

INDEX TO
NOTEBOOK NO. 170

(August 9 to September 4, 1901.)

- August 9. Hart and vicinity, Shelby, Ferry to Hesperia. Flowing well data.
- August 10. Hesperia, McLaren Lake. Old drainage line east of Hart. Features west of Hart.
- August 11. Flowing wells at Hart and other wells. Drive southwest past East Golden into Benona Township and return.
- August 12.
- August 13. Drive east through Elbridge and Leavitt Townships to Walkerville and return. Well data.
- August 15. Drive with J. N. Cotton northeast of Hart into Mason County and return. Wells at Crystal Valley and elsewhere. Some overflow.
- August 16. Hart to Smith Corners and Pentwater and by boat, Pentwater to Ludington. Deep drift. Trip to AuSable Lake and return.
- August 18. Trip south from Ludington and back.
- August 19. Ludington to Scottville, Wiley, Custer, Lincoln River and return to Ludington.
- August 21. Scottville, Victory Corners, Freesoil, Fountain, with team, then railroad to Baldwin. Features in Lake County.
- August 23. Trip southwest from Baldwin past Carr into Newaygo County and return past Big Star Lake.
- August 24. Trip northwest from Baldwin past Stearns, Branch, Custer, Bacheller, Millerton and Canfield.
- August 25. Sunday excursion, Baldwin to Grand Rapids and return to White Cloud.
- August 26. Trip northwest from White Cloud to Dowling Creek and Otia, then railroad to Baldwin.
- August 27. Drive southeast from Baldwin into Newaygo County and return.
- August 28. Railroad, Baldwin to Reed City. Drive to Big Rapids.

August 29. Big Rapids to Hersey and Reed City. Drive northwest of Reed City.

August 30. Drive Reed City to Luther and return.

August 31. Returned to Ann Arbor.

Sept. 4. Ann Arbor to Marion with C. A. Davis.

NOTE: Notes made September 9 and 11, 1901 also are in this notebook but have been included with the typewritten transcript of Notebook No. 171 which immediately follows this one.

August 9, 1901.

Donated by _____

Hart, Michigan - 655 feet. I began field work here after nearly three weeks' intermission in reading proof of Monograph XLI.

Hart Station stands on a terrace 40-45 feet (43 feet by hand level) above the Pentwater River below Gurney's Mill dam. It is only 2 blocks (600 feet) wide, south of river valley, and is not present north. The channel is about 800 feet wide. The bluff is mainly a pink clay, laminated, and carrying few pebbles in its lower part. The clay in the north bluff rises 50 feet above the stream, and its upper 10 feet is more pebbly and shows less distinct water bedding planes than the remainder. It, in places, looks like ordinary till. Above the clay is sand with occasional thin beds of gravel rising 25 feet or more, or to fully 75 feet, above the stream. Back of this, to the north, there is a moraine with swells 15-25 feet high. It has much sand on it. Above, or east of Hart, for a mile, and for two miles down the river, the stream is bordered closely by morainic topography, there being only a narrow terrace such as that on which the station stands, but two miles below Hart, in the northwest part of Section 8, the river enters the lake plain which stands about 70 feet above Lake Michigan.

East of Hart about a mile, in the east part of Section 9, a plain sets in that was apparently an old line of discharge for glacial waters toward the southeast, there being a broad valley leading along the south branch of Pentwater River to Section 5, Ferry Township and thence across a swampy divide to the north branch of White River near Ferry (Reed Post Office).

The waterworks supply at Hart is from flowing wells a mile south of the station, near the fairgrounds. The wells are about 116-170 feet deep. They are on ground 45 or 50 feet above Hart Station. I am told by the proprietor of Hotel Wiglon that there is a rise of 43 feet to the pumping station from the hotel and this is but 3-5 feet above Hart Station.

A boring was made near the waterworks that reached the bottom of the drift at 371 feet and was continued 29 feet into the rock. It failed to get a good water supply so is not in use. The driller of the deep well, C. C. Jacks of Muskegon, states that for 40 feet there was a mixture of clay with sand and gravel but below that depth the drift was largely clay (blue) and boulders were struck at several levels in it. The rock first struck seemed to be sandstone but became shaly below. This well was 150 feet north of the Slaght warehouse and 10 feet from Street. Number 2, east of warehouse, is 170 feet and has a good flow. Number 3, about 40 rods southeast from No. 2, 160 feet, also flows. Number 4, about 40 rods south of warehouse, 129 feet, flows. Number 5, 12 rods south from No. 4, 116 feet, flows. (See letter from C. D. McLouth, August 20, 1901, for above data, and August 11 in this notebook for other data.)

I am told by T. S. Gurney that there is about 40 feet fall in Pentwater River below the dam at Hart, so the railroad station is not far from 80 feet above the lake and the flowing wells 120-125 feet, or very nearly 700 feet above tide.

Aneroid 29.145 at Hart Station, 650 feet \pm A.T., at 1:30 p.m.; 29.100 at waterworks plant in south part of village, 690-700 feet \pm A.T. There is a gradual rise from this station up to and 1/4 mile beyond the waterworks to the base of a prominent range of morainic hills whose north border trends west-east across middle part of Sections 19, 20, 21 and 22, Hart Township. This sloping plain has a sandy coating, in places 20-30 feet, but much of it has clay (probably till) near the surface. With the exception of a narrow range of hills directly east of Hart on line of Sections 9 and 16, 10 and 15, the tract from Pentwater River south to the high range just noted is a gently undulating tract with much till. It has only a few boulders. It extends

west to Mears and east to the old line of glacial drainage above mentioned (in Sections 15 and 22, Hart Township). I do not yet know its significance. At Mears it changes to a gravel plain or sand plain that covers several square miles in southeastern Golden, northeastern Benona and northwestern Shelby Townships. There is a moraine on the west and north sides of that sandy plain in Golden Township which probably crosses the Pentwater just below Hart and which may include the range directly east of Hart on south side of river. The sand plain is evidently an outwash apron from that moraine. This till tract that extends east from Mears may be an intermorainic tract.

I drive south from Hart to Shelby across the prominent moraine. It is very uneven in structure as well as in altitude. The road passes over patches of stiff clay that seem to be of limited extent, much of the surface being sandy or a sandy loam with boulders in moderate amount.

I reach an elevated point where the road bears southwest into Section 29, Hart Township, and follows a very sharp ridge for 1/2 mile in Section 29 that overlooks basins on the east, 100 feet or more below it. The aneroid reads 28,780-800 on this crest, or 975-985 feet A.T. There are several points in view in Sections 30, 31 and 32, Hart Township, that reach about 1,000 feet, and the south edge of Section 27, Hart Township, seems to be fully 1,000 feet. I cross a sag near corners of Sections 28, 29, 32 and 33, Hart Township, and rise to a crest about 600 rods from south end of line of Sections 32 and 33 that registers about 28,780, or 985 feet \pm . A point on east-west road 60-80 rods east of center of Section 32, is probably 1,010 feet. The west half of Section 5, Shelby Township, may contain points that reach 1,000 feet A.T., also east part Section 6. The road leads down Stoney Creek valley to Shelby from near the town line but high morainic tracts are close at hand on each side the valley. There is an uneven surface along the

valley bottom so it is not certain to be a line of outwash. Aneroid 28,970 at Shelby Station, 807 feet. The deepest boring at Shelby is 516 feet and it is not in the rock, but rock may have been struck at bottom. The boring was made some years ago by the miller, G. B. Getty, with a view to obtain a flowing well. It is on low ground about the same altitude as the railroad station (807 feet). From memory, Mr. Getty gave the following record:

Clay and mixed drift	40± feet
Sand with water	40± feet
Clay	25± feet
Sand with little, if any, clay	400± feet
Clay at bottom of well	<u>11 feet</u>
Total -	516 feet

Mr. Getty noticed no muck soil or other indications of a break in the sand deposit but no particular notice was taken. The water fell short considerably of reaching the surface when the boring was abandoned but now water stands almost level with the surface. The boring stopped at a rock which bent the pipes so that they could go no deeper.

The waterworks supply at Shelby is from wells excavated 70 feet with small pipes that extend from the bottom down about 30 feet farther. They are largely through sand, there being less clay than at Mr. Getty's boring. The head is some distance below the surface. Aneroid 28,820 at cemetery 1/2 mile east of Shelby on north edge of Section 16 = 942 feet. Points 100-120 rods southeast are 20 or 30 feet higher, or about 970 feet. Much of Sections 10 and 15, 11 and 14 are about 950-975 feet on high ridges and knolls. Boulders are not numerous till I reach a ravine in Sections 12 and 13. This is literally paved with them, and they abound eastward as far as the west bluff of the glacial drainage line in Sections 8 and 17, Ferry Township. There are very sharp knobs in the northwest part of Ferry at northeast corner of Shelby Township, rising abruptly 50-75 feet.

There are gentler swells in this moraine in the southwest part of Ferry Township. The knobby drift is said to cover Sections 19 and 18 and to pass south-southwest from there across Sections 25 and 36, Shelby, to Section 2, Grant Township. There are more boulders on this knobby drift than on the swell and sag tract east of it. It seems likely that this bouldery, knobby drift marks a margin of the ice that has a general north-east trend from Claybanks to here in northwestern Ferry Township. It crosses the old glacial drainage line near the present divide in its swamp in Section 5, Ferry. Sections 3, 4 and 9, Ferry Township, on the east side of the channel, are also reported to be very bouldery and are full of knobs.

The channel has a very flat bottom at the present divide with a peaty swamp in it. Aneroid 29.030 at channel near middle of line of Sections 8 and 17, Ferry Township, or about 750 feet A.T. The width here is about a mile, and that width is maintained to north branch of White River, 1 mile north of Ferry. From there down to the line of Ferry and Otto Townships, it is about $1\frac{1}{2}$ miles. It enters the great sand plain in Sections 2 and 3, Otto Township. At Ferry the plain or bottom of this channel is about 20 feet above North Branch. Aneroid 29.020 at Ferry at 4:45 p.m. The aneroid is working toward low barometer so that the glacial channel may be considerably less than 750 feet A.T.

B. A. Wiswell, in Section 34, Ferry Township, on the plain near North Branch of White River, made a well 78 feet that overflows: Clay at surface 5 feet; sand 10-12 feet; blue clay to water vein at 78 feet. Water comes in through a joint in the clay. Water is laxative. Another flowing well was obtained by James Osborne in north part of Section 23, Ferry Township, near North Branch at depth of about 90 feet. East of Ferry, on south side

of North Branch there is a gently undulating till tract bordering the glacial drainage line in Sections 23, 24, 25 and 35, Ferry Township. It is known as the "Maple Range" because timbered heavily with maple. There was pine on the glacial drainage line. It stands, as a rule, only 25 or 30 feet above the bottom of the drainage line.

East of Maple Range, in east part of Sections 25 and 36, Ferry, and in Sections 30 and 31, Newfield, there is a flat, sandy swamp with elm and other hardwood timber. North from here in Sections 17, 18, 19 and 20, Newfield, there is a strong moraine. Its south border is near the east-west road in south part of Sections 19 and 20. Much of Sections 27, 28, 29, 33, 34 and 35 are a sandy tract with but little undulation, yet standing a few feet higher than the oak barrens south of them. There seems to be till at slight depth, as shown by springs issuing in banks of streams. This sandy tract rises northward into the moraine and also eastward to what seems to be the inner slope of a moraine. The north part of Sections 25, 26 and 27, Newfield are strongly morainic and the moraine extends north from there to North Branch of White River. It is very bouldery and the boulders also occur in White River valley in Sections 27, 34, 35 and 36, Newfield. The south edge of Sections 36 and 35 is on a moraine south of White River. It now seems probable that the moraine here has a north-south trend and is cut through by White River in vicinity of Hesperia. The river bottoms in Hesperia have till at surface in places. Aneroid 28.990 at Hesperia on low plain 15 feet \pm above White River = 730 feet \pm A.T.; 28.970 on broad terrace in south part of village = 750 feet \pm that represents the glacial valley bottom.

There are three flowing wells at Hesperia as follows: G. E. Eldridge's in north part of village, 175 feet, has head more than 32 feet above surface

or fully 50 feet above White River. Water is chalybeate and is used largely by citizens for drinking. H. K. Bush's, in west part of village, is 119 feet and rises only 4 or 5 feet above surface. Altitude is about the same as Eldridge's. This has some sulphur and is not so popular as Eldridge's. D. M. Maze's well, near Bush's, is similar in depth and in water. The drift penetrated is thought to be largely blue clay. Isaac Branstrom, 3 miles south and 3/4 mile west of Hesperia, has a flowing well only 40 feet deep.

At McLaren Lake, 4 miles north of Hesperia, and in a string of lakes west of it along north branch of White River, marl is found in large quantity. It was probed 24 feet near outlet of McLaren Lake without reaching bottom. A lake and marsh in Section 10, Newfield Township, also has heavy marl deposits. (Information by O. D. Hawley, postmaster at Hesperia). Mr. Hawley reports that North Branch is among knolls and ridges in a narrow channel all the way from McLaren Lake down to where it enters the large glacial drainage line in Section 23, Ferry Township. This seems to indicate that there is a north-south moraine leading past North Branch and White River in east edge of Oceana County and western Newaygo County.

August 10, 1901.

