

GEOLOGICAL SURVEY OF MICHIGAN
ALFRED C. LANE, STATE GEOLOGIST

**GEOLOGICAL SURVEY OF MICHIGAN
LOWER PENINSULA
1896-1900**

**VOL. VII
PART II
GEOLOGICAL REPORT ON HURON COUNTY
MICHIGAN**

BY
ALFRED C. LANE

ACCOMPANIED BY ELEVEN PLATES AND TWELVE
FIGURES INCLUDING TWO COLORED MAPS

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, Sept. 15, 1900.

To the Honorable, the Board of Geological Survey of Michigan:

HON. HAZEN S. PINGREE, *President.*
HON. PERRY F. POWERS.
HON. JASON E. HAMMOND, *Secretary.*

GENTLEMEN—Herewith I transmit as Part II of Vol. VII, a report on the geology of Huron county, the Thumb of Lower Michigan. Like Part I, 500 copies are issued separately, while 1,000 are bound in the complete volume. Of Chapter IX, 100 copies have been printed for Prof. C. A. Davis, and the same number of § 2 and of § 3 of Chapter X for my co-adjutors Bryant Walker, Esq., and Mr. W. F. Cooper.

I trust this report may aid the residents and well drillers of the county in getting good water supplies, may save money in proving up the resources of the county in coal, gypsum, limestone, and grindstone, and may call attention to the probable value of the shale deposits. Just at the moment I notice items in the daily press concerning lead, a subject which I have also examined.

To my fellow geologists it may be interesting to see what can be done with the sub-surface geology, when outcrops are very rare, by means of records and tests of farmer's wells.

It will probably be of use to them also to have the Marshall of this region more fully treated, and a definite and detailed geological column made out, covering the dividing line between Devonian and Carboniferous.

I feel that I ought to call attention here as well as in the text to the important help which I have received from Messrs. Davis, Gordon, Walker and Cooper, whose names ought almost to have appeared on the title page, and also to the fact that the work of preparation of this report, though always in my charge, was largely done during the administration of my predecessor, Dr. Hubbard.

With great respect I am your obedient servant,
ALFRED C. LANE,
State Geologist.

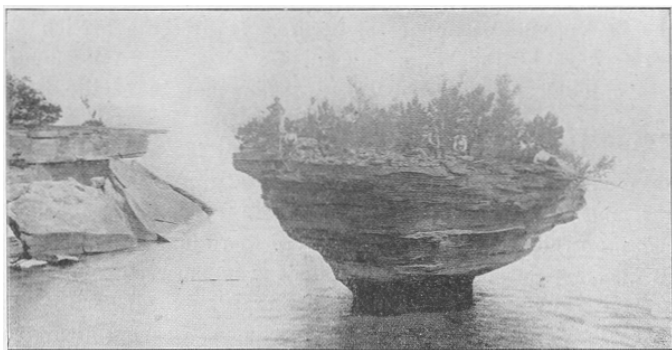


Figure 1. The Flagstaff (or Bowsprit) at Point aux Barques. The Thumbnail of Michigan, illustrating the undercutting action of the waves.

CHAPTER I. INTRODUCTION.

§ 1. Historical.

The lower peninsula of Michigan has been likened to a man's hand. In such a comparison Saginaw Bay must be supposed to separate the thumb from the rest of the hand. Huron county is the end of the thumb thus formed, so that we may look upon the ledges which line its northernmost margin (Fig. 1), as representing the projecting thumbnail.

Few counties of the lower peninsula have more rock outcrops exposed than Huron county; and none, perhaps, have a greater variety of mineral industries. Coal, limestone, grindstones, and salt, are among the substances which have been already marketed, while pyrite, plaster, cement rock and mineral waters yet await development.

It is not surprising, therefore, that this region early attracted attention. Schoolcraft in his narrative* speaks of the coarse gray loosely compacted sandstone, after passing Elm Creek in the advance to Ship Point (Pointe Aux Barques). He continued up into "Saganaw" Bay to "Point Aux Chênes," i. e. Oak Point, and then crossed the bay, stopping at an island "which the Indians called Shawangunk," composed of a dark colored limestone, of dull and earthy fracture and compact structure. It presents broken and denuded edges at the water level." He observed in it nodular masses of chalcedony and calcspar. "The margin of the island bears fragments of the boulder stratum."

This must be Charity Island, as he says it is about midway of the bay, and he says it is the largest of a group of islands, and southernmost in position. Usually there are but two islands placed upon the map, but when we were there in 1896 there was a small bar just out of water about half way between, and as we see from Plate V, at the time of Schoolcraft's expedition the lake was very low, and between that and 1856 some wearing away may have been done. We cannot understand how Schoolcraft called the largest island "southernmost." By a not unnatural mistake in an early explorer coasting

along the shore he identified this limestone with that around Thunder Bay. For a long time investigation like settlement was superficial, and mainly along the shore of the county, and waited for the ax of the woodman to strip it of its covering of pine and lay it bare for exploration.

*"Summary Narrative of an Exploratory Expedition to the source of the Mississippi River in 1820; with appendixes, comprising all the official reports and scientific papers of both expeditions. By Henry R. Schoolcraft. Philadelphia, 1855," pp. 54 and 310. There are two other editions.

§ 2. Previous geological reports, Houghton, Winchell, Rominger.

The very first annual report of the State Geologist* mentions the cliffs of Point aux Barques, whose picturesque beauty, reminding one of the prows and sterns of vessels, drawn up on the shore like the Greek fleet before Troy, suggested the name of the point to the fancy of the early-voyageur (Pl. II).

Houghton's second annual report refers to the limestone of the Charity Island,† and the fourth annual report contains in Bela Hubbard's sub-report further details, and a correlation of the Point aux Barques sandstones with the Waverly sandstone of Ohio.‡ In the state library are two old Mss. maps which I have used and think belong to Houghton's survey.§ With the untimely death of Douglass Houghton the Geological Survey stopped, and we have a period during which there is little recorded advance in local geological investigation. Yet during this time in 1850 the famous grindstone quarries were opened by Capt. A. C. Poor, and the product soon became widely known.

*Douglass Houghton: Report of the State Geologist, 1838, H. R. No. 14, p. 9. Also H. D. No. 24, pp. 276-317 and S. D. No. 16.

†Second Annual Report of the State Geologist, 1839. H. D. No. 23, pp. 386-507, S. D. No. 12, pp. 264-391, H. R. No. 23 and S. R. No. 23 (misprinted No. 13).

‡1841, p. 567 of H. S. and J. D. No. 11, pp. 472-607. This report was also issued separately as H. D. No. 27.

§For the magnetic variation on the coast at Sec. 17, Grove Township, is given at 1° 10' 0" E., whereas in 1858 the Lake Survey found it to be 8° 30' E. at nearly the same point. Also a Mss. note refers to the state of a ledge in 1842, and there are many geological notes.

In the latter part of the fifties Alexander Winchell, Michigan's most eminent geologist, began his work and in his first report* we find a careful description of the rocks exposed along the shore. On page 75 he describes the rocks around the Point aux Barques lighthouse, and the grindstone quarries. On pages 80 to 82 he gives a description of the rocks of the Marshall group from Hardwood Point, on Sec. 35, T. 19 N., R. 12 E., past Flat Rock Point, "Point au Pain Sucre," to Point aux Barques. On page 88 he describes Pt. au Chapeau, on Sec. 7, T. 18 N., R. 12 E., as belonging to his Napoleon Group. The "Michigan Salt Group" he divined, without actually seeing it exposed, to be near the mouth of the Pigeon River, i. e., Caseville. This conclusion which we have verified, is a marked illustration of his sagacity as a geologist.

The Carboniferous limestone he recognized (p. 100) near the Shebeon, "Cheboyong" Creek, on the S. W. $\frac{1}{4}$ of Sec. 22, and the N. W. $\frac{1}{4}$ of Sec. 13, [Sic.] T. 16 N., R. 9 E., and on the shore of Wild Fowl Bay and its islands, viz.: on "Shungwoigue," otherwise called Stone Island, and on "Ashquaguindaigue," now known as North Island.

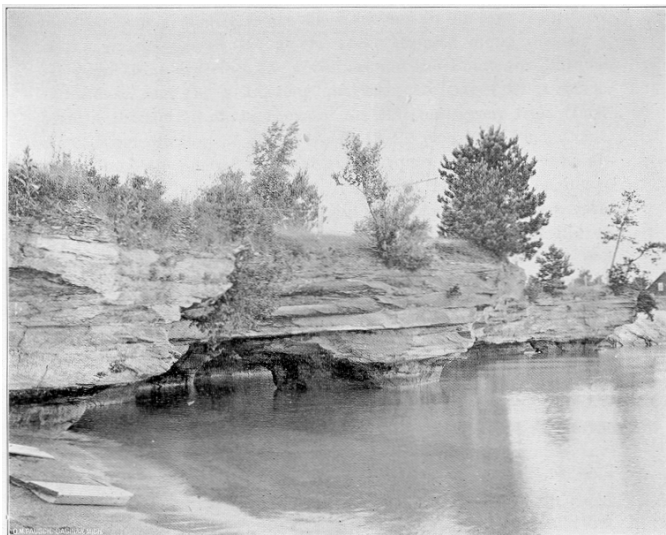


Plate II. Illustrates the resemblance of the cliffs at Point Aux Barques to the sterns of steamers, a small tree frequently playing the part of a flagstaff; the cliffs are composed of Lower Marshall sandstone and their upper level is determined by the Algonquin terrace.

(Reproduced through the courtesy of the F. & P. M. R. R.)

Finally he estimated that the coal formation should strike the lake near Sebewaing,—and the position of the Sebewaing coal mines, located as they are near the margin of the coal basin verifies his prediction (p. 121). Winchell was much interested in the rocks of Huron county, especially from a palæontological point of view, and he continued for many years publishing papers† in which fossils collected from Huron county were described or compared, which we can only refer to here, leaving their fuller discussion to the palæontological part of the report, Chapter X.

*First Biennial Report of the Progress of the Geological Survey of Michigan. Dec. 31, 1860, Lansing, 8-vo., pp. 339.

†1862. Descriptions of Fossils from the Marshall and Huron Groups of Michigan. Proc. Acad. Nat. Sci., Phila., XIV, 1862, pp. 405-430.

1862. Amer. Jour. Sci. and Arts, 2d Series, XXXIII, p. 353.

1863. Descriptions of Fossils from the Yellow Sandstones lying beneath the "Burlington Limestone" at Burlington, Iowa. Proc. Acad. Nat. Sci. Phila., XV 1863, pp. 2-24.

On the Identification of the Catskill Red Sandstone Group with the Chemung. Amer. Journ. Sci. & Arts, 2d Series, XXXV, 1863, pp. 61-62.

1865. Descriptions of New Species of Fossils, from the Marshall Group of Michigan, and its supposed equivalents in other states. Proc. Acad. Nat. Sci. Phila., XVII, 1865, pp. 109-133.

1865. Some Indications of a Northward Transportation of Drift Material in the Lower Peninsula of Michigan. Amer. Journ. Sci. & Arts, 2d Series, XL, pp. 331-338.

1869. The Mineral Fertilizers of Michigan, Report Department of Agriculture, Washington, Second Session, 44th Congress.

1871. On the Geological Age and Equivalents of the Marshall Group.

Beside the papers mentioned in the foot note, which relate more particularly to the palæontology, other papers bearing more or less on the physical geography or geology of Michigan are as follows:

In 1871 he published an article in Harper's Monthly on the climate of the Great Lakes (XLIII, p. 279-281), to which we shall have to refer. In 1873 he prepared for Walling's Atlas (republished in 1883 by R. M. and S. J. Tackabury) a number of articles which were reprinted under the title "Michigan, Being Condensed, Popular Sketches of the Topography, Climate and Geology of the State" (8vo., pp. 121).

In 1875 he published a rectification of the geological map of Michigan, that he had prepared for Walling's Atlas,* and in 1878 prepared the chapter on Michigan in J. Macfarlane's "Geological Railway Guide," which gives the geological formation supposed to underlie each station. This book was revised in subsequent editions up to 1890. While, however, there is some progress indicated in these publications in the general conceptions of the geology of the state, there is nothing added to the detailed geology of Huron county which calls for especial mention.

In the meantime Dr. Carl Rominger had published in 1876 his principal work on the geology of the Lower Peninsula,—Volume III of the Reports of the Geological Survey of Michigan. That volume also contains a very valuable appendix by Dr. Garrigues, State Salt Inspector, on the various deep borings and their brines. In that report, which we do not summarize here as it is of the same series as this report, many outcrops not before noticed and many new deep borings, were described from Huron county, and a number of fossils, the two forms of Lithostrotion being figured. All these will be referred to in due place. Dr. Rominger added much to our detailed knowledge of Huron county and as we shall see took a somewhat different view of the stratigraphy around Port Austin from that taken by Winchell.†

The opening of the Sebewaing coal mines in 1890-1891 was announced in the reports of the Commissioners of Mineral Statistics, for 1890 and for 1891‡. On the map accompanying Rominger's report this area was indicated as outside the Coal Measures.

*Proc. Am. Ass. Adv. Sci., XXIV, Part 2, pp. 27-43.

†Loc. cit., p. 76.

‡C. D. Lawton, 1890, p. 66; J. P. Edwards, 1891, p. 119.

§ 3. Recent work.

In 1892, when the present writer under the direction of the then State Geologist, M. E. Wadsworth, began editing the well records and other material which had been collected by Dr. Wadsworth's predecessor, C. E. Wright, his attention was naturally called to the discrepant views of earlier geologists, and, especially by Hon W. L. Webber of Saginaw, to the advances that had since been made in the development of the county.

Beside the coal mining and grindstone quarrying there had been considerable quarrying around in the neighborhood of Wild Fowl Bay, the large Bayport quarries being-opened in 1888. Thus, though the report of Volume V gave the data then at hand, the county was recognized as one where farther field work promised economic and scientific rewards. The writer made a preliminary visit in December, 1895, and in 1896 the summer was spent in field work there. During part of the time he was assisted by Dr. C. H. Gordon, and by Prof. C. A. Davis of Alma College. Prof. Davis and the writer have worked Ranges 12, 13 and 14 together, and the botanical notes are entirely, and the plan of the chemical work largely, due to Prof. Davis. The western Ranges 9, 10 and 11, have been more particularly studied by the writer who is also generally responsible for the assembling of the data, the language of the report, and the construction or preparation of the illustrations.

During the same summer Messrs. F. B. Taylor and G. K. Gilbert of the U. S. Geological Survey made a rapid visit to the county, being engaged in tracing the old lake shores. The result of Mr. Taylor's work was given to the public that summer at the meeting of the Geological Society of America, and published in an important paper to which we shall have frequent occasion to refer.* A map from this paper we have with his permission reproduced in Plate VI, as it gives a good idea of the general relations of Huron county geographically as well as its position and relations during the Champlain epoch and in general we are guided by Taylor in naming and correlating the beaches.

The county has also occasionally been visited by other geologists, whose notes so far as we are informed have not been given to the public.

*Bull. G. S. A., 1897, Vol. VIII, pp. 31-53.

This report was chiefly written in the winter of 1896-97. In the fall of 1897, incited thereto by the writer, who sent a short unpublished abstract of his results to the meeting of the A. A. A. S. in Detroit, that fall, the county was visited by W. F. Cooper, who has done much work on similar beds in Ohio, and by Mr. George F. Girty of the United States Geological Survey. The writer guiding Mr. Girty also revisited the county, especially studying the eastern part around Harbor Beach which he had not previously visited, and doing some additional work on Ranges 14 and 15, and studying the rate of erosion on the eastern shore. Mr. Girty and Mr. Cooper have added to our palæontological knowledge of the county, and

material by Prof. A. Winchell and by Mr. Cooper add much to the value of the palæontological chapter.

At the same meeting Mr. Gilbert read a paper on the change of level of the land around the Great Lakes,* which incorporates some observations which he made or had made in the county. Other work has prevented anything but a cursory revision, prior to publication, in the fall of 1899. Some work for the survey on the clays and shales by H. Ries and on coal by H. J. Williams has been included.

*Nat. Geog. Magazine, Sept. 1897, VIII, pp. 233-247; also 18th Annual Report U. S. Geol. Survey, 1898, Part II, p. 624.

§ 4. Acknowledgments.

While Messrs. Gordon, Davis, Cooper and the writer have been directly employed by the Survey, the value of this report is largely due to the records carefully kept and freely furnished them by others, whose disinterested love for science and appreciation of the importance of scientific facts deserve a word of mention here. Too often are records and samples which are of great scientific value, and may later be of money value, thrown away because of no immediate importance.

Among those who have thus furnished valuable material to the Survey, Hon. W. L. Webber of Saginaw may first be mentioned, for the whole determination of altitudes rests primarily on lines of levels freely furnished by him, without which the work would everywhere be distinctly less accurate. Not only this, but he has also given access to records of various explorations, and rendered the work of the Survey every assistance in his power.

The officials of the Pere Marquette Railroad Company have also been most courteous, both in response to inquiries, in loaning illustrations and in other ways. Much information has also been derived from well drillers, who have always shown a willingness to help the Survey in its work. For example Mr. John Russell of Unionville, to whom is largely due the credit for the development of the Sebewaing coal mines, gave access to the records of borings for water which he has been carefully keeping for years, and he and Messrs. Hofmeister, Bullock, Smith and others have saved samples of the wells they were engaged upon. Want of space forbids a detailed enumeration of all those residents of the county who have assisted us. Their names will, to a large extent, be found scattered through the report as authority for the various data. In return for their courtesy it is hoped that this report may do something toward advancing the interests of the county, assisting in more intelligent and economical development of its water supply, in more extended use of its other varied natural resources and in more interesting teaching of physical geography and natural history by illustrations drawn from natural features near at hand. Outside the district the Survey is under obligations to Bryant Walker, Esq., of Detroit, who has determined the shells of the shell marl, with the exception of the Pisidia; to Dr. Victor Sterki, who

of our map. Some use has also been made by us of the profiles of drains filed in the office of the County Drain Commissioner.

§ 5. Maps.

The maps in the State Library referred to are interesting as recording forgotten names and islands which have vanished.

The only geological maps of Huron county are those incorporated in some general map like those issued by Winchell in Walling's Atlas (loc. cit.) and by Rominger and Lane, in Volume III, respectively V, of this series of reports. As to the topographical maps, the early maps prior to the U. S. Land Survey in 1845 and 1848, are sufficiently well represented by Jeremiah Greenleaf's Universal Atlas of 1848. They are far from accurate. White Rock is half way down in Sanilac county. Willow Creek, called Black River, empties into a marked bay between Rogers Point and Pt. aux Barques, which is about where Burnt Cabin Point should be. Sugar Point is perhaps Flatrock Point, and the Pigeon River masquerades as Sugar River. Oak Point is Pt au Chenes. Charity Island is Shawangunk, and the islands off Wild Fowl Bay are rolled up into one mythical I. au Traverse and planted square across Saginaw Bay.

1856. Farmer's map in 6 sheets, 7½ miles to the inch, summarizes the result of the United Land Survey, and was a most excellent map. This was issued and reissued, in various scales and at various dates.

1871. Walling's County Atlas of Michigan, already mentioned, contains beside the geological map of the state, a separate map of Huron county, which is interesting historically, in showing streams lakes and roads now no more, and occasionally it is more accurate than recent maps. We used blue prints of this to some extent. It was derived from the notes of the United States Land Office, and shows the original courses of the streams which have in some cases been much changed by ditches. The Land Office maps also show the original swamp areas.

1872. I have a sectional map of this date with no author nor publisher given which seems to follow Mss. maps in the State Library at the Capitol, that are independent of the U. S. Land Office, already referred to.

1875. In this year a large county map on the scale of two inches to one mile was issued by F. W. Beers of Philadelphia. This map showed ownerships.

1883. The Walling atlas was reissued with added railroads by Tackabury.

1890. An Atlas of Huron county was published by E. R. Cookingham and Company, with a general map of the county on a scale of one-half inch to one mile, with township maps on a scale of two inches to one mile, and village plats mainly on a scale of four hundred feet to one inch. These were largely constructed from deeds in the County Records, and have been the principal base

In 1856-7. The United States Lake Survey carefully surveyed the coast of Lake Huron in this region, and the Chart of Saginaw Bay, published in 1860, gives the results on a scale of 1:120,000, very nearly one-half inch to the mile. As above mentioned we have been permitted to use photographs of the field sheets, which were on a scale of 1:16,000.

The following list of names which have been applied to the geographical features may be of service. There are three types of names,—those of English, of French, and of Indian derivation. In many cases one is a translation of the other.

[illegible]

Abbreviations:
 Schoolcraft's Narrative, S.
 U. S. Land Office, L. O.
 U. S. Lake Survey, L. S.
 Walling Atlas, and Tackabury's reissue, 1883, T.
 Cookingham's Atlas, C.

Winchell's Geological Report, 1860, W1.
Rand McNally; Railroad Folders, etc., R. R.
Rominger's Geological Report, 1869-1873, Ro.
Sectional Map of Michigan, 1872, M.
Farmer's map, F.
Mss. Maps of Houghton's Survey, H.

Table I. Geographic names of Huron county, showing equivalents used by sundry authorities. Preferred names are italicized. The order is geographical from the S. E. corner of the county around by the north to the S.W. corner.

CHAPTER II. GEOLOGICAL COLUMN.

§ 1. Pleistocene, i. e., unconsolidated materials, soils, and subsoils. (a)*

Although repetition is involved, it is best to give at once a general account of the principal materials which make up the frame of the county, geologically speaking, whether rocks in the popular sense, or soils, or subsoils. At the same time we may give some reference to their nearest representatives elsewhere, for so one will be able to understand more intelligently references to them scattered through the text. A more detailed account of

their character may be gathered from the chapter devoted to their distribution.

An imaginary section down into the earth's crust, showing the various materials of which it is composed at any place, is called the geological column at any place. Plate LXXIII of Vol. V, of these reports, gives such a geological column for the Lower Peninsula. We proceed therefore, to give an account of the geological column under Huron county (Pl. I).

*This letter and corresponding letters in parentheses below, have the same meaning as in Plate LXXIII of Vol. V.
2-PT. II.

Our first division includes the materials most recently laid down; or even now in process of formation. Such are the finer material, called sand, and the coarser material,—called shingle and gravel,—of the present shore lines. Along the west coast the sand is frequently blown back from the beach into undulating mounds known as dunes. Off shore and in shallow waters muds and oozes are forming. The streams deposit "alluvium," that is silt and sands and even gravels, especially along their courses upon their flood plains in times of freshet. In the smaller lakes and in the great lake in sheltered stretches we find shell marls forming, mixtures of mud, decayed vegetation and the cast off shells of fresh water snails and similar animals with precipitated lime. Such shell marls make, if drained, a wonderfully fertile soil and are also coming into demand for the making of cement. Such a lake, once known as Bear Lake, has been drained just southwest of Port Austin and the land is said to yield unusually large crops of timothy. Out from the edges of the lakes, as is well seen around Rush Lake, the marsh creeps slowly but surely, fills them up, and makes deposits of muck or peat, converting them into swamp. Occasionally masses, or irregular sheets, of bog iron ore are formed, the iron ore being leached by organic acids out of the surrounding sands, which are left unusually white, the iron being later reoxidized and deposited.* Waters thus charged with dissolved iron become covered with an iridescent scum on becoming exposed to the air. Such scums are well marked on the shore west of Caseville, and are sometimes mistaken for oil, by those who do not observe closely, but they lack the characteristic odor, and the sheet of scum breaks up into angular forms. A similar type of chemical deposit is that formed by the deposition of lime from calcareous springs when they reach the surface. Such deposits of calcareous tufa or travertine, as they are called when they form exposed to the air, were observed around a spring in the bank of Willow Creek, while if they form beneath lakes or bogs they produce marl or bog lime. Similar materials to those now forming in these different ways we also find where they cannot have been formed under present conditions. Thus rolling ridges of dune sand swing southwest from Caseville to Bayport, cutting off Sand Point, far from the present shore line. Thus, too, south of Badaxe beds of shell marl exist under the muck, where there is no longer any pond, and even the marsh is fast being drained. Again near Huron City cliffs overlook benches of shingle, where no storm could now

sweep the waves of Lake Huron. Around Pigeon, Elkton, and Badaxe, and often elsewhere we find beds of clay evidently deposited in a body of water. In fact all over the county ridges of sand and gravel are found, and long trains of boulders, which are like the present shore line formations.

*Prof. Davis observed a good instance of this leaching of iron oxide on the southeast ¼ of Sec. 36, T. 15 N., R. 10 E., Sp. 19174.

These we still class as recent deposits, but we see that we must look far enough back into history for the time of their origin, to find a somewhat different physical geography from the present. In the county we also find deposits, still unconsolidated, and not rock in the popular sense, but often firmer and more solid than those already mentioned and classed as "hardpan," whose origin we can ascribe to no agent now working in the county. The deeper cuts in the hills around Verona or Ubyly show well these deposits. All water deposits show some banding and stratification and in them the material is assorted according to grain, and especially is the very fine clayey material (0.005 mm. in diameter or less) washed out from the coarser and deposited separately. The coarser stones are also more or less rolled and rounded. But in the material we are considering, whose shortest name is "till,"* we find stones of various sizes and irregular, frequently of angular or grotesque shape, firmly compacted together with a clayey cement. The stones and boulders which we find in this deposit, and also strewn over the surface of the county, are not derived altogether from rocks which are to be found in ledges in the county, but come from far away in Canada,—a conspicuous jasper conglomerate with blood red bits of jasper sprinkled here and there in the white quartz, masses of vein-quartz, heavily loaded with pyrite, granite, hornblende and staurolite schist, etc. This material is such as is deposited under glaciers, and the glacially grooved surfaces of the limestone in the Bayport quarries (Pl. IX) also give evidences of the presence of a vast sheet of ice that once came down from Canada, and crept heavily over the country down to the Ohio River. The period of this ice sheet is known geologically as the Pleistocene, or Quaternary. