same way the carbonic acid slowly generated by decomposing organic matter, would crowd out the sulphuric acid from the sulphate of lime to a slight extent, which would in its turn claim a certain proportion of the sodium (Na) from the sodium chloride (NaCl), thus giving rise to the complicated associations that we find.

Sebewaing Township (T. 15 N., R. 9 E.).

Section 1.

1950 N., 1280 W., 80 feet deep, 65 to rock, with Cl low. SO_4 trace. J. Graves, owner. A. T. 631.

1950 N., 880 W., 122 feet deep, 68 to rock; Cl low, drilled by A. Jahnke for Ch. Marotski. Chas. Falle drilled 300 ft., near by in a vain attempt to obtain a flow.

620 N., 50 W., 160 feet deep; Cl low, SO_4 low. A. T. 629.

1000 N., 980 W., 11 feet deep. A. T. 630.

Section 2.

In southwest quarter. Drilled by J. Russell for Henry Gettel, A. T. 630.

DRILLER'S RECORD.

	Thickness.	Total.
Clay	62	62
Hardpan	6	68
Limerock	2	70
Slate	20	90
Sandrock	30	120
Limerock	8	128
Sand rock (Napoleon sandstone)	65	193

and in the same quarter, J. Russell drilled a well for Mrs. J. Gettel as follows:

	Thickness.	Total.
Old well	66	
Hardpan	4	70
Limerock	5	75
Slate	27	102
Dark sandrock	15	117
Sandrock	10	127
Limerock	4	31
Sandrock	2	133
Limerock	6	139
White (Napoleon) sandrock	15	154

980 N., 920 W., first well 100 ft. deep, SO_4 low, second surface well dry. A. T. 630.

1360 N., 820 W., 12 feet deep, dug. A. T. 628.

980 N., 1440 W., 190 feet deep, 80 to rock, the first 50 or 60 feet "slate" (shale), then 40 feet and more sandstone; Cl low. L. Ebert, owner. A. T. 622.

1640 N., 1950 W., 140 feet deep, 60 to rock, the casing driven 90 feet, i. e., 30 feet into soft rock; Cl med. SO_4 tr. A. T. 616.

Section 3.

780 N., 1950 W., deepened from 75 feet, which may be about the depth to bed rock, down to 135 feet, at present Cl med. SO_4 tr. *It was harder when shallower.* A. T. 616.

1240 N., 1950 W., 157 feet deep, about 70 to rock. Drilled by C. Hofmeister for C. Winter. The water never overflowed, though at first it came just to the top, and always remains nearly full. Cl low. SO_4 tr. There is another shallow 6 foot well.

1700 N., 50 W., Depth to rock 60 feet, total depth 160 feet. Cl med. SO_4 low. Carl Beck, owner. A. T. 628.

620 N., 50 W., depth 290 feet. A. T. 620.

50 N., 1100 W., Cl med. SO_4 low. See Russell's record following, probably of this well. A. T. 620.

Section 4.

1130 N., 1450 W., well 18 feet deep, water yellow and probably surface water. A. T. 610.

800 N., 50 W., well 210 feet deep, and around here it is 80 to 90 feet to rock; Cl. med. SO_4 trace. Geo. Gremel, owner. A. T. 610.

120 N., 50 W., 205 feet deep, 96 to rock, and then sand rock all the way down. Water begins at about 160 feet and at 205 feet we pass through the waterbearing rock. F. J. Gremel, owner. A. T. 612.

1890 N., 50 W., 20 feet deep, not drilled. A. T. 608.

Section 5.

50 N., 50 W., shallow well in surface sand, of which there are extensive ridges and dunes on the south line of the section. A. T. 612.

Section 7.

Southeast quarter. Test well by J. C. Russell for J. C. Liken on Kobeld's land. No. 1, May 9th, 1894. A. T. 590.

	Thickness.	Total.
Clay	52	
Hardpan	4	56
Loose sandrock	2	58
Sandrock	2	60
Light slate rock	6	66
Fire clay	2′ 7″	68′ 7″
Black slate	4′ 8″	73′ 3″
Fire clay	5′	78′ 3″
Slate and iron	1′ 4″	79′ 7″
Coal	1′ 2″	80′ 9″
Dark sandrock	1′ 8″	82′ 5″

Test well No. 8, on Kobeld's land near the railroad, as recorded below. A. T. 590½. Record as follows:

	Thickness.	Total.
Clay	43	
Sandstone	15	58
Shale and slate	6	64
Coal	6 in	64½
Hardpan	8	72½
Slate	17	89½
Coal	4	93½
Fire clay	3	96′ 6″

No. 9. Test well on Kobeld's land (Coreyell's series). Depth 99 feet. A. T. 590. Record as follows:

	Thickness.	Depth.
Clay	50	
Sandrock 2 ft. very hard	15	65
In black slate	4′ 6″	69′ 6″
Coal	6″	70
Hardpan	3′	73
Blue shale	5′	78
Coal	15′ 4″	93′ 4″
1 ft. in fire clay		99

S. E. ¼. No. 2 test well for J. C. Liken on Kobeld's land. Probably put down May 26th, 1894. Depth 85 feet 9 inches.

	Thickness.	Depth.
Clay	52	
Loose sandrock	1	53
Sandrock	7	60
Iron pyrites	1	61
Black slate rock	5	66
Fire clay rock	1	67
Slate rock	14′ 4″	81′ 4″
Coal	2	83′ 4″
Brown rock	2′ 5″	85′ 9″

S. E. ¼. No. 2 test well for Sebewaing Mining Company. Depth 91 feet 11 inches. About 590 A. T. Record as follows:

	Thickness.	Depth.
Clay	50′ 6″	
Hard-pan	5′ 6″	56
Loose sand rock	1	57
Hard pan	4′ 10″	61′ 10″
Soap or slate rock	13′ 3″	75′ 1″
Black slate rock	4′ 4″	79′ 5″
Coal	1′ 6″	80′ 11″
Fire clay	6′ 6″	87′ 5″
Fine sand	4′ 6″	91′ 11″

No. 1 test well for Sebewaing Mining Company. Depth 130 feet. About 590 A. T. Record as follows:

	Thickness.	Depth.
Clay	50	
Hardpan	7	57
Loose sandrock	2	59
Small vein of sand		
Hardpan	3	62
Black slate	13	75
Light slate	19	94
Black slate	24	118
Fine sandrock	12	130

Section 8.

S. W. ¼. Block 2, Lot 9, of Chappell's subdivision, 980 N., 1600 W. Cl med. +, SO_4 tr. Henry Muller. Original depth 273 ft. It was deepened in August, 1896. This well was cased to 192 feet, afterward to 194 feet, and the deep casing has improved the water. Flow was strong; 2 gallons in eight seconds. T. 52.5°; 10 foot head. Record as follows:

	Thickness.	Total.	Correlation.
Old well	57	......	Pleistocene.
Loose sandrock	2	59	Coal Measures.
Light slate rock	24	83	
Black slate rock	5′7″	88′7″	
Coal	3	91′7″	
Dark sandrock	3	94′7″	
Water sandrock	10′5″	105	
Offset at	126½	......	
Slate with hard streaks	102	207	Grand Rapids group.
Dark lime rock	16	223	
Slate with hard streak	12	235	
Soft slate rock	12	247	
Sandrock	67	314	

1360 N., 1316 W. About 50 feet southwest of corner of Young and Center streets, Lot 3, Block 2, of J. C. Liken & Co.'s plat. J. Bauer, owner. A. T. 596. Driller's record as follows: A. C. Lane was present at the drilling and the notes in brackets are his.

Clay (old well 20′)	48	......	
Hardpan (clay with little stones, Sept. 2)	16	64	Pleistocene.
Light shale	10	74	
Black shale	7	81	Coal
Black slate	8	89	Measures.
(Sept. 3, down to 95′2′, coal between 81 and 88 ft? Lighter fire clay at bottom).			
A little coal			
Black shale	12	101	
Sand rock	3	104	
Hard dry lime rock. Cl mod SO_4 mod.	9	113	Bayport, *i. e.*,
Sept. 5, Down to 118 ft., struck water in last 10 feet; the drillings full of brown angular fragments with some sulphide of iron and zinc, showing probably that they have passed through a siderite nodule.			Maxville.
Light lime rock (effervescing freely)	14	127	Limestone.
A drop of 7 in., SO_4 mod. Cl med. + Sp. gr. 1.002 +,			
Light and blue shale	50	177	
Sept. 9, sandy shale 7′ below the drop, then blue shale 12 to 144 this day.			
Sept. 10, 145-155 blue calcareous shale.			
Sept. 11, 155-170 blue calcareous shale sticky.			
Work interrupted 12-13th.			
Sandrock	5	182	Michigan series.
Lime rock	6	188	
Sandy shale	10	198	
Light shale	8	206	
Dark lime rock	19	225	Soule beds.
Light shale	24	249	
Lime rock	3	252	
Water sand rock	48	300	Napoleon sandstone.
Fine sand rock	10	310	Upper Marshall.

Finished Friday, Oct. 2d, 1896. Good flow.

S. E. ¼ of N. W., on dividing line between Campbell and Martini's place, about 100 feet from the street.

1130 N., 1430 W. Cl med. SO_4 med. Hard. Sp. Wt. 1.004. Head fluctuates every day. In 1889, 10 foot head, Aug., 1896, 3 foot head, in Sept., 1896, 2 foot head. It failed entirely soon after. Martini and J. W. Campbell, owners. Depth 280 to 285 feet (330?). No flow until at the very bottom, then with one blow of the drill at least 10 feet head. A. T. 596.

675 N., 1265 W., Main street, opposite Fourth street. Flowing well T. 8° R. = 50° F. Depth 365 feet. Owned by Hæberlein's Brewery. This well is deeper than necessary for water, and they stopped going further for fear of getting salt. It is 5° less hard than Mosner's well and has less S. It is cased to 160 feet, then there is blue slate 20 feet, the rest is solid rock,—about 300 feet to sandstone. It is probable that the driller commenced getting into the red rock which other records show underlies the Napoleon, and is commonly taken to be a sign of salt. A. T. 607.

650 N., 1350 W. Block 11 W. C. Chappell's addition 400 ft. N. of 1-16 line and 50 feet west of center. Depth 275 feet. A. T. 600. Chappell's well.

This well is slightly salty, and used to flow, but the casing burst and the water leaked into the old mine. In Jan., 1898, the leak is said to have become so bad that the heads of all the other flowing wells dropped. It seems to be largely responsible for the drop of the head in the Napoleon.

1100 N., 1537 W. N. W. corner Union. Mosner's hotel. Flowing well, supplies 6 pipes, 3 or 4 foot head. Cl. med. T. 54° F. Depth 298 feet. An analysis lost showed Fe_2O_3 Na Cl., S, Mg., etc. A. T. 593.

1160 N., 1420 W., S. E. of N. W. Depth 304 to 307 feet. Owner, C. F. Bach. Drilled in December by C. Hofmeister. Sp. gr., 1.003. Cl med. SO_4 low. A. T. 597.

Flowed at first, but has ceased. They keep pumping it night and day by a wind mill.

750 N., 1800 W. N. W. of S. W. Depth 293 feet. Sebewaing Coal Co. A. T. 593.

Forms a white scale in boiler. Salt and iron evident.

1010 N., 1400 W. Cl med. SO_4 low. Depth 160 to 170 ft. A. T. 596 feet. Behind Likens' store.

700 W. and about 650 N. A. T. 610. Bach's well.

Used to flow but stopped when the Martini-Campbell well started.

About 1200 N., 1950 W., at Stave Mill. Depth 115 feet. A. T. 593. Liken and Bach, owners

490 N., 1460 W. A. T. 600.

Original coal exploration.

490 N., 1375 W. Depth 86 feet. A. T. 600.

Original shaft 86 feet to bottom of coal passing through boulders of sandstone.

On Chappell's land. Depth to rock 50 feet, total depth 112 ft. 3 in. A. T. 596. J. C. Liken's well No. 10. Record as follows:

	Thickness.	Depth.
Clay	50	
Sandstone	10	60
Hardpan and gravel	2	62
Sandstone	13	75
Light shale	7	82
Slate	23′ 7″	105′ 7″
Coal	4′ 5″	110
Fireclay	2′ 3″	112′ 7″

Section 9.

1350 N., 1400 W. Depth 70 feet (120). A. T. 607.

Used to flow but has not flowed since 1889. It was later deepened in testing for coal, but we have no record of it; only a few inches of coal at most, were found.

50 N., 1900 W. Cl tr. SO_4 med. Depth 160 to 180 feet. A. T. 607. Driller J. C. Russell, for Graves. Cf. Sec. 1.

Section 10.

50 N., 1680 W. Depth 164 feet. Cl tr. SO_4 trace. A. T. 620.

This well is in blue stone not sandstone, but of a pale ash blue color. Water at 64 feet and rose to within 9 feet of surface at first, at 164 feet depth rose to within 7 feet of the surface. Now (1896) it is lower.

50 N., 1200 W. Depth to rock 60 feet, total depth 247 feet. Cl low. SO_4 0; at 180 feet water rose to within about 1 foot of surface. A. T. 622.

Mainly blue rock at bottom, 50-60 feet in sand rock.

50 N., 600 W. Cl med. SO_4 trace, stains of Fe. Depth 490 feet. A. T. 624.

Chas. Voltz, owner; Chas. Hofmeister, driller.

At 180 feet water, which at first rose to within 2 or 3 feet of surface. At 220 feet water again; got red rock after passing through sandstone at bottom.

1950 N., 460 W. Cl low. Depth to rock 80 feet, total depth 182 feet. At 140 feet in sandstone as much water as it ever got.

1850 N., 760 W. A. T. 620.

Section 11.

1780 N., 240 W. Cl trace, SO_4 strong. Depth 145 feet. A. T. 630.

1950 N., 1280 W. Cl low, SO_4 strong. Depth to rock 50 feet, total depth 172 feet. Water at 57 feet and rises to 18 feet below surface. This well is cased to rock and has white sandstone at the bottom. This well has two slightly different records, the one above was furnished at the house, the one below from J. Russell.

J. Russell, driller. Joseph Gruen, owner. A. T. 630.

August 29, 1895.

	Thickness.	Depth.
Red clay	9	
Blue clay	48	57
Hardpan and boulders	2	59
Sand and gravel	1	60
Slate or soap rock	4	64

Deepened June 26th, 1896.

	Thickness.	Depth.
Hard dark rock	6	70
Slate rock	14	84
Hard dark rock	1	85
Slate rock	2	87
Hard dark sandrock	4	91
Black sandrock	5	96
Hard flint rock	2	98
Sandrock	18	116
Very hard rock	3	119
Sandrock (Napoleon)	51	170

50 N., 1240 W., Cl low, SO_4 strong. A. T. 630.

Depth 200 feet. about 80 feet of casing. E. Rievert, owner.

50 N., 820 W. Cl low. SO_4 med. Depth to rock about 70 feet, total depth 300. A. T. 630. D. H. Voltz, owner.

Sandstone at 70 feet, then a few feet of soap rock, then sandstone the rest of the way to 300 feet. (?)

50 N., 320 W., Cl low. SO_4 med. A. T. 630. Depth about 96 feet. This well is cased for 58 feet. Cost (50c a foot for first 50 feet, $1 a foot thereafter) + $29 for casing = $100. Caleb Voltz, owner. C. Hofmeister, driller.

120 N., 50 W. Cl low, SO_4 strong. Depth to rock 182 feet.

1240 N., 1950 W. Depth 60 feet. A. T. 630.

Water is said to have been struck just on top of rock, but the well is filled up. W. Kuehn, owner.

N. E. of N. W. ? A. T. 630. C. Finkbeiner, owner. J. Russell, driller. Aug. 13, 1895.

	Thickness.	Depth.
Red clay	14	
Blue clay	43	57
Hard pan	8	65
Slate or soaprock	9	74
Very hard lime and sandrock	20	94
Sandrock	16	110
Very hard rock	2	112
Water sandrock	16	128

Section 12.

1950 N., 1760 W. Depth 128 feet. A. T. 630.

1500 N., 50 W. Cl low, SO_4 trace. A. T. 630. Depth 90 feet.

680 N., 50 W. Depth 86 or 200 feet. A. T. 630.

Section 14.

1950 N., 1580 W. Cl trace, SO_4 strong. A. T. about 630. A. Voltz.

50 N., 1680 W. Cl trace, SO_4 med. A. T. about 632. Depth to rock 90, total depth 268 feet. At first in soaprock, then harder rock and sandstone.

50 N., 1360 W. Cl trace, SO_4 med. Depth to rock 80, total depth 296 feet. A. T. 632. This well is cased for 80 feet.

50 N., 700 W., Cl trace, SO_4 strong. Depth 150 feet. Bauer, owner. A. T. 632.

Section 15.

1850 N., 1950 W. Cl low SO_4 trace. Depth to rock 70 feet, 74 casing, total depth 216 feet. A. T. 620.

Riever and Studer's cider mill. C. Hofmeister, driller. From 69 to 80 feet this well passed through buff limestone, from 80 to 105 feet green calcareous shale. No coal was found, and it did not go down to sandstone.

When the water in this well is roily rain is expected in 24 hours.

1950 N., 200 W. Cl low, $SO_4$0, A. T. 625. Depth to rock 84 feet, total depth 200 feet. John Adams, owner. No more water than a second well has at 107 feet. About 4 feet in sandrock.

400 N., 1950 W. Total depth 135 feet. Cl low, SO_4 med. A. T. 622.

Water level 24 feet below surface. This well is cased for 100 feet, gas pipe is used for 70 feet.

670 N., 1950 W. Sp. Wt. 1.003, Cl low, SO_4 med. Ruppert and Sanders, owners. Drilled by J. Russell.

This well was 150 feet deep, afterwards deepened to 200 feet.

Section 16.

1950 N., 520 W. Cl low. Total depth 260 feet.

400 N., 50 W. Cl low, SO_4 med. A. T. 625. Depth to rock 73 feet, total depth 126 feet. There is said to be about 2 in. of coal in this well.

650 N., 50 W. Sp. Wt. 1.004 Cl strong, SO_4 trace. A. T. 624. Depth to rock 72 feet, total depth 350 feet. This well goes through sandrock to red paint rock. Soft water, which stood at first 4 ft. 3 in. below the surface afterwards fell to 20 feet below the surface.

Section 17.

W½ of N. W. ¼, on land of Henry Liken, Jr., Sebewaing. No. 3 test well for Saginaw Bay Coal Company. A. T. 600. Total depth 82 feet 1 inch. Record as follows:

	Thickness.	Depth.
Sand	3	
Clay	52	55
Hardpan	4	59
Hard sandrock	5	64
Light slate	13	77
Black slate	2	79
Coal	2′ 10″	81′ 10″
Reddish slate	3″	82′ 1″

N. ½ of N. W. ¼, on Beck's land, Sebewaing. No. 2 test well for Saginaw Bay Coal Company. Total depth 84 feet. Record as follows: A. T. 600.

	Thickness.	Depth.
Clay	65	
Hardpan	7	72′
Black slate	8′ 8″	80′ 8
Sulphur and iron	8″	81′ 4″
Coal	2′	83′ 4″
Sandy fire clay	8″	84

S. E. ¼ of N. W. ¼ on Schilling's place. Records from J. C. Liken.

No. 1.

	Thickness.	Depth.
Clay	60	
Hardpan	7	67
Rotten shale	1½	68½
Slate	13	81½
Coal	4′ 5″	85′ 11″

No. 2.

	Thickness.	Depth.
Clay	62	
2 ft. gravel at 40 ft.		
68 ft. to sandstone.		
Sandstone	10	78
Shale	4	82
Slate	13	95
Coal	4′ 7″	99′ 7″

N. W. ¼. Sebewaing Mining Company. J. Russell, driller. Record as follows: (Note the greater depth to rock.)

	Thickness.	Depth.
Clay	59	
Hardpan	2	61
Sand and gravel	3	64
Hardpan	11	75
Large boulders	1½	76½
Slate and sand mixed	13½	90
Black slate	12′ 1″	102′ 1″
Coal	4′ 2″	106′ 3″
Rotten slate	1	107′ 3″

Section 18.

900 N., 600 W. Sp. Gr. 1.005, Cl strong, SO_4 med. Depth 300 feet. A. T. 590. Record below. Well at the Saginaw Bay mine, record below by J. Russell.

	Thickness.	Depth.	
Sand	8		
Clay and dry quicksand	12	20	Pleistocene
Blue clay	28	48	
Boulders	5	53	
Sandrock	38	91	Coal measures.
Cave in of slate	21	112	
Slate, soft	6	118	
Fireclay	6	124	
Sandrock	10	134	
Sand and slate mixed	70	204	Grand Rapids group.
Dark limerock	19	223	
Soap limerock	7	230	
Hard limerock	17	247	
Hard sand rock	4	251	Marshall
Fine sand rock	13	264	
Slate rock	1	265	

N. E. ¼. A. T. 590.
No. 1 test well for Saginaw Bay Coal Co.

	Thickness.	Depth.
Sand	4	
Clay	55	59
Hardpan	6	65
Light slate	6	71
Sandy fireclay	15	86
Hard black rock	2	88
Sandy fireclay	19′ 6″	107′ 6″
Hard black rock	5′ 6″	113
Water sandrock	1′ 6″	114′ 6″

1900 N., 1100 W. Cl strong, SO_4 med. Fe indications, Sp. Gr. 1.006. Depth 284 (384?) feet. This well has fine flow and stands on the edge of the old shore about 4 feet above lake.

1750 N., 100 W. Sp. Gr. 1.007, Cl strong, SO_4 med. T. 52° F. Depth to rock 52 feet, total depth 303 feet. 592 A. T.

This well had a strong flow 4 feet above ground, but the strength of flow varies with the weather. It was deepened 22 feet since first put down, which did not improve the flow.

	Thickness.	Depth.	
Clay	51		
Sand and gravel	1	52	
Loose sandrock	2	54	
Hard rock	2	56	
Dark sandrock	18	74	
Coal about	6 in.	74′ 6″	
Sandrock	1′ 6″	76	
Slate	6	82	
Coal	3′ 8″	85′ 8″	
Bottom slate	1′ 4″	87	
Sandrock	13	100	
Light slate or sandy fireclay	96	196	Michigan
Hard dark rock	24	220	
Slate	20	240	
Hard lime rock	8	248	
Sand rock	55	303	Napoleon sandstone

About 16 feet east a well was put down for coal and found none where this found 3 ft. 8 in., see the following record:

	Thickness.	Depth
Clay	50	50
Hardpan	5	55
Sandrock	30	85
Coal	1	86
Clay	2	88
Sandrock	30	118
Shale	8	126′ 6″

1750 N., 94 W. On the Lutz farm N. part of 18. J. C. Liken's farm. A. T. 590.

No. 5.

	Thickness.	Depth.
Clay	45	
Sandrock	21	66
Sticky blue shale	6	72
Slate	10	82
Coal	4′ 4″	86′ 4″
Fireclay	1′ 6″	87′ 10

No. 6 on same farm.

	Thickness.	Depth.
Clay	45	
Sandrock	5	50
Sand and gravel	20	70
Shale	3′ 6″	73′ 6″
Coal	2	75′ 6″
Hardpan	2	78′ 6″
Sandstone	21	100

No. 7 same farm.

	Thickness.	Depth.
Clay	43	
Sandstone	9	52
Shale and slate	10	63
Coal	1	63
Hardpan	8	71
Slate	8	79
Coal	3′ 2″	82′ 2″
Fireclay	1	83′ 2″
Sandstone	2′ 4″	85′ 6″

1300 N., 1000 W. No. 5 test well for Saginaw Bay Coal Co., on their own land. July, 1894. J. Russell, driller.

	Thickness.	Depth.
Sand	3	
Clay	39	42
Hardpan	3	45
Sand rock	26′ 4″	71′ 4″
Coal about	5″	71′ 9″
Sand rock	8	79′ 9″
Slate	6″	80′ 3″
Sand rock	7′ 1″	87′ 4″
Coal	4	91′ 4″
Light shale	3″	91′ 7″

N. E. ¼ of S. E. ¼. No. 4 test well for Saginaw Bay Coal Co., on land of B. Engelhard, Sebewaing.

	Thickness.	Depth.
Sand	4	
Clay	58	62
Hardpan and gravel	10	72
Sand and gravel	18	90
Slate	3	93
Coal	2′ 7″	95′ 7″
Bottom slate	5″	96

1050 N., 1000 W. No. 10. Depth to rock 45 feet, total depth 79 feet 7 inches. A. T. 586 (4.5 above datum). Record:

	Thickness.	Depth.
Clay	43	
Sand and gravel	2	45
Sandstone	15	60
Limestone	6″	60′ 6″
Sandstone	7′	67′ 6″
Slate	1	68′ 6″
Sandstone	6′ 6″	75
Slate	1	76
Coal	3′ 7″	79′ 7″

1060 N., 600 W. No. 9. Depth to rock 76 feet, total depth 90 feet 6 inches. A. T. 588 (6.3). Record:

	Thickness.	Depth.
Clay	45	
Sand and gravel	5	50
Hardpan	26	76
Slate	11	87
Coal	3′ 6″	90′ 6″

940 N., 0 W. No. 13. Depth to rock 64 feet, total depth 86 feet 5 inches. A. T. 598 (16.7). Record:

	Thickness.	Depth.
Clay	63	
Sand and gravel	1	64
Sandstone	17′ 4″	81′ 4″
Slate	1	82′ 4″
Coal	4′ 1″	86′ 6″

500 N., 750 W. No. 14. Total depth 163. A. T. 585 (12.6).
90 N., 1040 W. No. 12. Depth to rock 58 feet, total depth 118 feet. A. T. 592 (9.7). Record:

	Thickness.	Depth.
Clay	58	
Sandstone	42	100
Slate	14′ 3″	114′ 3″
Coal	3′ 9″	118

Section 20.

900 N., 1250 W. A. T. 620. Chas. Winter, owner.

	Thickness.	Depth.
Clay	74	
Sand and gravel	45	119
Fine sand rock	30	149
Lime and dark sand rock	67	216

Section 21.

900 N., 50 W., Cl med. +, SO_4 med. A. T. 620. Depth 180 feet +.
1460 N., 50 W., Cl low, SO_4 med. A. T. 620. Total depth 230.
980 N., 50 W., Cl low, SO_4 med. A. T. 620. Depth to rock 100 ft. Total depth 193 feet. This well has 4 in. casing for 60 feet, and 3 in. casing for 100 feet.
800 N., 1950 W. Cl strong, SO_4 strong. Sp. Wt. 1.003. A. T. 620. 80 feet to rock, total depth 367 feet.
This well is cased to rock. The water becomes more brackish after pumping. (Cathartic on harvesters unused to it.)
1950 N., 160 W. SO_4 low, Cl med. +, Sp. Wt. 1.002. Depth to rock 86 feet, total depth 270 feet.
At first the water in this well rose to within 18 feet of surface. The first rock is sandstone, 20 feet, then some coal, then soaprock, and then the sandstone whence the water came.
50 N., 420 W. Cl low, SO_4 med. A. T. 620. Depth to rock 72 feet, total depth 285 feet.
The water in this well rose to within 22 in. of the surface. This well has about 70 feet of white sandstone, Napoleon, at the bottom.
50 N., 1640 W. Cl 0, SO_4 med. A. T. 620 feet. Depth 100 feet +.
This well flowed at first, now the water stands 20 feet below the surface.

Section 22.

50 N., 300 W. Cl 0, SO_4 low. A. T. 630. Depth 168 feet. John Sting, owner.
300 N., 1100 W. A. T. 626. Depth to rock 66, total depth 105 feet.
This well had 66 feet of surface, of which the bottom, 35 feet, was "putty" clay, then 6 feet of hardpan, 1 foot as hard as emery, (?) about 6 in. limestone, with a spring between limestone and sandstone, then 32 feet sandstone and soaprock.
300 N., 1200 W. Cl trace, SO_4 med. A. T. 626. Depth to rock 70 feet, total depth 124. This well ends in 3 feet hard rock, then 3 ½ feet sandstone.
1240 N., 1800 W. Cl low, SO_4 low. A. T. 620. Depth to rock 60 feet, total depth about 200 feet. Shell rock hard as flint over the last 20 feet of sandstone, very little soap rock.
1460 N., 1950 W. Cl low, SO_4 med. A. T. 620. Total depth about 400 feet. A. Bach, owner.

Section 23.

1950 N., 1360 W. Cl trace, SO_4 med. A. T. 635. Total depth about 200 feet.
560 N., 1950 W. Cl 0, SO_4 med. A. T. about 635.

Section 26.

1300 N., 1950 W. Cl trace, SO_4 med. A. T. 632. Total depth 100. This well used to flow. All around this neighborhood it is 100 to 115 feet to water.

Section 27.

1950 N., 200 W. Cl 0, SO_4 med. A. T. 630. Depth to rock 60 feet, total depth 205 feet. This well is cased for 60 feet.
1950 N., 900 W., Cl trace, SO_4 med. +, A. T. 629. Depth to rock 74 feet, total depth 168 feet.
1400 N., 1950 W. Cl low, SO_4 low. A. T. 625. Total depth 140 feet. When the wind is from the west the water is said to be cloudy.
50 N., 540 W. A. T. 630. Total depth 95 feet. This well is not flowing.

Section 28.

1950 N., 700 W. Cl low, SO_4 med. Depth of casing 95 feet, total depth 227. A. T. 620.
1950 N., 100 W. Cl 0, SO_4 med.
200 N., 1950 W. Cl trace, SO_4 trace. Depth to rock 50 feet, (?) total depth 79. This well is in white sandstone and is cased for 50 feet.
740 N., 1950 W. Cl low, SO_4 low.
1740 N., 1950 W. Cl low, SO_4 med. Total depth 294 feet.
1120 N., 50 W. Old mill which had a drilled well.

Section 29.

1950 N., 260 W. SO_4 strong, Cl med. +, Sp. Wt. 1.003. Depth to rock 140 feet,(?) total depth 228 feet. A. T. about 620 feet. Water was struck at 200 feet. This well used to flow and is cased for 140 feet,—is evidently in the channel.
1800 N., 1950 W. Depth to rock 150 feet, total depth 260. Owner, F. Becker.