Hesperia, Michigan. Aneroid 29.040 on low plain 15-20 feet above White River = 730 feet \pm A.T.; 29.060 at White River. I go north on road 1/2 mile west of county line to McLaren Lake. It leads over a till moraine with a good many boulders in the first three miles. Aneroid 28.910 on summit near line of Sections 13 and 24, Newfield. There are some knolls 50 or more feet in height south from here but to the north there are small sharp hummocks. There are but few boulders and the drift is rather sandy on the borders of McLaren Lake and for some distance west on borders of North Branch. Aneroid 29.000 at McLaren Lake. There is a range of very sharp knolls running east-

west from near center of Section 3 nearly across Section 4, Newfield Township. It stands 40-50 feet. Lower swell and sag tracts south of it and still more above a swamp north of it in Leavitt Township. Possibly this range was at the south edge of the ice while it covered the swamp north of this range. Upon passing west from Section 3 into Section 4 the surface is found to be a swell and sag topography with much sandy drift. Aneroid 28.950 \pm on swells. Farther west in Sections 5, 6, 7 and 8, Newfield Township, there is much nearly plane surface but the altitude is high. The aneroid registers about 28.930 on the general level in these sections. There are numerous basins and but few swells from Section 4, Newfield Township, to west part of Section 12, Ferry Township. It is perhaps an outwash tract from morainic tracts on the north-west. Upon entering Sections 2 and 11, Ferry Township, a deeply channeled region is entered that is scarcely so high as the nearly plane tract to the east. This continues across Sections 3 and 4. Boulders become numerous in Section 3. This is probably a continuation of the bouldery tract in north-western Ferry Township.

I trace the glacial drainage line from Section 4 northwest to the junction of the forks of Pentwater River in Section 10, Hart Township. Its width is reduced to about $3/4$ mile in Section 31, Elbridge Township, in passing through very high tracts, but farther north in Sections 23, 24, 25 and 26, Hart Township, it is fully $1\frac{1}{2}$ miles. It narrows again to $3/4$ mile near the two forks of Pentwater in Sections 10, 11, 14 and 15, Hart Township. The north border of the very high tract passes from Section 27, Hart to Sections 18 and 17, Elbridge Township. East of Hart is a high ridge of drift standing about 140 feet above Hart Station, or 800 feet \pm A.T. Wells on this ridge are about 100 feet deep; the drift is sandy and stony.

In the afternoon I drive northwest from Hart, coming to the old lake border in northwest part of Section 8, Hart. There is a gravelly sand here

covering part of Section 5 and much of Section 6, Hart Township, and Section 31, Weare Township. It may be a delta deposit. The aneroid reads 29.320 here and the plain is about 60 feet above the river in Section 5.

I go west on road between Sections 6 and 7, Hart Township, and Sections 1 and 12, 2 and 11, Golden Township. A sand ridge comes in from the north along west side of a small creek in Section 1 and, turning west, runs through the south part of Sections 1, 2 and 3. It is apparently a dune ridge formed along the old lake shore. It is 10-30 feet high. North of it there are frequent ridges clear to Pentwater. I go west to the lake shore on line of Sections 5 and 8, Golden Township, and level up to this plain. Clay rises 50 feet and the top of the bluff is nearly 80 feet. (14 measurements of 5 feet, 8 inches). Gravel reaches to 75 feet, above which the sand has few if any pebbles. This seems to make the plain high enough to correspond with the highest lake plain near Whitehall Lake.

The till comes to the surface of this plain in the northwest part of Section 9 and southeast part of Section 8, Golden Township. It runs nearly out to the lake front in Section 8 and has low swells. Possibly these stand above the old lake level. In Sections 9, 10, 11 and 12 there is a bouldery moraine standing 30-50 feet or more above the lake plain. It has considerable till but is also gravelly. It carries sharp knolls 20-50 feet high. This sharp moraine turns south across Sections 15 and 16, 22, 27, 28 and 33, Golden Township. West of it is a plain coated thinly with sand, on the north and east borders of Silver Lake. On the west there are high dunes that lead through Sections 19, 18 and 17 to the lake at Richmond Inlet. The outer and highest ridge is not more than a mile at any point from the present shore of Lake Michigan. It reaches a height of over 100 feet in west part of Section 17 and neighboring parts of 18 and 19.

The knobby moraine leads from Section 33 westward across Section 32, Golden Township and Section 6, Benona Township.

I go east between Sections 28 and 33, Golden Township, and enter a deeply pitted gravel plain in west part of Sections 27 and 34. Pits 30-50 feet. The moraine is very bouldery on the border next to this gravel plain. Aneroid 29,220 on border of gravel plain or about 180 feet above Lake Michigan. This plain extends to Mears on the northeast and nearly to Shelby on the southeast. Its south border is in Sections 2, 3 and 4, Benona Township, at a high morainic tract. The Pere Marquette follows the east border from Mears to Shelby. The west border runs through the central part of Sections 23 and 27 in a northeast-southwest course. This gravel plain seems to be an outwash apron from moraine just outlined which lies north and west of it. The moraine is not present at the northeast edge of the gravel plain but instead there is a nearly plane till tract, as noted above, leading eastward past Hart. The moraine seems to skirt around the north side of this till tract past Hart. There is, however, a moraine leading down to the forks of Pentwater River in Section 24, Pentwater Township, along west side of the north Pentwater which may find its continuation in the moraine in Golden Township from Section 12 southwestward which I have mapped this afternoon. It seems quite as likely, however, that the Pentwater moraine drops below the old lake level and is continued as a waterlaid belt through the sandy tract immediately south of Pentwater. Clay underlies that sandy tract at moderate depth. The moraine in Golden shows a remarkably crooked inner border so that I feel rather uncertain as to continuations. It may make an abrupt turn north from Section 12 to connect with the Pentwater moraine or it may continue its eastward course past Hart.

August 11, 1901. 9:00 a.m.

Aneroid 29,440 at Hart Station, 655; 29,400 at flowing wells in south part of town. These wells are scattered over several acres. The waterworks has five. There is another at the Slaght Warehouse and three others at private residences 1/4 mile or more east and northeast of the fairground. The first well was made at the Slaght Warehouse and it is 171 feet. J. K. Flood made one southeast of fairground in north edge of Section 20 that is only 117 feet and it overflows 12 feet above surface and throws 3 gallons per second from a 3-inch pipe. In southwest part of Section 16, John Billings has a well about 125 feet deep that will overflow 30 feet above surface.

There are two other flowing wells on west side of Section 16 (referred to above as northeast of fairground) of similar depth and head to Billings' well. One is at Mr. Waller's; the other at VanAnsbury and Fuller's. The waterworks wells are usually about 150 feet. The drift at all these wells is largely blue till.

Mr. Flood, who gave the above information, thinks the deep well north of Slaght Warehouse is only about 300 feet and is into rock 35 feet. It was drilled by A. A. Jack of Muskegon and failed to get a flow. (Mr. Jack reports it to be 400 feet and is 29 feet into rock.) Wells on upland between Hart and Shelby are, in several cases, 160 to 200 feet. One, in southeast part of Section 29, Hart Township, was dug 160 feet by Leonard Demmon who resides there - altitude 975 feet \pm . It is known as the "deep well" but several tubular wells near it are deeper. Mr. Flood says there is considerable till along the north face of the strong moraine south of Hart, but upon going south a mile or so, the till becomes scarce and wells go to a great depth almost entirely through sand and gravel.

I drive south between Sections 19 and 20, Hart Township, rising about 175 feet. Aneroid 29,210 at corners Sections 19, 20, 29 and 30. There is a sandy till here with a liberal sprinkling of boulders. I go west between Sections 19 and 30 over a few deep valley-like depressions. I then go south near town line and find sharp hills that reach 950-975 feet A.T. Aneroid 29,080-29,100 on highest points on east side of road near east line of Section 25. West of the road, near center of Section 25, a point reaches 950 feet. The hills are very steep sided here. The road leads down a valley-like depression in Sections 25 and 36, Golden Township, to the gravel plain that extends south from Mears. It is not a smooth valley, like a line of glacial drainage, but has irregularities of bed and slope. Aneroid 29,260 on this low tract in southeast part of Section 25. Aneroid 29,350 on pitted gravel plain at East Golden in Section 36 where the railroad crosses east-west wagon road; 29,410 in deep basin west of railroad; 29,360 at southwest border of gravel plain at corners of Sections 1, 2, 11 and 12, Benona Township. The gravel plain is much indented by basins in its southeast part so that only a minor part is up to the level of the plain. There is a very sharp range of hills extending from Section 11, Benona Township, westward to the lake at Little Point Sable or Peach Ridge Landing. It has a very irregular south border owing to valley-like recesses where gravel plains head up in the moraine. One of these valley-like recesses extends from the center of Section 15 north-northwest to northeast part of Section 9. It is nearly 1/2 mile wide. Between this recess and the next one to the west there is a strip of moraine, but little more than 1/2 mile wide, extending from the northwest part of Section 15 across the NE $\frac{1}{4}$ of Section 16 and the central part of Section 9, Benona Township. West of it is a recess of plain surfaced sandy gravel extending up north about to the

corners of Sections 4, 5, 8 and 9. In Section 8 there is a morainic topography in NW $\frac{1}{4}$, but in Section 7, the gravel plain extends about to the north border, though there is a sharp knoll 30 feet high near center of Section. The gravel plain does not extend west to the lake but instead a lower morainic tract runs south along the lake bluff to Section 31, Benona Township. The moraine in the northern part of Benona is very high near the line of Sections 11 and 10, reaching about 950 feet, but from there west, it seldom, if ever, gets above 900 feet A.T. It carries a good many boulders and has both till and assorted material at surface. Its knolls are very steep sided in much of the range, making a difficult tract to cultivate, but it is a fine tract for peach orchards. The plain south of this range stands about 200 feet above Lake Michigan at the north border where it fits into the moraine but apparently slopes southward.

A well on the plain in Section 15, at Ludwig Weber's, is 86 feet. It penetrated little, if any, clay. John Anderson, across the road from Weber's, has a well 108 feet. On the moraine in Section 16, Charles Burmeister has a well 150 feet and in Section 9, Fred Burmeister has one nearly 200 feet. Aneroid 29.270 at Fred Burmeister's.

Aneroid 29.315 on gravel plain in Section 7, Benona; 29.520 at Lake Michigan near northwest corner Section 13, T.14N., R.19W; 29.360-400 on moraine at border of lake in Sections 12 and 13, T.14N., R.19W; 29.300 on crest just east of corners of Sections 12 and 13, R.19W., and Sections 7 and 18, T.14N., R.18W. This morainic strip that extends south along the lake front is very bouldery and contains some till. The drift here seems, however, to be largely sand and gravel. Wells, in some cases, have been sunk to Lake Michigan level and water rises but little in them. This moraine has but little relief above the plain of sandy gravel east of it

and has only a few sharp knolls. It is in striking contrast with the very sharp range in northern Benona Township. Possibly it is a continuation of the small moraine that I traced yesterday west and south across northern and western Golden Township. It is like that moraine in being very bouldery and has about the same strength.

High dunes set in near the center of Section 30, Benona, and extend south about a mile. The highest are over 200 feet. There are also very high dunes at the southwest border of Stony Lake.

Only the south part of Sections 31, 32 and 33, Benona Township were covered by Lake Chicago and parts of Sections 4, 5, 6, 8 and 9, Claybanks Township. The lake plain reached about 75 or 80 feet above Lake Michigan. There is a flat surface, and some wave cutting at borders but there are only slight developments of a beach ridge. I find none on the northeast border in Benona Township.

There is a strip of gently undulating till north of Stony Creek covering much of Sections 14, 21, 22, 23, 26, 27, 28 and 29. Sandy strips traverse it, one of which I crossed in the west part of Section 28. The aneroid reads about 29,360 on the highest part of this till tract in Sections 21, 22 and 23 or about 90 feet above the old lake plain and 165 ± feet above Lake Michigan. Aneroid 29,455 at Stony Creek in Section 23; 29,400 on a sandy terrace on east bank. On the line of Sections 23 and 24 I cross a sharp sand ridge trending east-west at this point. It is on a till plain or gently undulating till tract. It is only a few rods wide and 15-20 feet high. It looks like the ridges on the lake bottom on the tract northwest of Hart that were formed by wind, but here there is no sandy plain to furnish material, there being only a thin coating of sand on the till. Possibly this is a sandy esker though I hardly think so. It is not

clear to me yet how the glacial waters escaped from the Mears sand plain. Stony Creek would seem to be the probable line of discharge but it does not carry such a strip of sand and gravel as I should expect from a strong line of glacial drainage, nor does it show much cutting or erosion. Is it possible that this sand ridge is the shore of a small lake that stood in the valley? The only way in which I can conceive a lake to be held here is by postulating the presence of the ice sheet at the lower end of Stony Creek valley. The moraine that runs south along the lake bluff may prove to be contemporaneous with the Mears sand plain and the ice margin may have run south from Section 31 to Clay Banks. In that case, there was perhaps an eastward discharge for the glacial waters into the channel that leads past New Era. One line would be through Sections 7 and 8, Shelby, and another through Sections 19 and 20. I find little or no evidence of a strong drainage across Section 8 past Shelby village but Sections 19 and 20 may have furnished a good line of discharge. There seems to be a channel leading through there 80 rods \pm in width. I only saw it from Section 13, Benona where I had a good view southeastward. Aneroid 29,340 on Mears sand plain near north end of line of Section 13, Benona, and Section 15, Shelby. It carries basins here 20-30 feet deep and has a very sandy gravel. Upon going east to Shelby the aneroid indicates a rise instead of descent in this plain and there is a moraine leading across the low tract on which Shelby stands just west of the village. The slope of the plain is such as I should expect if the ice stood on its east border and discharged water westward but I don't see how that could have been if this is Lake Michigan drift. Aneroid 29,280 at Shelby Station, 807 feet at 5:30 p.m.; 29,200 at Stony Creek in northeast part of Section 5, Shelby Township; 29,050 on moraine on line of Sections 32 and 33, Hart Township, 100 rods \pm north of township line. A

point on east-west road in Section 32 is probably 25 feet higher. Aneroid 29.050 on high point 80 rods north of south end of line of Sections 28 and 29, Hart Township. For 1/2 mile north the road keeps on a ridge with nearly this height. Aneroid 29.340 at flowing wells near fairground, south part of Hart; 29.400 at Hart Station at 7:00 p.m.

August 13, 6:30 a.m.

Aneroid 29.410 at Hart Station; 29.290 on ridge $1\frac{1}{4}$ miles east. This high altitude continues half way of line Sections 9 and 16, Hart Township. The road then descends to the line of glacial drainage on Pentwater River. Aneroid 29.385 on broad bottom; 29.410 on bridge 25 feet above river. The terrace here has till at surface but near each bluff there is a thin coating of sandy gravel. Only the south parts of Sections 11 and 12, Hart Township, are morainic, the north half being on the bottoms following the east branch of Pentwater River. There is also only a slight extension of the moraine north into Sections 18 and 9, Elbridge Township. The moraine is less prominent in Sections 11, 12, 13 and 14, Hart Township, than in the western part of Elbridge Township, much of it being only 50 feet or less above the flat tracts on Pentwater. It is very prominent in much of the south half of Elbridge Township and in Sections 15, 16, 17 and 18 in the north half. Points near the corners of Sections 17, 18, 19 and 20 probably reach 1,000 feet A.T. (Aneroid 29.040-060 on high points.) The topography on this elevated part is a sharp knob and basin with variations of 20-40 and, in some cases 75-100 feet in short distances. Wells are 100-180 feet and have but little head. They are largely through sand and gravel. Boulders are a conspicuous feature over nearly all the morainic portion of Elbridge Township. In the southwest part of Section 27, southeast part of Section 28 and in much of the southern tier of Sections in Elbridge Township there is a nearly plane surface, part of which is gravelly and sandy, but

most of it has till at or very near the surface. Boulders are present where till is at or near surface in about as great numbers as on the rolling tracts to the north.

Leavitt Township, T.15N., R.15W., is largely a swamp except in the northern third and a strip on the west and south borders. Sections 17, 18 and part of 19 and 20 are a pitted gravel or sand plain that seems to be an outwash from the moraine in Elbridge Township. The swamp is probably a line of eastward discharge for glacial waters. It is now drained eastward by the Beaver River drainage system. The west part of the swamp has sand beneath it, but where the road crosses the swamp in Sections 15, 22 and 23, there are strips of till with boulders, and till appears on neighboring parts of the moraine both in northeastern and southeastern part of the township. The glacial outwash seems, therefore, to have dropped its load west of the place where the road crosses the swamp. The aneroid read 29.250 on the swamp at corners of Sections 29, 30, 31 and 32, Leavitt Township at 10:30 a.m. or nearly 200 feet lower than the highest points in Elbridge Township. I go east to Section 35 and then north and west to Walkerville across swamp. Aneroid 29.170 at Walkerville at 1:00 p.m.; 29.145 at Walkerville at 2:00 p.m. There seems to be a change to lower barometer so Walkerville is not so high as this reading indicates. Mr. George Merryfield, one mile south of Walkerville, on south edge of Section 8, has a well 170 feet, largely blue clay. The wells in Walkerville are 50-60 feet or less and are largely through blue till. There is a bouldery moraine in the northern 1/3 of Leavitt Township with knolls 10-60 feet high. Its south border is in the northern part of Sections 10, 11 and 12 but it covers Sections 7, 8 and 9 and extends a little into Sections 15 and 16. There is both till and assorted material in the knolls. The till is, in places, stiff clay of pink color at

surface, but quite as often it is a loose, sandy-textured till. This morainic tract only extends a short distance into Newaygo County (1-2 miles) where it reaches a great sand plain. The sand plain extends north and west, coming into the northeast part of Colfax Township (T.16N., R.15W.,) in Sections 13, 14, 23 and 24.

Colfax Township is morainic in the southeast corner in Sections 22, 23, 25, 26 and 36 with clayey to sandy loam soil and a moderate number of boulders. On the highest points the altitude is perhaps 25-50 feet above Walkerville. There is considerable cedar swamp land in Sections 26, 27, 35 and 36, standing 50 feet or more lower than the high points on the moraine. The southwest quarter of Colfax Township is largely a sand plain. A tract south of School Section Lake, in Sections 15, 16, 21, 22, 27, 28, 33 and 34, is largely sand with very little loam. There are basins and sloughs in it occupied by cedar. West from this, in the northwest part of Section 20 and southwest of Section 29, there is a tract of low morainic hills, 30 feet \pm above the plain. West from these hills there is a more loamy soil than east, but the surface is nearly level except for basins; these are rather numerous. The northwest quarter of Colfax Township is a strongly morainic tract with considerable clay loam and boulders. It is deeply indented by basins in Sections 17 and 18. The moraine extends east into the west edge of Section 11. The remainder of Section 11 and much of Sections 1, 2, 3 and 12 are in low bottoms bordering Pere Marquette River. The information concerning the north and west parts of this township was obtained from J. N. Cotton, who is now County Treasurer, but who formerly lived in Section 25, Colfax Township. He states that a well in east part of Section 23 on low ground was sunk by A. J. Cole to a depth of 180 feet without obtaining water. It was in sand 15 feet but the rest was a stiff

blue clay. Wells in the sand plain in Section 22 enter clay at about 20 feet.

I found some till in south part of Section 32 and southwest part of Section 33, Colfax Township, on a tract only 10-20 feet above the sand plain. This till tract extends south past Walkerville, covering much of Sections 5 and 4. Section 6 is a sand plain except in the southwest corner where there is a strong moraine. This strong moraine extends from Section 7, Leavitt Township in a curving course (concave) eastward through the northeast part of Elbridge Township, eastern half of Crystal Township and northwest quarter of Colfax Township, and the sandy plain around which it sweeps seems to be an outwash apron from the moraine. The morainic tract leading eastward from Walkerville seems to be an older one than the very prominent moraine, but the two are perhaps combined in Elbridge Township. The pitted sand plain in Sections 17, 18, 19 and 20, Leavitt Township, lies just south of the intersection of the two moraines, so it may pertain to the large later one.

In returning to Hart, I drive across this plain in Section 18, Leavitt Township, and pass onto a high island-like, very bouldery hill in Section 13, Elbridge Township. Aneroid 29.100 on sand plain in Section 18 (about same altitude as Walkerville) at 5:00 p.m.; 29.000 on hill in Section 13, Elbridge Township; 29.190 at creek near line of Sections 13 and 14; 29.260 at same creek on line of Sections 10 and 15, Elbridge Township. The low tracts around Mud Lake and in north part of Section 13 are also bouldery and have low knolls on them. As far west as the "Twin Bridges" at middle of line of Sections 10 and 15, Elbridge Township, the lowland along east fork of Pentwater is a mile or less in width, but west from these sections it soon expands to $2\frac{1}{2}$ miles and continues with that width into northeastern part of Hart Township. Part of it is swampy. It seems to be sandy

throughout, but the sand may not be deep. A flowing well on its south border at Isaac Timmon's on east side of Section 8, Elbridge, entered blue clay at 30 feet, under the sand, and continued in it 63 feet farther. Its head is 18 feet above surface. No other flowing wells have been obtained in this south border of the valley but it seems to be a good place to prospect for them. Aneroid 29.160 at Elbridge Post Office, 1/2 mile south of Timmon's well; 29.270 at Timmon's well at 6:15 p.m.; 29.280 on terrace of Pentwater River 2 miles east of Hart; 29.310 at Hart at 7:40 p.m. Average water power of Pentwater River at Hart is estimated by the miller at T. S. Gurney's mill to be 75 horsepower. The lowest stage has about 50 horsepower and in spring freshets it reaches 150 horsepower.

Mr. Hinman's well, on south bluff of Pentwater River, in Hart, is 200 feet deep and largely through clay. The color is blue except for a few feet of pink color at top.

David Eisenlohr, Section 20, has well 156 feet that has scarcely any head. Altitude is 950 feet or more.

Bert Wright, across road in Section 17, has well about 180 feet. J. Schaffer, in same section, has well about 150 feet, and W. H. Landon, one about 140 feet. Landon's well is in a sag and has about 20 foot head.

Mrs. Wolf, in Section 17, has well 156 feet, and George Woodner one 150 feet.

In Section 16, north part, William Tennant has well about 180 feet. Jerry Thompson has deep well on east side Section 16.

In Section 21 there are several wells 100 feet or more in depth. Mr. Newsdoffer, in northeast corner of Section 20, has one 180 feet. John Plass, across the road, has one about the same depth. George Toles, northeast corner Section 21, has one about 100 feet.

A. Evans' well, west side of Section 27, is 100 feet. William Wambaugh, across road in Section 28, has one of similar depth.

Oscar Weirich's well, in west part of Section 27, is 87 feet. A. France's well, in southwest part of Section 27 is 90 feet and the head is only 6-8 feet from bottom.

The wells above noted all penetrate a large amount of dry sandy drift and none of them have much head. They are on ground 900-960 feet A.T.

August 15, 1901. 7:30 a.m.

Aneroid 29,200 at Hart Station. I drive with J. N. Cotton north from Hart to middle of line of Sections 3 and 4, then go east. Aneroid 29,140 on north bluff of river at bend of road in Section 8. Knolls just east are 20 feet higher.

Aneroid 29,020 on a summit near corners of Sections 4, 5, 8 and 9. There is much higher altitude about 2 miles north near north end of line of Sections 32 and 33. There is a large amount of till, and timber is largely hardwood from Pentwater River to where we turn east in Section 4, but north from here, there is pine with the hardwood timber and there is more sandy soil. The southeast half of Section 3 and nearly all of Section 2 and all of Section 1, Hart Township, are on the sandy plain that leads south past head of South Pentwater to White River at Ferry. It seems to be an outwash apron in Sections 2 and 3, Hart Township from the moraine on its northwest border, and the south part of Section 36, Weare, and Section 31, Crystal Township are also likely to be an outwash sand plain. The moraine runs east almost into connection with the high moraine of Crystal Township, there being only a gap $3/4$ mile wide in Sections 29 and 32, Crystal. It is a low swampy tract that was perhaps a line of southward discharge for glacial waters after the ice had withdrawn a little from the moraine. This moraine

seems to make better connections toward the east with the great moraine than it does to the north with a weaker moraine in southwestern Eden Township, Mason County. The gap on the north is three miles or more and is occupied by a sandy plain.

There are flowing wells on the line of Sections 34 and 35, Weare Township, on the south border of the moraine, nearly at the level of the sandy plain. John Lipps' in southwest part of Section 35, is 135 feet and barely rises above surface. Aneroid 29.170 at well = 680 feet \pm . It was mainly through blue till. Victor Symonds, in east part of Section 34, had a flow from a well 56 feet deep but the head is now a foot below the surface. H. Warmuskarkar, across the road from Symonds, also had a flow from similar depth, but it has now ceased flowing. These wells are only 40 rods north of Lipps' and at about same altitude. Southwest from these flowing wells on higher ground, wells are 70-100 feet or more. Adam Cheney has one 106 feet in northeast corner Section 4, Hart Township, and Frank VanDerhenck, 70 feet, in north part Section 4. Some blue clay in each well.

There is till in Section 35 and north half of Section 36, Weare Township, but farther south is sandy. Aneroid 29.085 on moraine near Baptist Church on line of Sections 25 and 36, Weare Township; 29.150 in swamp in Sections 29 and 32, Crystal where, as above noted, there is a gap between the moraine that leads in from Hart and the high moraine of eastern Crystal Township. The high moraine sets in near the west edge of Sections 28 and 33, Crystal Township. Aneroid 29.000 at top of knoll 80 rods from west end of this section line; 28.980 at corners of Sections 26, 27, 33 and 34, Crystal Township. Drift here is gravelly and has a moderate number of boulders. Mr. Cotton says boulders abound in south part of Sections 33 and 34, Crystal Township, and Section 3, Elbridge Township.

Aneroid 28.885 at middle of line of Sections 27 and 34; a point 40 rods northeast is 30 feet higher. Some basins near east end of line of Sections 27 and 34, and nearly flat border of a few acres. It does not, however, open into an outwash apron for over a mile farther east. Turning north between Sections 26 and 27 we reach a summit near middle of Section line where aneroid reads 28.800 on road. It reads only 28.760 on high points each side of the road only a few rods distant. If the aneroid is correct, this hill reaches 1,040 feet A.T. There are, however, only a few acres that rise above the 1,000 foot contour. The high ridge leads north-east from here through Section 13, Crystal Township, into Section 18, Colfax Township and thence east-northeast to Section 11, Colfax. The highest points in view, however, are lower than the points near line of Sections 26 and 27, Crystal Township. There is a very high range extending west from Section 13 across Sections 14, 15 and 16 and the adjoining parts of Sections 9, 10, 11 and 12. The highest point is in west part of Section 14 and probably is less than 25 feet lower than ones in Sections 26 and 27, as determined by hand level. Much of Sections 1, 11 and 12 is very elevated, standing above 900 feet. This high country has a sandy loam soil in Crystal Township with a moderate number of boulders. The northeast quarter of the township has few settlers nor roads. We drive east from corners of Sections 14, 15, 22 and 23 to Crystal Valley. Aneroid 29.020 at the section corners names, in a sag or valley 150-200 feet below the neighboring hills.

Aneroid 29.110 at Crystal Valley at 11:30 a.m. Jared H. Gay has a well in south part of village that overflows 5 feet above surface -- depth 97 feet. It was in clay from the surface down to water-bearing gravel at 95 feet. The color was reddish for 20 feet and blue below that depth. Mr. Perkins' well, in Crystal Valley, nearly overflows. It is 126 feet deep. Mrs. Carroll's well, 95 feet, also rises almost to the surface. Dr.

Kittridge's well, east of the village in Section 16, rises so that water is piped out into lower ground without using a pump. Its depth is about 100 feet. There is a sandy plain covering Sections 3, 4, 5, 6, 7, 8, 17, 18, 19, 20 and 29, Crystal Township; and all of Weare Township north of the southern two tiers of Sections, except part of Sections 2, 3, 6, 7, 18 and 19, which have till. This sand plain seems to descend to the west in the direction of present drainage. It is probably a line of glacial discharge from the ice margin in Eden Township, Mason County. From Crystal Valley we take a road northward to Section 5 and then eastward to Section 2, Crystal Township, skirting around the border of the high moraine of eastern Crystal Township. This moraine extends north into Mason County from the northeast part of Crystal and northwest part of Colfax Township, Oceana County.

We go north across North Pentwater to Fern, rising into a swell and sag till moraine near that village. The moraine has its south border near the North Pentwater from Fern westward across Eden Township into the edge of Riverton Township, and a till tract then extends to Sections 27 and 34, Riverton, and Section 3, Weare Township. West from these sections is an extensive plain coated with sand that is almost swampy it is so flat. It covers much of Sections 27, 28, 29, 32 and 33, T.17N., R.17W., in Riverton and Summit Townships.

We got records of but two wells in Eden Township -- one at C. D. Major's, near center of Section 31, is 70 feet and has only 10-12 feet of water in bottom. P. E. Bailey, in west part of same section, has one of similar depth. Both are largely in till. Aneroid 29.170 at Major's well = 725 feet \pm . The swells rise but 10-30 feet above sags as far as I can get a view on this moraine. Boulders are not numerous in southern Eden Township.

Aneroid 29.270 at north branch Pentwater River on line of Sections 10 and 11, Weare Township. The bluff here is about 40 feet high. On the north there is till but on the south assorted material. There are a few knolls and basins in the sand south of the river here but they may be due to wind action. As we go south, the surface becomes lower and flatter. Aneroid 29.280 at Crystal Creek on line of Sections 14 and 15. This is about 30 feet below the bordering sand plain. South of the creek there are long, low dunes trending east-west. They may be from the shore of a bay connected with Lake Chicago. They vary, however, 40 or 50 feet in altitude. Aneroid 29.260 at lowest and 29.210 at highest on line of Sections 22 and 23, Weare Township. There is a more prominent and more nearly continuous ridge on the south at higher altitude than on the rest of the belt of dunes. It is much like the one noted in the north part of Golden Township along shore of Lake Chicago, being 15-25 feet high and narrow as an esker. It runs east only a short distance into Section 23. Possibly it marks the shore of a small lake that preceded Lake Chicago and discharged southward from Crystal Valley to East Pentwater River across the swamp noted this morning in Sections 29 and 32, Crystal Township. This may have been the line of discharge from a lake which was formed by the ice at the Pentwater moraine. After the ice had melted, the Lake Chicago waters probably extended as a bay up at least to the road I am on -- two miles from east side of Weare Township. Aneroid 29.250 at Smith's Corners = 655 feet on old plain of Lake Chicago. The Hart moraine is prominent immediately south of here with a height of 50-75 feet \pm . We skirt around the west edge of this moraine to South Pentwater in Sections 5 and 6, Hart. Aneroid 29.240 on the old lake plain at border of moraine; 29.320 at river in Section 5, Hart Township; 29.265 at Hart at 5:15 p.m. = 655 feet \pm .

August 16, 1901.

Hart, Michigan. Aneroid 29.370 at 12:30 noon. I drive north to Smith's Corners, reaching an altitude about 780-800 feet A.T. in north part of Sections 32 and 33, Weare Township. Aneroid 29.220-240; 29.370 at Smith's Corners = 655. I here go west to Pentwater River across a sandy plain, descending gradually. Aneroid 29.400 at bluff of Pentwater River = 635 feet; 29.455 at stream about 585 feet; 28.360 on till ridge on west side of Pentwater River in southeast part of Section 24, T.16N., R.18W, Pentwater Township. This 670 foot \pm ridge has its crest near the west bluff of the river from here northward through Sections 19, 18 and 7, T.16N., R.17W., Weare Township, and there is a gradual slope westward from it to the base of the high dunes along the lake shore. There are a few low sand ridges on this slope and also a thin coating of sand, but till is struck at slight depth.

At Pentwater the dunes are only about 100 feet high and there seem to be few higher ones for several miles south from there, but to the north dunes soon reach 150 feet and possibly 200 feet.

A boring made by Sands and Maxwell at Pentwater is 187 feet. It was mainly through blue till and did not strike rock. Ordinarily, wells here are but 12-15 feet and get water at top of the till under the sand. Julius Nielson, in northwest part of Section 1, Pentwater Township, has a well 28 feet deep that overflows. It is on low ground near Bass Lake. There is another flowing well on east side of Bass Lake that is 122 feet. It is at Carl Jensen's.

I take boat to Ludington from Pentwater. High dunes extend north only to Section 23, Summit Township (T.17N., R.18W.) From there to Section 27, T.18N., R.18W., there are high bluffs largely of till where a moraine comes out to the lake front. The bluff in Section 3, T.17N., R.18N.,

reaches fully 200 feet and it is nearly as high in Section 34, T.18N., R.18W. From Section 3 north there is more sand interbedded with the till than south from this section. A large part of it is horizontally bedded but some places show inclined beds.

The drift at Ludington extends below sea level, being about 650 feet on ground only 12-15 feet above level of Lake Michigan. Mr. George Abear furnished the following data which he got by quizzing men at the Salt Works who were present when the wells were sunk. It may, therefore, be only approximate.

1. Sand	256 feet
2. Blue clay (hard and tough).....	100± "
3. Largely sand, but with thin beds of clay ...	294 "
Total drift -	650 feet

The shale which underlies the drift extends to 900 feet from surface. Below this it is mainly limestone to the salt at 2280 feet. The salt bed is 16-18 feet.

The surface sand is only 161 feet at a well a mile east of the one just noted. Clay comes up at the north end of the bridge in Section 24, only 2 miles from Lake Michigan to a level 60 feet above the lake. A well in this section at W. S. McConaughy's is 130 feet and has much clay. Its head is only 25-30 feet below surface. The well is 60 feet above lake level.

Mrs. Bishop has a well on west side of Section 13, only two miles from Lake Michigan and about 60 feet above the lake level that is 268 feet. Top was sand about 30 feet; then blue clay, 100 feet ±; balance largely sand, 138 feet ±. Made by Mr. Garlock, a well driller from Scottville. Ludington stands on a sloping sandy tract that rises from lake level eastward to about 60 feet in east part of city. The waterworks supply is from Lake Michigan through a crib out a short distance from shore north of the mouth of Pere Marquette River.

August 18, 1901. 7:15 a.m.

Aneroid 29.340 at Ludington at Lake Michigan level. I cross at ferry in west part of the city to a narrow sand spit between the Pere Marquette Lake and Lake Michigan. It is mainly but 8-10 feet above the lake. There is a small drift knoll with laminated clay and some gravelly material on this spit that rises 35 feet above Lake Michigan. It covers less than an acre. The old mouth of the river is between it and the south bluff. The present mouth is an artificial cut a mile north of the old mouth. The sand has now completely filled the old channel. Aneroid 29.345 at Lake Michigan at 7:45 a.m.

Aneroid 29.290 in Buttersville on bank of Pere Marquette Lake near the salt wells. The wells are in a ravine at a level only 10-20 feet above Lake Michigan. This bank is upon the lake plain. This shows a rapid southward rise, reaching about 80 feet above the lake at its south border, aneroid 29.260. This is on south edge of Buttersville in Section 27. From here I rise southward through a billowy moraine with boulders to a summit near where the second wagon road runs east, probably near line of Sections 27 and 34. Aneroid 29.100 = 220 above Lake Michigan at summit in road; 29.180 at sag in Section 34. A gully in this sag at lake bluff shows about 100 feet of stratified material, sand with thin pebbly beds in it. This is 1/4 mile north of a schoolhouse, Section 34. Aneroid 29.130 at schoolhouse.

At first road leading east, south of the schoolhouse, there is a gully opening west of road in to the lake in which assorted material appears in inclined as well as horizontal beds. Till grades into sand horizontally as well as vertically. This is the section of the bluff.

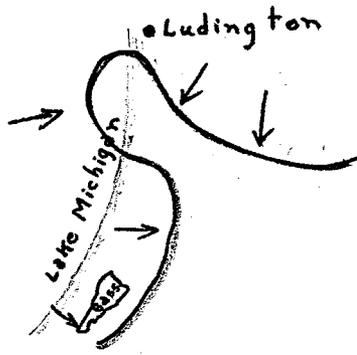
1. Till of pink color, grading into sand 30-50'
2. Fine sand with wet outcrop 30'
3. Blue till extending to lake level, probably .. 80'

Just south of this gully is the highest point on the lake bluff in this locality. Aneroid 29.075 at 9:15 a.m. This probably exceeds 800 feet A.T. There are several points fully as high as this within a mile back from the lake. South from this high point, the lake bluff is largely till. There is a range of hills eaten into by the lake in Section 10, T.17N., R.18W. The depression back of it along which the road runs is 75 feet or more below the level of the highest points. Aneroid 29.160 at Fairview school in Section 15.

A. E. Cowell, who lives near schoolhouse, has a good well only 49 feet, but his neighbors to the north have bored to great depths without success. Charles King, about a mile north of schoolhouse, bored 150 feet without success and Delos Holmes, in Section 3, T.17N., R.18W., went fully 200 feet without success.

In north edge of Section 23 the road leaves the moraine and enters the lake plain, aneroid 29.220; 29.310 at level of Bass Lake, 585 feet \pm . Dunes set in near center of Section 23 and soon reach a height of 75-100 feet or more. The moraine, where crossed near lake bluff, has a sharp knob and basin topography with abrupt changes in level of 50-100 feet. It is strewn with boulders (large), some being 10 or 12 feet in diameter.

The south border bears south of east across Sections 14 and 13. A low till tract with gently undulating surface leads south from Sections 13 and 18 along the east side of Bass Lake back 1/2 mile to a mile from the lake, and connecting with the well-defined till ridge noted east of Pentwater on west bluff of North Pentwater River. It scarcely reaches an altitude 100 feet above Lake Michigan and is not so strong as the strong moraine north of here. Aneroid 29.220 on crest on county line.



Blue line indicates probable ice margin. This blue line shows how the ice may have formed a sharp turn or a reentrant in the district southeast of Ludington, the strong moraine being formed on south side of a lobe in Pere Marquette valley and the weak one at east side of the Lake Michigan lobe. East of this weak moraine there is a flat tract almost swampy in Riverton Township, Mason County, covering much of Sections 27, 28, 29, 32 and 33. Aneroid 29.240 on this tract on line of Section 33, Riverton, and Section 4, Weare Township, or about 60-70 feet above Lake Michigan. It was probably covered by Lake Chicago in the sections above named. A narrow, swampy tract runs north through Section 23 past the east end of the prominent moraine and connecting the swampy tract just noted with a flat tract in northeastern Riverton Township which may also have been covered by Lake Chicago. Its altitude seems to be 80 feet or less above Lake Michigan. I go west ^{between} below Sections 21 and 28 along south side of the high moraine and then turn north over it on line of Sections 20 and 21, 16 and 17. It is a strong moraine with a relief of fully 200 feet above the flat tracts south and north of it. Aneroid 29.000 on crest near Arthur Edwards, who lives on west side of Section 16. Some points may be 25-50 feet higher between here and the lake front. Mr. Edwards' well on this crest is 204 feet and has only 18 feet of water. The till at surface is only 21 feet, below which the well is largely through sand and gravel. There are several wells along the high part of this moraine 125-180 feet or so deep. J. A. Martin has one in northeast part of Section 20 on ground 75 feet or more lower than Edwards' that is 180 feet deep and passed through considerable clay. Continuing north I come to the north border of this moraine just

south of the Mason and Oceana railroad on line of Sections 4 and 5, T.17N., R.17W. Aneroid 29.215 at railroad. John Burns has a well on the plain in northwest corner of Section 4, 85 feet, with but little water, it being largely through clay, but 120 rods south, he got a good well at 35 feet from sandy drift.

Aneroid 29.300 at Pere Marquette Lake southeast of Ludington two miles. The plain south of this lake has some thin patches of surface sand. In places, till a few feet at surface overlies heavy deposits of sand. In other places, till extends to some depth, the structure being quite variable. On the north side of the Pere Marquette marsh in east part of Ludington in Section 24, till is exposed up to 50 or 60 feet above lake level and is only coated by a thin deposit of sand which, in places, is drifted into dunes 15-20 feet high.

August 19, 1901.

Ludington, Michigan. I go east to Scottville along north side of Pere Marquette marsh, keeping within a mile of the marsh. The altitude is quite uniform at about 75 feet above Lake Michigan much of the way. The surface is flat south of road but north of it there are occasional low sandy ridges. It is probable that Lake Chicago covered this area and the flat tract south of the river for a mile or two back from the marsh to where the moraine on the south sets in and to a moraine on the north that passes just east and north of Amber. The border on the south would be in Sections 27, 26, 25 and 36, T.18N., R.18W., and in Sections 6, 5, 4, 10, 14, 13, T.17N., R.17W., and Sections 7 and 6, T.17N., R.16W., and Sections 31 and 30, T.18N., R.16W. It would return westward on north side of Pere Marquette marsh through north part of Section 24 and northeast part of Sections 14 and 15 past Amber, and thence pass northward near the line of

Sections 9 and 10, 3 and 4, T.18N., R.17W., where it connected with a bay that extended up Lincoln or Little Sable valley probably into T.19N., R.16W. There is a flat-surfaced tract to the west of the line noted except for a few sand ridges that seem to be dunes, but to the east, the surface does not appear to have had any wave action on it and parts of it are rather undulatory with swells and basins and the ordinary glacial aspect.

At Scottville I interviewed a well driller of the firm Stanford and Garlock of that village. He made a well for Chester McFarland $3/4$ mile east of Scottville, 215 feet. It was mainly clay in the upper 100 feet; the remainder was largely sand. The head is 50 feet or less below surface. The waterworks well at Scottville is 52 feet and is all clay to water vein in gravel near bottom. Many wells between here and Custer are 50-75 feet and occasionally 100 feet, largely through till.

From Scottville I drive south 4 miles through the plain that seems to have been covered by Lake Chicago. It is considerable sand near the corners of the four townships 3-4 miles south of Scottville, but generally sand is not conspicuous. I go west across the plain to the border of the high moraine near corners of Sections 10, 11, 14 and 15. The moraine scarcely touches Section 14 but is well developed in Section 15 and southwest part of Section 10.

I go south a mile then east between Sections 14 and 23, 13 and 24, entering a gently undulating swell and sag till moraine after crossing a marshy flat in Sections 14 and 23. This moraine is far less prominent than the one in western Riverton and Summit Townships, yet it may be the continuation. Its northwest or inner border passes across the south part of Section 13, Riverton and Section 18, Eden. It runs north from there through Sections 7 and 5, T.17N., R.16W., and near the line of Sections

31, 32, 29 and 30, T.18N., R.16W., to Pere Marquette River opposite Scottville.

Aneroid 29.260 at Scottville, 679 feet; 29.280 on plain 1 mile south of river; 29.280 at corners of Sections 1 and 12, Riverton and Sections 6 and 7, Eden Township; 29.280 at railroad near corners of Sections 10, 11, 14 and 15, Riverton Township; 29.250 at Wiley Station at 10:30, also 29.250 at swamp $1\frac{1}{2}$ miles west of Wiley. The moraine northeast of Wiley rises considerably in places so that on the highest points the aneroid reads about 29.160. These high points are 2-4 miles south-southwest of Custer. Wells on the high part are, in some cases, shallow as in vicinity of schoolhouse 2 miles south of Custer where they are only 25-30 feet on ground where aneroid reads 29.160, but many wells are 100-125 feet in that neighborhood.

Aneroid 29.220 on brow of bluff south of Pere Marquette River south of Custer; 29.320 at river; 29.290 at top of till on the terrace north of river; 29.280 on terrace; 29.260 on upland; 29.275 at Custer, 671 feet A.T. at noon in a ravine; 29.270 at 1:40 p.m., 671 feet. I drive north and find a nearly plane till tract with aneroid 29.220-240 for about a mile north, 700-715 feet. There is then a flat till tract except a few low knolls in Section 3, T.18N., R.16W., extending to south fork of Lincoln River in Sections 33 and 34, T.19N., R.16W. A strip of sandy land a mile or less in width leads down this stream from Section 34. Aneroid 29.250 at stream, 690. North of this sandy strip is an undulating till tract rising 40-60 feet above the sandy tracts. Aneroid 29.180, 750 feet on highest point on line of Sections 21 and 28, T.19N., R.16W. The till extends west into Section 20, but Sections 17, 18, 19 and 30 have a sandy surface and much of Section 29 and west half of Section 20 are sandy with ridges 10-30 feet high. The sandy strip extends up Lincoln River to within $1\frac{1}{2}$ miles of Fountain and over a swamp that lies south of Freesoil. It lies mainly south of the river for there

is a till tract immediately north of the river in T.19N., R.17W. This sandy tract, as already noted, may be an arm or bay of Lake Chicago. I work westward along the south border of this sandy tract to the corners of Townships 18 and 19 North, Ranges 16 and 17 West. The border turns west about 1/4 mile north of these corners and runs across Sections 36 and 35, T.19N., R.17W. There are spots of sand in Section 1, T.18N., R.17W., and Section 6, T.18N., R.16W., but much of the surface is till with flat surface. Aneroid 29.225 at base of sand ridge in Section 20, T.19N., R.16W.; 29.240 on flat tract 1 1/2 miles north of Scottville.

I go west between Sections 1 and 12, T.18N., R.17W., and come to a morainic tract near west end of section line. The moraine rises 20-40 feet above the plain east of it and carries deep basins as well as swells. It has a few boulders. Aneroid 29.200 on highest points on line of Sections 2 and 11, T.18N., R.17W. The moraine leads from here south-southeast to Pere Marquette River at Scottville. It is about 1 1/2 miles wide. It extends north to the north part of Sections 34 and 35, T.19N., R.17W., where it is interrupted by the sandy plain along Lincoln River. Its west border leads from the southwest part of Section 34 southward near line of Sections 3 and 4, 9 and 10, T.18N., R.17W., and then swings east past the north edge of Amber village. In places north of Amber the drift is gravelly and sandy, but as a rule, it has a stiff till.

The lake plain sets in at the west border of the moraine in T.18N., R.17W. Aneroid 29.250 on border of lake plain 1 mile west-northwest of Amber. This is about the same altitude as Amber Station, 671 feet, for that also is at the border. I take a road west through Sections 16, 17, and 18, T.18N., R.17W., and descend about 40 feet in Sections 16 and 17, or to a level 50 feet above Lake Michigan in east part of Section 18. I hold

this level to Ludington. There are occasional sandy ridges from Ludington eastward about to the line of T.18N., Ranges 17 and 18 West, but farther east there is a flat surface nearly to Amber. Sand ridges there appear and, as noted this morning, a strip of sandy ridges is found from Amber westward on south side of the Pere Marquette railroad in Sections 22, 21, 20 and 19 but not in the sections south of them. I should have noted that the moraine south of Custer has much till and hardwood timber in Sections 26, 27, 28, 33 and 34, T.18N., R.16W., and Sections 3, 4, 5, 8 and 9, T.17N., R.16W., but east and south from these sections, it has considerable sand and gravel and pine timber. The pine tract is largely an unsettled region. Aneroid 29.260 at Scottville, 679 feet.

August 21, 1901.

I drive from Scottville north to the township corners and then westward across the moraine in Sections 35 and 34, T.19N., R.17W., coming to sandy ridges in the west part of Section 34. Till is near surface in Section 33 and there is hardwood timber from Scottville to Victory Corners (on line of Sections 32 and 33, Victory Township) but farther west there is pine land and sand is deep.

I go north from Victory Corners across Lincoln River, passing through the sandy plain. It stands about 650-660 feet A.T. There is till for a few feet above level of streams here. North of the north of main fork of Lincoln River I rise to a moraine. It is covered by sandy ridges in Sections 19 and 20 and 30 like the till tract just east of Victory Corners but farther north and east it rises above the sand ridges. This moraine may be a continuation of the one that leads northwest from Scottville nearly to Victory Corners but it trends nearly at a right angle to that moraine. From the west side of Victory Township (T.19N., R.17W.) it leads

northwestward to Freesoil, occupying much of the tract between Lincoln River and Great Sable River. It projects a little westward into T.19N., R.18W., in Sections 12 and 13. It is composed, in the main, of a stiff, clayey till and has but few boulders. Some sections have a nearly plane surface while others have numerous swells 10-20 feet in height. The altitude is 100-150 feet above Lake Michigan. There are points about two miles west of Freesoil that may exceed 150 feet above the lake. Wells on this moraine reach a depth of 200 feet in a few cases, but usually are 100 feet or less in tubular wells, and shallow when dug. Jesse Barton, in south part of Section 18, Victory Township, has a well 180 feet. John Hagerty, in same section, has one 95 feet, and Theodore Brown, 67 feet. There are several in Sections 12 and 13, Hamlin township (T.19N., R.18W.) that are 80 feet or more. Loxsen brothers, in northeast part of Section 20, have a well 200 feet, and Pliny Turner, near line of Sections 11 and 14, has one 198 feet. In Turner's well there was 160 feet of blue clay, below which is sand. There is 80 feet of water. Wesley Stanford, in northeast part of Section 4, has a well 50 feet. Mr. Stanford says there are a few clay spots north of Great Sable River in Section 28, T.20N., R.17W., but most of that township is sandy with pine timber. There is some till along north side of the township.

Mrs. Mary Gray, NW $\frac{1}{4}$, Section 29, Freesoil Township, has a well 78 feet and other wells between there and Freesoil are 100 feet or more. The topography is sharply morainic in Sections 19, 29 and 30, Freesoil Township and stands 25-50 feet above Freesoil Station, or fully 700 feet A.T., Freesoil being 670 feet. Aneroid 29.240 at Freesoil at 11:20 a.m.; 29.280 on low bottoms bordering Great Sable River at Freesoil; 29.210 on moraine a mile south of Freesoil; 29.250 on swamp in Sections 33 and 34, Freesoil

Township and Sections 3, 4, 9 and 10, Sherman Township = 660 feet A.T. \pm ; 29.240 at Fountain at 12:20 noon, altitude 694 feet. Changed to 29.220 at 1:00 p.m. The swamp south of Freesoil is probably near the head of a bay of Lake Chicago. On its east side there are prominent morainic hills in Sections 25 and 36, Freesoil Township and low knolls in northeastern Sherman Township. The swamp extends but little east of the Pere Marquette railroad between Freesoil and Fountain. Lincoln River is among drift knolls at Fountain and for more than a mile west of that village. Aneroid 29.220 at Fountain at 1:00 p.m., 694 feet A.T. I take train to Manistee Junction, passing through a till tract nearly to Tallman which is traversed by swamps. The knolls are 10-25 feet above the swamps. Aneroid 29.200 at Batchelor, 29.200 at Tallman, 707 feet A.T.; 29.210 at Manistee Junction, 703 feet A.T. There is but little till between Tallman and Manistee Junction, though a few spots occur. The surface is nearly plane and is largely sand barrens.

I take train to Baldwin from Manistee Junction or Merritt Station. There are cuts about 1 mile west of Branch that are largely sandy gravel but they contain some till. Aneroid 29.160 in cuts 10 feet below surface 1 mile west of Branch; 29.180 at Branch, 726 feet A.T. This station is on a flat, nearly swampy, plain with a few boulders. Aneroid 29.145 at Stearn's siding, 764 feet A.T. This is in the valley of Pere Marquette River, about 40 feet above the stream. High tableland just north rises to 900 feet or more. Aneroid 29.100 at lake near township corners 3 miles west of Baldwin; 29.060 at Baldwin, 834 feet A.T. at 2:00 p.m. This village is on a gravelly plain scarcely 20 feet above Baldwin Creek, a tributary of Pere Marquette River. There is till in a few places, a clay pit having been opened in southwest part of village and it is said to outcrop along a stream farther west. There are a few surface boulders where the till is at or near surface. They are

found from Baldwin south to Pere Marquette River nearly three miles.

A gravel pit has been opened just south of Baldwin in Section 3. The pebbles are very largely limestone, probably 90 per cent. These pebbles wash easily and make a fine road bed. The clay is also used on some streets in Baldwin. Wells in this village are very shallow, 10-20 feet.

Just north and west of Baldwin there is a low bluff 20 feet \pm above the plain. It is apparently the west bluff of a glacial drainage line that came in from Luther across a large swamp that is traversed by Baldwin Creek from its source west of Luther southward to Sections 20 and 29, T.18N., R.12W. The Register of Deeds of Lake County, Mr. Hollister, outlined for me the extent of this swamp in Townships 18 and 19 North, R.12W. Mr. Hollister also outlined the extent of a morainic tract that extends southwest from the north end of this swamp past the south side of Wolf Lake and thence westward near line of Townships 18 and 19 North, Ranges 13 and 14 West.

From this moraine a spur extends northeast nearly to Canfield Township that covers the abrupt eastward turn of the railroad south of Canfield. The railroad passes around the northeast end of this spur.

Mr. Hollister also outlines the extent of a morainic tract in southwest part of Lake County and gives some information concerning its extent in the eastern part of the county. The eastern range of townships is nearly all a high moraine standing 1,000-1,300 feet A.T.

August 23, 1901. Baldwin, Michigan.

Aneroid 29.100 at 7:15 a.m. I go west and rise about 25 feet a mile west of the station, aneroid 29.070. There are basins in this tract, some of which contain ponds and marshes. The surface, aside from basins, is

generally flat. The drift is, in part, gravel and cobble but tends to be sandy. This tract has jack pine timber nearly large enough for lumber, also oak large enough for railroad ties.

About $2\frac{1}{2}$ miles west of Baldwin Station I drop to a plain no higher than that at Baldwin, aneroid 29.100, and this seems to extend down the Pere Marquette River, descending rapidly. The stream descends about 10 feet per mile by air line and the plain nearly as much. Aneroid 29.130 on plain 4 miles west of Baldwin; 29.140 on bluff of Pere Marquette River, in Sections 1 and 12, T.17N., R.14W.; 29.200 at river near corners of Sections 1, 2, 11 and 12.

Aneroid 29.050 on upland west of river, near corners of Sections 3, 4, 9 and 10. This was timbered with heavy pine and is gravelly, but farther west, on line of Sections 4 and 9, there is a till moraine with numerous boulders. Aneroid 29.000 at crest near schoolhouse No. 2, Lake Township = 925 feet \pm . A well here is 170 feet and only has 6 feet of water. It was largely through till (information by A. R. Nash, Section 4). The moraine has a great relief on the west border, but on the east it is not so conspicuous. Aneroid 29.120 at corner of Sections 4, 5, 8 and 9; 29.160 at schoolhouse at corner of Sections 7, 8, 17 and 18 at west border of sharp moraine = 775. To the east and south from here the moraine rises abruptly 100 feet or more. To the west there is a more gradual descent. Aneroid 29.230 at Carr Post Office = 715 feet \pm , southeast corner Section 12, T.17N., R.15W., Branch Township, Mason County. There is a flat, almost swampy, clay plain west and north from here, becoming sandy upon approaching either branch of Pere Marquette River. There are a few clay spots, I am told, in this plain in T.18N., R.15W., but it is largely a sand plain. There are some swampy basins in it of considerable extent. I go south from Carr along county line and am in a strong moraine to the county corners

of Lake, Mason, Newaygo and Oceana. It has but little till except on its inner or northwest slope. It covers Sections 19, 20, 29, 30, 31 and 32, Lake Township, T.17N., R.14W., and part of Sections 5 and 6, T.16N., R.14W., in Newaygo County. It extends west in Mason County across Sections 24, 25, 26, 35 and 36, T.17N., R.15W., and continues, as noted August 15, into northern Oceana County from southeastern Mason County. Aneroid 29.060 on highest part of moraine 2-4 miles south of Carr Post Office = 875 feet \pm ; 29.210 at Pere Marquette River = 725 feet \pm , on line of Oceana and Newaygo counties. There is a swampy plain here, $1\frac{1}{2}$ miles wide, south of which is a pitted gravel plain 80 feet above the river. Aneroid 29.120 on pitted plain on line of Sections 13 and 18 = 800 feet \pm A.T. This high plain extends west a long distance, but is cut off toward the east by the lower plain bordering Pere Marquette River. There is till from Sections 19 and 24 southward along the county line but it extends east only across part of Sections 19 and 30 and barely into Section 32, T.16N., R.14W. The low, swampy sand plain comes in there and extends east over much of T.16N., R.14W.

Aneroid 29.140 at store in northeast part of Section 31 at 11:30 a.m.; 29.130 at 1:00 p.m. = 800 feet \pm ; 29.150 at swampy plain east of store on line of Sections 29 and 32; 29.200 at Pere Marquette River near corners of Sections 26, 27, 34 and 35 = 750. The bluff is about 20 feet. East and southeast about $1\frac{1}{2}$ miles from this place is a range of drift knolls. It extends south from there 2 or 3 miles and north-northeast across the west part of T.16N., R.13W. Its relief is usually but 50 or 60 feet above the bordering plains and its width is only $1-1\frac{1}{2}$ miles. I have it in view toward the east as I drive north through Sections 26, 23, 14, 11 and 2, T.16N., R.14W.

There is an isolated knoll on the county line in Section 1, T.16N., R.14W., and Section 36, T.17N., R.14W., that rises 60 feet above the bordering plain and covers 80 acres or more. There appear to be a few low knolls southeast from here that may serve to connect this with the range of hills in west part of T.16N., R.13W. That range of hills incloses several lakes (see Newaygo County map). Big Star Lake stands in a sandy plain that rises about 30-40 feet above water level, it being higher on the west border than on the east. In part of the southeast shore, till is exposed near water level and Mr. Campau has a well there that enters till in lower part. From Big Star Lake I drive east to the Pere Marquette Railroad and then north to Baldwin.

The basins are conspicuous not only between Big Star Lake and the Pere Marquette River but to some extent they occur near Baldwin on the low plain. They are also conspicuous for 3 or 4 miles south of Big Star Lake.

August 24, 1901. 7:15 a.m.

Aneroid 29.320 at Baldwin, 834 feet A.T. I go west from north edge of Baldwin to some lakes near line of Sections 32 and 33, T.18N., R.13W., rising about 25 feet as on the road west from south part of Baldwin yesterday. I go north $1\frac{1}{2}$ miles and take road northwest through a tract of jack pine and scrubby oak, rising gradually toward the west. Aneroid 29.280 at line of Sections 28 and 29; 29.240 in Section 19, T.18N., R.13W.; 29.230 in east part Section 24, T.19N., R.14W. Basins here are 20 feet or more. Aneroid 29.220 at a small clearing, probably on line of Sections 14 and 23, about 920 feet A.T. There are no knolls on this tableland. It seems to be an outwash apron from the moraine that traverses the north part of this township. That moraine is probably a continuation of the one noted yesterday south of Pere Marquette River, but it seems to be wanting or very

feebly developed for about three miles north of the river. There is a low swampy plain extending north from the river on the west side of this table-land. Its east border, as outlined by Mr. Hollister, is in Sections 27, 21, 16, 8 and 5. Aneroid 29.400 at Stearns, 764 feet at 9:00 a.m.; 29.450 at Branch at 10:00 a.m. = 725. B. F. Barnett has a well here 44 feet that was through sand to the gravel at bottom, but surface boulders occur near here, and there is till in cuts in railroad 1 mile west. Section 19, east of Branch, is thought to have clay at slight depth for water is near surface. The swampy conditions continue northward near county line to Millerton.

I go west near line of Pere Marquette railroad for six miles from Branch and find till in spots. It is more conspicuous west of Manistee Junction than east, and becomes practically a continuous sheet near east line of Custer Township. It rises in low swells 5-10 feet above the sandy tracts near it. I go north along line of Custer and Branch Townships across a swell and sag till moraine with swells 15-30 feet high. There are some patches of sand. Aneroid 29.490 at township line 3 miles east of Custer; 29.450 on same line $3\frac{1}{2}$ miles north where road turns east between Sections 30 and 31, T.19N., R.16W. I go east to Batchelor. Aneroid 29.460 = 700. Fred Shearer, a well driller at Batchelor, says the deepest wells in the township are about 90 feet. One with that depth is at John Brant's, in south part of Section 27. It was red clay 10-12 feet and bottom was sand. In Section 35, Dr. Kibbe has a well 58 feet, all sand. The hills near there have some till at surface, but are largely sandy drift. Between Batchelor and Fountain wells are only 12-25 feet.

A well at schoolhouse west of Millerton on low ground among hills is 62 feet. Water is within 15 feet of top. It was till at surface and sand

below. A well at Mrs. Dora Lawson's, in Section 4, T.17N., R.16W., is 120 feet. It is on elevated moraine. There were a few feet of till at top, below which was cobbly sand.

Aneroid 29.490 at Batchelor at 1:20 p.m., about 700 feet A.T., where it read 29.460 $1\frac{1}{2}$ hours ago. The southeast quarter of Sheridan Township is nearly all strongly morainic with knolls ranging in height from 20 up to 100 feet. The rest of the township has gently undulating surface with considerable till. Aneroid 29.410 at schoolhouse $1/2$ mile west of Millerton; 29.430 at Millerton at 3:00 p.m. The swamp that leads south from here to Branch seems to be $1\frac{1}{2}$ miles wide where it makes a break in the moraine south of Millerton. It seems probable that the strong moraine in southeast quarter of Sheridan Township is a continuation of that east of the swamp, though it may prove to be a younger moraine. There are some very sharp, gravelly hills a mile south of Millerton at west border of the swampy tract. There is said to be much low swampy land north of Millerton for several miles. It extends east a couple of miles.

The greater part of T.19N., R.14W., is rather low and either swamp or sand plain but there is a high range of morainic hills on the south border and a tableland on the east border. There are low sandy hills around the lakes in the north part of the township. Aneroid 29.370 at Sable River in Section 11, T.19N., R.14W.

Aneroid 29.250 on tableland west of Canfield in Section 7, T.19N., R.13W. Timber here is light, mainly jack pine, but the lowland to the west had heavy timber -- largely pine. There is a gravelly drift rather than sandy on this tableland. Canfield stands on it. Aneroid 29.250 at Canfield at 5:15 p.m.; 29.110 on crest of morainic ridge about a mile south of Canfield. From here I see a group of very prominent hills north of

Manistee River on east side of Pere Marquette railroad. The ridge I am on has few boulders but carries cobblestones. This is a spur from the east-west moraine farther south. The tableland between it and the moraine is a pitted gravel plain and stands much higher than the one at Canfield.

Aneroid 29.150 on gravel plain in Section 20, T.19N., R.13W. This plain extends scarcely a mile west of the meridian of Canfield. The basins are, in some instances, 40 to 50 feet deep. The lower plain, on which Canfield stands, has only shallow basins.

Aneroid 29.070 on crest of moraine on line of Sections 32 and 33, T.19N., R.13W. A cleared field 1/2 mile west is perhaps 30 feet higher. Hills east and southeast of Wolf Lake seem to be fully as high as the ridge I am on. There are very few boulders here. The drift is cobbly and gravelly. Aneroid 29.160 on plain at south border of moraine near township line, T.18N. and T.19N., 1 mile west of Pere Marquette railroad. The moraine is low where the railroad crosses but becomes very prominent east of it on south side of Wolf Lake. The plain south of this moraine descends southward. Aneroid 29.240 1/2 mile north of Baldwin courthouse; 29.270 on lower plain at courthouse. There are several lakes north of Baldwin in the south row of Sections in T.18N., R.13W., that contain marl.

These lakes and also Big Star Lake are found to vary several feet in level from year to year. At present, Big Star Lake is 6 or 7 feet below a beach that it occupies only a few years ago. Vegetation sets in above the old beach but the slope is bare below it. Mr. Hollister says the lakes northwest of Baldwin in Section 32 are, at times, so high that the road passing between them had to be graded up and a crossing built, but at other times, the water level is 3 or 4 feet below the road. The relation to wet and dry periods cannot be clearly made out by Mr. Hollister.

August 25, 1901. 9:00 a.m.

I take Sunday excursion from Baldwin to Grand Rapids. Aneroid 29.270 at Baldwin, 834 feet; 29.250 at county line south of Baldwin 6 miles, 850 feet \pm . The range of hills in west part of T.16N., R.13W., is near the railroad on west side for a mile or more in Sections 4, 9 and 12, and is in view much of the way to Lilley. The highest points seem to be about 75 feet above the railroad. A few boulders appear on the slope in Section 10.

Aneroid 29.240 at Lilley, 867 feet A.T.; 29.240 at Bitely. There are a few low swells and occasional boulders near Bitely. The plain extends south to the curve on the railroad in north part of Section 10, T.15N., R.13W. A strong moraine is here entered and an ascent of about 100 feet is made to reach Otia. The drift is very sandy and cuts show only a few cobblestones and boulders. Basins are a conspicuous feature. The crest in the vicinity of Otia has only low swells. A few boulders appear south of Otia, but there is only a little till in view from the railroad. About two miles south of Diamond Lake the railway comes to a plain, aneroid 29.200, and follows its east border southward to White Cloud. Aneroid 29.240 at White Cloud, 870 feet at 10:45 a.m.

The railroad touches a moraine near Twin Lakes. South of there, deep basins appear on the gravel terrace. Aneroid 29.460 at Newaygo, 20-25 feet above Muskegon River; 29.505 at Grand Rapids. I stop off at White Cloud on the return.

August 26, 1901. 6:00 a.m.

Aneroid 29.100 at White Cloud, 870 feet. C. G. Ubellar at the Atlantic Hotel has a well 104 feet deep that is thought to have struck a rock near bottom, but it may be a boulder. The head is at considerable

depth. Aneroid 29.130 at White Cloud, 870 feet at 6:45 a.m. I drive north, rising to a higher plain. Aneroid 29.090. This only covers the south part of Section 32, the north part being morainic. Going west on line of Sections 29 and 32, 30 and 31, T.14N., R.12W., and Sections 25 and 36, 26 and 35, T.14N., R.13W., I pass through a strongly morainic tract standing 900-960 feet A.T. It has some till and a few boulders but is largely sandy drift. It was timbered with pine. Section 36 and northeast corner of Section 35 are morainic, but Sections 31, 32, 33, 34 and south part of Sections 27, 28, and 29 are on the plain that borders White River. Aneroid 29.160 on this plain near corners of Sections 26, 27, 34 and 35, Lincoln Township, T.14N., R.13W., at 7:40 a.m. In this township, the south edge of the moraine is very broken, but on the high tracts to the north, there are some nearly level fields of 80 acres or more. The high tracts in Sections 16, 17 and 20 have considerable till. Aneroid 29.010-29.020 on high tracts near corners of Sections 16, 17, 20 and 21. This high tract only extends a mile west but runs east past Diamond Lake.

I take road northwest down a ravine to the sand plain at west end of moraine. Aneroid 29.190 on sand plain at dam on Dowling Creek in Section 7. This altitude is maintained from there north to the state road at line of Sections 20 and 29, T.15N., R.13W., where I turn east to Otia.

The sand plain has but few pebbles. It seems to have been a line of discharge for a glacial stream. The moraine rises abruptly on its border in Sections 8 and 5, T.14N., R.13W., and Sections 32, 33, 27 and 22, T.15N., R.13W. Aneroid 29.190 on sand plain at corner of Sections 20, 21, 28 and 29, T.15N., R.13W.; 29.040 on moraine at Otia, 964 feet A.T., at 10:00 a.m.

Two wells near the post office are about 70 feet, but one at the post office is only 28 feet. The moraine extends scarcely a mile east of Otia. One can look from here over a wide plain to the east extending about to Woodville. In T.15N., R.12W., the plain covers all but the east range of sections with a little of Sections 2 and 11 and a little on the west border of Sections 6, 7, 18 and 19. It has extensive swamps and sandy flats.

I am told at Otia that the moraine that I saw in the western part of T.16N., R.13W., extends south about to Shaw Post Office in Beaver Township, covering much of Sections 6 and 7, T.15N., R.13W., and Section 1 and parts of Sections 2, 11 and 12, T.15N., R.14W. It may be the continuation of the moraine that comes up from the southwest into Section 26, T.15N., R.14W. I take train from Otia to Baldwin at 10:30 a.m. Aneroid 29.170 at Baldwin, 834 feet.

August 27, 1901. 7:00 a.m.

Aneroid 29.190 at Baldwin, 834 feet A.T.; 29.210 at cement plant in Section 14, T.17N., R.13W. There is a great deposit of marl in lakes and marshes in this vicinity along the east fork of Pere Marquette River. Aneroid 29.250 at Pere Marquette River on line of Sections 22 and 23 near the junction of east and south forks; 29.220 on plain south of river.

There is a low ridge extending eastward from Section 26 across Section 25 and southeast part of Section 24, T.17N., R.13W., and along the borders of Sections 19 and 30, 20 and 29, T.17N., R.12W. It rises 30-40 feet above the sand plain north of it. Aneroid 29.150-160 on crest. It is only 1/2 mile to a mile in width, and seems to be of gravelly constitution. South of it is a pitted plain but little lower than the crest of the range. Aneroid 29.170 on plain in Section 30, T.17N., R.12W.

This range is apparently the continuation of that noted in the western part of T.16N., R.13W., but it is scarcely half as broad. It connects at the east with a moraine that leads north-south from Section 10, T.17N., R.12W., across Sections 15 and 16, 21, 28 and 33 and thence south-southwest to Otia through Sections 4, 8, 17, 18 and 19, T.16N., R.13W., Sections 24, 25, 35 and 36, T.16N., R.13W., and Sections 1, 2, 11, 12, etcetera, in T.15N., R.13W. This moraine is prominent when viewed from the west side, rising as it does 75-100 feet or more above the plain west of it, but on the east side, it has very little relief above a sandy plain that borders it.

I follow the west border of this moraine southward to Pere Marquette River in Section 8, T.16N., R.12W., at place where Myers and Dudley's mill stood. Aneroid 29.165 at river on line of Sections 8 and 9. The valley here is very thickly strewn with boulders and there is a space of scarcely 1/2 mile between bluffs that rise 75 feet \pm above the stream. The moraine crosses from Section 4 on the north to Section 8 on the south side of the river.

Aneroid 29.090 on gravel plain east of moraine near east line of Section 17, T.16N., R.12W. The moraine in the central and west part of the section rises 20-30 feet higher. I take road southwest in Sections 17 and 20, keeping near the border of the plain and moraine. I then go east on line of Sections 20 and 29 across Pere Marquette River, aneroid 29.100. Between here and another branch farther east is a swampy plain on which some till occurs and a few boulders. There is said to be till down the valley from here to Myers and Dudley's mill on line of Sections 8 and 9, and a moderate number of boulders.

A strong moraine sets in in Sections 15, 22 and 27, just east of the east stream. Its west border bears south-southeast from Section 22, T.16N.,

R.12W., to Woodville and northeast across Sections 15, 14, 11 and 2 into Lake County. It is the great moraine that covers western Mecosta County and much of Osceola County, as noted last June. The part of this moraine in T.16N., R.12W., has a rather sandy till with sand and gravel and only a few boulders. It is billowy with knolls 25 to 50 feet high. Much of it will be profitable for agriculture but as yet there is only a sparse settlement. Aneroid 29.000 at J. E. Cunningham's on west side of Section 24, T.16N., R.12W., at 11:40 a.m. = 1,000 feet \pm . Mr. Cunningham's well is 34 feet. John Britton has a well in Section 36, northwest part, 60 feet. Much of the drift is very loose till and was originally timbered largely with pine. Aneroid 28.980 at Cunningham's at 1:00 p.m.; 28.940 on east side of Section 13, T.16N., R.11W., where I came to the north-south state road; 28.980 at Grass Lake in Section 12 (marked Cook's Station on old map from state atlas). The west border of this great moraine is in Sections 36, 25, 24, 13, 11 and 2, T.17N., R.12W., and it continues thence northward along east side of the great 'swamp in Townships 18 and 19 North, R.12W., to Luther.

In T.17N., R.12W., there is a sandy plain separating this great moraine from a small one that was traced this morning from Section 10 southward into Newaygo County. Aneroid 29.000 on this sand plain in Section 26. Sherman Wood, on sand plain in Section 22, has a well 71 feet. It was mainly sand. There was 12 feet of gravel at 40-52 feet. Aneroid 28.980 at Mr. Wood's at 3:00 p.m. = 1,000 feet \pm . I cross over the moraine west of Mr. Wood's and find its crest rises but little above the plain on the east, possibly 40 feet in the most prominent places, but it is about 100 feet above the plain west of it. Aneroid 29.080 on plain west of the moraine in Section 16 = 910 feet \pm . I cross back over the moraine in Section 15. It has a gravelly, sandy drift at surface carrying a few

boulders, but the cement company of Baldwin has bored and dug into it at several places in Sections 10 and 15 and found clay. The excavations are on the slope on west side and north end of the ridge. Mr. Houk of the cement company, states that in Section 10 the clay reached 84 feet above Pere Marquette River and the moraine 120 feet. The clay has very few pebbles where exposed along the river in Section 10. I collect a specimen of it from about 25 feet above river level. It is planned to use this clay in the cement mill near Baldwin. Mr. Houk found 94 feet fall in the river from the clay in Section 10 down to the junction of this stream with south fork near the cement works about 7 miles by direct line. This clay extends below the base of the moraine and rises nearly to the level of the plain east of the moraine. Whether it is as nearly pebbleless in its upper part as in the part exposed in the river bank was not determined, though Mr. Houk thinks there were few, if any, pebbles in it wherever he has tested.

There is a swamp at the north end of this moraine, covering parts of Sections 2, 3, 10 and 11 that is about as low as the plain west of the moraine. Aneroid 28.970 on crest of moraine in Section 10, T.17N., R.12W., = 1,010 feet \pm ; 29.100 at river in north part of Section 10; 29.060 on low bluff $1\frac{1}{4}$ miles west of Nirvana = 925 feet \pm . If the moraine continues north from Section 10 it is banked against the great moraine east of it. This low bluff west of Nirvana has a flat surface & is composed of gravel and cobble. There are pits opened for road and railroad ballast west of Nirvana. This gravel plain seems to have an eastward rise into the moraine as if formed as an outwash on the west side of the moraine. It hardly seems probable, however, that this is a Saginaw moraine, though that hypothesis should be considered. There seems to be no question that all the

small moraines west of this great system are Lake Michigan moraines while those east of this system are Saginaw. The features in Mecosta County have led me to refer this great system to the Lake Michigan lobe (see notes in June 1901) but that may prove to have been a wrong or partially wrong interpretation.

August 28, 1901. 8:00 a.m.

Aneroid 29.190 at Baldwin, 834 feet A.T. I take train for Reed City. Crooked Lake, near Forsman, stands only 6-8 feet below the plain. Aneroid 29.190 at lake; 29.150 at station east of lake; 29.130 at east border of low plain $1\frac{1}{2}$ miles west of Nirvana; 29.100 near west side of higher plain 1 mile west of Nirvana; 29.070 at Nirvana, 974 feet A.T. The station is about 15 feet above a swamp that runs west on the north side of the railroad and 20 feet below the higher gravel plain. Hills 50-75 feet high set in immediately southeast of Nirvana. There are also prominent ones east and north within $1-1\frac{1}{2}$ miles.

The railway rises through a strong moraine with hills 40 or 50 feet above track to the northwest part of Chase Township. Aneroid 28.950 where I came out in Section 6, Chase Township to a view of the country east = 1,090 feet \pm . There are points near here 50 or 60 feet higher or about 1,150 feet A.T. There are few boulders in view west of this point but they abound east from here all the way to Reed City. Aneroid 28.965 at Chase, 1,075 feet A.T. This is only 10-15 feet above Pere Marquette River. Hills about two miles east of Chase reach an altitude 1,200-1,250 feet A.T. Aneroid 28.850 at Oliver (probably nearly 1,200 feet A.T.). Hills north of here are probably 50 feet higher. There is considerable till in railroad cuts between Oliver and Reed City. Aneroid 29.025 at Reed City at 9:25 a.m., 1,034 feet A.T.; 28.980 at noon.

I drive to southwest part of Reed City, rising near the cemetery to 1,100 feet A.T. I then go south a mile and take road west rising to a tract 1,175 feet \pm at corners of Sections 17, 18, 19 and 20. Aneroid 28.800. A well near here, in north part of Section 20 at John Schmidt's, is 150 feet; there are still deeper ones in this neighborhood, as well as good ones of shallower depth. Aneroid 28.850 at line of Lake and Osceola counties, Sections 13 and 24, Chase Township, and Sections 18 and 19, Richmond Township. The drift is rather sandy near Reed City in Section 9 but farther south and west it is largely till and here near the county line it is a stiff clayey till. This clayey till covers much of the eastern half of Chase Township. It is boulder strewn and has a swell and sag topography.

The western half of the township has much sandy drift and is more broken than the eastern. This sandy drift is said to form a belt 3 to 5 miles wide that extends northward to Luther and southward through eastern Newaygo County to the Muskegon River. It has a greater altitude in southwestern Chase and western Barton townships than the tracts east of it. A hill in the southeast part of Section 33, Chase Township, is about 1,250 feet and one $2\frac{1}{2}$ miles south in west part of Section 15, Barton Township is 1,100-1,150 feet with perhaps still lower elevation in sags. The following aneroid readings illustrate the above statements: Corners Sections 13, 14, 23 and 24, Chase Township, aneroid 28.840; corners Sections 14, 15, 22 and 23, Chase Township, aneroid 28.850; corners Sections 22, 23, 26 and 27, 28.820; corners sections 21, 22, 27 and 28, 28.750; (a point 80 rods west is 30-40 feet higher, or nearly 1,250 feet A.T.); line of Sections 33 and 34 at summit 40 rods north of county line, aneroid 28.680 = 1,280; a point 20 rods west is about 20 feet higher or nearly 1,300 feet A.T. A well here was dug by Ed Stephens to a depth of

120 feet. Altitude 1,280 feet \pm -- 28.720 at county line, corners of Sections 3 and 4, Barton Township and Sections 33 and 34, Chase Township. Border of bouldery till moraine 1/2 mile east of corners, 28.760. Corners Sections 2 and 3, Barton Township and Sections 34 and 35, Chase Township, 28.805; corners of Sections 23, 10 and 11, Barton Township, at Hawkins Post Office, 28.850. This is on low ground near a creek. The swell and sag till moraine covers east part of Sections 3 and 10 and all of Sections 1, 2, 11 and 12, 13 and much of Section 14, the southwest corner only being high sandy drift. Aneroid 28.800 at corners Sections 10, 11, 14 and 15; 28.630 on high point in NW $\frac{1}{4}$ of Section 15, the highest point in this vicinity, probably 1,300 feet or at least 1,275 feet. This high point has boulders on its slope but the drift is gravelly. Corners of Sections 11, 12, 13, and 14, Barton Township, 28.850. In Section 23 and east part of Section 24 the drift is rather sandy, but boulders abound and there is some till.

The sandy ridges run from Section 15 south-southeast covering Section 27 and extending east over part of Sections 35 and 26. Farther south it constitutes the divide between the Muskegon and Pere Marquette Rivers. Aneroid 28.850 at corners Sections 23, 24, 25 and 26; 28.880 at corners Sections 25, 26, 35 and 36. The south side of Section 25 and much of Sections 35 and 36 had pine timber and the drift is rather gravelly, but from here southeast to Big Rapids, there is much till. Aneroid 28.870 at township corners on county line west of Big Rapids. Aneroid 28.850 on knoll 3/4 mile east of county line on line of Green and Big Rapids Townships; 28.925 at corners Sections 32 and 33, Green Township and Sections 4 and 5, Big Rapids Township; 29.030 at corners Sections 33 and 34, Green Township and Sections 3 and 4, Big Rapids Township. Much hardwood timber and drift, mainly till, in this vicinity. This altitude is at level of west border of the gravel plain on Muskegon River. Aneroid 29.050 at Mr.

Hanchett's in north part of Big Rapids at altitude about 900 feet A.T., at 5:45 p.m. This is 25 feet or less above Muskegon River.

August 29, 1901. 7:30 a.m.

Aneroid 29.035 at Big Rapids on plain about 900 feet A.T. The constricted place in Muskegon valley between Big Rapids and Paris seems still, as it did last June, to be a place where an ice margin crossed the valley. Boulders are very numerous here and for some distance west. I am surprised to find boulders north of Paris on the low bottom land. They abound for $1\frac{1}{2}$ miles north but do not appear to occupy the low bottom above that point. There is a terrace or flat-topped tract on east side of river on the bend that stands above this low bottom 30 feet or more. It looks like a fluvial plain. If so, the low boulder-strewn bottom has been reduced from it. There are low swells on the low bottom that make it look all the more like glacial topography, yet it may be that a stream would leave such swells in the process of excavating a valley. Aneroid 28.980 at Crapo, 983 feet, at 9:00 a.m. This is on the low gravel plain 30 feet above the river.

I go east three miles along the county line, rising into a very bouldery moraine. This fills the bend of the river south of Hersey. Aneroid 28.820 on township line, 80 rods north of county line, = 1,150 feet \pm ; 28.985 at Hersey, 991 feet, at 10:00 a.m. There is considerable till in the moraine south of Hersey though it has sharp sandy and gravelly knolls. I go north a mile from Hersey and take road west to Reed City. Boulders are very numerous in west part of Section 12 and in Section 11, Richmond Township, T.17N., R.10W. From there west I am in the valley of Hersey River. It has a width of about $1/2$ mile and is perhaps a line of

glacial drainage for waters issuing from the ice when near its headwaters. Aneroid 28.930 at Reed City at 11:00 a.m., 1,034 feet; 28.850 at Reed City at 2:40 p.m.

I go north 1/2 mile, then east, rising into country 1,100-1,200 feet, the surface being very uneven. The drift is loose-textured till and the timber largely pine in northeast part of T.17N., and southeast part of T.18N., R.10W. Sections 1 and 2 have but few boulders and a very sandy till. Sections 35 and 36 north of there have many boulders and much till. Wells near corners of Sections 26, 27, 34 and 35 are in several cases about 35 feet and several farther south and west have about the same depth. The altitude here is about 1,200 feet. I go east between Sections 26 and 35, 25 and 36, and reach a point east of the section corners that registers 28.610 or about 1,250 feet. A well at a schoolhouse on south side of Section 25, at altitude about 1,200 feet, is 92 feet, and one at farm house near it is over 100 feet.

This high tract has till at surface but on slopes of basins sand and gravel outcrop. There are many deep basins as well as sharp knolls on this high tract. Aneroid 28.590 near middle of line of Sections 19 and 20, T.18N., R.9W. From here a high ridge leads northward that has some hardwood timber and considerable till. East of it is a high tract of pine land with sharply morainic topography. Some points on it may reach 1,300 feet in this township. There is a little till and hardwood timber. Milton Moffitt, in Section 30, T.18N., R.9W., has a well 150 feet. Its altitude is about 1,250 feet. Aneroid 28.590 near middle of line of Sections 19 and 20, T.18N., R.9W. In T.18N., R.10W., there is hardwood with only a few pine tracts of limited extent but the drift is largely a loose-textured till that breaks up like sand on the roads instead of packing, so they are hard

to travel. The stiff clay seems to be confined to sags. I take the center east-west road west to center of township and then go south to Reed City.

August 30, 1901. 7:00 a.m.

Aneroid 28.800 at Reed City, 1,034 feet. I go west from north edge of town, rising soon to 1,100 feet and on the edge of Lake County to 1,200 feet. There is much till but only a moderate supply of boulders. There is a strong moraine with swells 20-40 feet or more. I turn north on line of Sections 1 and 2, Chase Township and Sections 35 and 36, Pinora Township, reaching, on line of Sections 35 and 36, an altitude about 1,225 feet. West of the road, in Section 35, points reach 1,250 feet. In the west part of Sections 26 and 23 and in Sections 22 and 27, there are hills that probably reach 1,300 feet A.T. There is a very hilly tract in the western two-thirds of Pinora Township and eastern part of the adjoining township on the west that was timbered with pine and has a sandy drift. There are said to be spots of clay and places where boulders abound, but generally, boulders are scarce. This tract is not inhabited. Several wells in the southeast part of Pinora Township are about 100 feet in depth and they penetrate considerable till or "clay". The eastern third of the township has much hardwood timber though strips of pine extend out into it. Aneroid 28.700 at railroad crossing on line of Sections 13 and 14, Pinora Township, probably about 1,125 feet. On the northeast side of the railroad in this township, few points reach 1,250 feet, but on the southwest side they may reach 1,300 feet. There are some farms in the northeast part of the township but there is also much unsettled land. Southwest of the railroad there is scarcely any settlement west of the road I took north. The

township north of Pinora has a sparse settlement. The northern one-third contains much hardwood and some pine timber still standing. There are gravelly hills east of Luther that were covered with pine. The southeast part has good farming land with considerable till. I go west through the south part of the township to the state road that leads north to Luther, following poorly travelled roads after I cross the railroad on line of Sections 29 and 32, with no residents until I am nearly into Luther. The drift is sandy except a strip along Little Manistee River where till and boulders occur.

Aneroid 28.770 at railroad crossing on line of Sections 29 and 32, Ellsworth Township; 28.730 where I intersect the state road 2 miles south of Luther; 28.850 at Luther, probably about 975 feet at noon; 28.860 at 1:00 p.m. I go northeast to a high gravel plain in Section 7, Ellsworth Township, aneroid 28.750. There is a moraine west of this in Sections 1 and 12, T.19N., R.12W., that rises but little above the gravel plain. On it there is a settlement and it is said to contain much good farming land with clay soil. This gravel plain seems to be its outwash apron. There is a much higher tract southeast of the gravel plain reaching 1,150-1,200 feet. The plain covers much of Sections 5, 6, 7 and 8, and extends to the river valley in T.20N., R.11W., Dover Township.

From Sections 4 and 9 eastward there is a strip of low land with small knolls and sandy or gravelly drift following up the river to Leroy. It is 1-2 miles wide and is bordered on both sides of the river by high morainic tracts. Aneroid 28.760 at Keenan Post Office and station in Section 8, Ellsworth Township, on gravel plain.

I went east from Section 7 to road 1 mile west of county line and took that road south, rising near corners of Sections 11, 12, 13 and 14 to

a tract over 1,200 feet. Aneroid 28.600 at the section corners. There is much till here and hardwood timber, but pine sets in a mile west and a strip extends west nearly to Luther in Sections 22 and 15, 21 and 16, 20 and 17, Ellsworth Township. Much of Leroy Township, Osceola County, except the strip of sandy land along the river above noted, is till and has a strongly morainic topography. Boulders are less numerous than in the district south of Reed City. The knolls are seldom sharp, but there is about 100 feet difference in altitude on the highest swells and in deepest sags or valleys.

I went east 2 miles on center east-west road in Leroy Township, then south 2 miles, then east a mile, and south along the G. R. and I. railroad past Ashton. The branch of Hersey River east of Ashton has no gravel plain but winds around among drift knolls, but the branch west of Ashton has a gravel plain fully 1/2 mile wide. Possibly an ice margin passed east-west across the head of the gravel plain in the north part of Lincoln Township, though I saw no evidence, aside from this gravel plain. The divide at head of Hersey River is not prominent in Leroy Township nor very bouldery, so there is not clear evidence in those lines in support of an ice margin passing east-west across the head of the gravel plain. There is, however, strongly morainic country at the head as well as on each side of the Hersey River gravel plain. The material in this gravel plain is rather fine gravel with some sand but not enough to make it hard wheeling. This plain extends south without much erosion as far as Milton Junction, but farther south it is much eroded. Aneroid 28.760 at Milton Junction, 1,095 feet at 5:00 p.m.

The deep borings at Reed City were noted last June. It is now planned to sink a prospect boring for oil about two miles north of Reed City to a depth of 2,000 feet, the work to be done by F. M. Gray, a Milwaukee well driller, P. O. Box 1, Milwaukee, Wisconsin.

August 31, 1901.

I take train to Grand Rapids from Reed City and thence to Ann Arbor. I note that the moraine and bouldery drift is close at hand along and east of the railroad from Morley to Howard City.

September 4, 1901.

I went from Ann Arbor to Marion, on T. And A.A. railroad.

side Sect. 16. In Sec. 21 there are several wells 100 feet or more in depth. Mr. Newsdoffer in NE corner of Sec. 20 has one 180 feet. John Flass across the road has one about the same depth.

George Tetes NE corner Sec. 21 has one about 100 feet.

A. Evans' well west side of Sec. 27 is 100 feet.

Wm. Wambaugh across road in Sec. 28 has one of similar depth.

Oscar Weirich's well in west part of Sec. 27 is 87 ft.

A. Francis' well in SW part of Sec. 27 is 90 feet and the head is only 6-8 ft. from bottom.

The wells above noted all penetrate a large amount of dry sandy drift -- and none of them have much head. They are on ground 900-960 feet A.T.

See small green notebook for aneroid readings.

Sept. 4, 1901. I went from Ann Arbor to Marion on T & AA RR. Sept. 5 drove from Marion to Higgins Lake in Roscommon Co. See notebook 171.

Sept. 6 was with Lane Davis and others in vicinity of Higgins Lake and Roscommon (see Notebook 171). Sept. 7 -- returned from Higgins Lake to Marion by way of Stratford, Moretown, Stittsville and Falmouth (Notebook 171).

Sept. 8, Sunday, spent at Marion.

Sept. 9, took morning train to Temple and drove from there as indicated in notes below. Sept. 10, rainy, finished reading proof of Mon. XII. Sept. 11 drove from Marion to Ewart and back as indicated in notes below.

Sept. 9, Temple, Mich. I drive south and find that a strip of till extends from the hilly tract south of Clarence westward nearly to the Muskegon River. It is greatly undulating and has a moderate number of boulders. Much of it is clayey. The till extends as far west as Secs. 28 and 33, Reading Tp. T 19 R 6 W. The altitude there is but little above Temple or about 1050-1060 ft. A.T. but within a mile or so east it rises to 1100 feet or more. The altitude at Clarence is about 1130 feet.

East of Temple also in Sec. 14 there is till and from there east into Greenwood Tp. till alternates with sand and swamp. There is a large amount of swamp in the NE quarter of Reading Tp. Greenwood Tp. has bouldery till and a large amount of good farming land. There are only 5 or 6 square miles of sand and swamp and this is in the NW corner. The appearance both in Greenwood and Reading is as if the ice margin passed E-W and ~~fronted~~ ^{fronted} south resting on the high range that leads westward along the borders of Tps. 18 & 19, T 5 W and the NE part of T 18 R 6 W (see Clare County map). It has been my supposition heretofore that the ice margin trended NE-SW across Greenwood Tp. (T 19 R 5 W) and fronted toward the northwest -- this making it a distinct Saginaw lobe which formed the moraine. But now it appears probable that ~~at~~ the reentrant between the Saginaw and Lake Michigan lobes extended no further north at the time this moraine was forming than the latitude of Clarence.

I am coming now to favor the interpretation that the great moraine in Osceola County and adjacent parts of bordering counties is interlobate.

I drove SE past Windover Lake around the west end of the prominent hills in NE part of T 18 R 6 W. There is considerable gravel in these hills and slopes south of them near Windover and Dollar Lakes in Secs. 11 & 14. J. W. Sutton has examined into its depth and thinks it may be extensive enough to justify opening a gravel pit by Ann Arbor R.R. Sutton's address is Lake George, Michigan. I drive past Lake George and take a road NE over the high range of hills to Lilly Lake reaching an altitude of 1240 feet SW of the Lake in Sec. 33 Greenwood Tp. The lake is about 1125 feet. This high range has some sandy till with the clear sand and gravel and a few boulders. But north of it as above noted there are clayey till and numerous boulders, and a swell and sag topography extending to the Muskegon River swamps. This clayey tract is 1100-1150 feet A.T.

The gravelly sand plain between Muskegon and Middle Branch Rivers, Tps. 19 Rs 6 & 7, seems to have its head in Secs. 1 & 2, T 19 R 7 and Sec. 7 R 6 W. It stands higher than the till tract east of the Muskegon in Secs. 14 & 22, T 19 R 6 W and is fully as high as till on west side of Middle Branch River in T 19 R 7 W. Its altitude is about 1100 ft. at the north end and 1084 feet at Pennock's Station. It is flat surfaced and has only a few saucer-like basins. The till tract north of it rises 20 feet or more above the gravel plain but has not a bluff as if there had been erosion. On the contrary it seems to have been formed about contemporaneously with the gravel plain. I return to Marion on the afternoon train.

Sept. 11, 1901 - 7 A.M., Marion, Michigan. I drive south from Marion through a low tract along Middle Branch River that has sandy gravel in low knolls 10-20 feet high. There is swampy land west of road in Secs. 28 and 33. The strip of sandy land is about a mile wide. It is not a sand plain but has knolls among which the stream winds. The till tracts are higher than the sandy tracts in this township; but upon passing south into Middle Branch Tp. I find a low till plain on west side of the stream. It is strewn with boulders as thickly as the higher tracts west of it. Boulders are numerous on the SE border of the till tract all through Middle Branch Tp. The border between till and gravel as already noted follows Middle Branch Creek across T 19 R 7 W. It then goes west through Secs. 2, 3, 4, 5, 6 and 7, Sylvan Tp. and Sec. 12 Osceola. It then swings southward across Secs. 14 and 23 to the bank of the Muskegon River $\frac{1}{2}$ miles above Evarts. There is a sandy and rather swampy plain in Sylvan Tp. SE of this till tract. It seems to have till at slight depth, and as noted last June there is till on the south bank of Muskegon River in this township.

Flowing Wells
The river seems to pass from a till plain or gently undulating till tract into a strong moraine near the line of Sylvan and Osceola Tps. This supports the view that the drift here is Saginaw rather than L. Michigan drift. There is a very bouldery tract in Osceola Tp. The flowing well in NE part of Sec. 26 Osceola Tp. noted last June is about 170 feet deep and flows 75 to 100 gallons a minute from a 2-inch pipe. Its force is very great. It discharges horizontally and the stream strikes about 8 feet from the orifice which is 3 feet above the ground. I filled a four gallon bucket in about 3 seconds. There is said to be 70 feet of blue clay under a thin coating of sand. There are two other flowing wells near this one at John E. Beach in SE corner of Sec. 23, 130 ft., and another in ~~Sec. 23~~ Sec. 24 but they are both weak compared with ~~this~~ this well, and are shallower. I do not find any accurate data on the wells. On my way to Evarts I learned of the following deep farm wells. R Floyd Roe, Sec. 33, Middle Branch, NW part, has well 106 ft. largely through gravel. A well on south side of Sec. 22, Middle Branch, at Ed Underwoods is 96 feet. John Framer, SW corner of same section, has a well 120 feet. A well on the Chas. Rose farm in Sec. 22, Hartwick Tp. is 205 ft. Wells 2-3 miles N. of Evarts are 80-115 feet on ground 1200 ft. John Rowley's in east part of Sec. 16 is 115 feet. Mr. Niergarths in SE part of Sec. 15

is 94 feet and has 20 feet of water. There is 50 ft. of clay below which it is through sand.

An. 28740 at Evarts at 1 P.M. 1002 feet A.T.

I go west between Secs. 28/33 29/32. There is a flat tract carrying boulders in Secs. 28 & 33 that stands but a few feet above the Muskegon gravel plain. It looks like a fluvial terrace being a very sandy drift but the boulders seem out of keeping with this interpretation.

West of this I rise through a till tract with deep basins and numerous boulders reaching 1175-1200 feet near the corners of Secs. 29, 30, 31 & 32. The altitude is still higher farther west. The drift to the west is said to be sandy except in a few spots. It is rather bouldery. As yet there are scarcely any settlers west of here on the eastern half of Cedar Tp. and there are only a few old lumber roads in that region. A tract of 24 miles in Cedar, 6 miles in Hersey, 8 miles in SErn Rose Lake and 9 miles in SWrn Hartwick Tp.

I find that the till tract in Osceola Tp. extends only 4 miles north and two miles west of Evarts. Farther north as well as west there is a very sandy drift and sharply morainic topography - Hummock, 20 ft. high, cover only a fraction of an acre. This hummocky topography covers the NE part of Osceola and south part of Hartwick Tp. It reaches an altitude of 1275-1300 ft. in the SW part of Hartwick Tp. and NW part of ~~Osceola~~ ^{Osceola}. The center N-S road in Hartwick is at the 1300 foot contour at several points in the south half. Boulders are numerous all over this hummocky tract and they abound also in till tracts east of it in SErn Hartwick Tp. being exceedingly numerous west and south of Avondale. I turned east between Secs. 22 & 27 Hartwick and continued to Avondale at corners of Secs. 23, 24, 25 & 26 making a descent of 150 feet -- Avondale being about 1150 feet. I then go north a mile and east into Middle Branch Tp. passing through a swell and sag till tract with knolls 25 ft. $\frac{1}{2}$ high having gentle slopes compared with the sharp hummocks of SWn Hartwick Tp. This swell and sag tract covers Secs. 24, 25 & 36 as well as 13, 14 and 22 and continues east across Middle Branch Tp. It now seems probable that the sharp hummocky moraine is the crest and the swell and sag tract the inner slope of a great moraine formed by ice ~~and~~ on the east of it. It seems likely to be interlobate. From the accounts given by supervisors last June I infer that the eastern part of Highland as well as the eastern part of Hartwick is on the inner slope toward the Saginaw ice lobe. I found a gravel hill on the SE part of Sec. 13 Hartwick 30 ft. high covering several acres. I go north between Secs. 17 & 18, 7 & 8, 5 & 6 Middle Branch and Secs. 31 & 32, 29 & 30 Marion through a gently undulating till tract with only a few boulders. It is about 1150 feet A.T. but fluctuates between 1130 and 1175 feet. A point 2 miles west of Marion is 1180 feet but this is higher than any point to the south for several miles. An. 28520 at Marion at 6:30 P.M. = 1119 feet A.T. See Notebook 171 for Sept. 12 and later work.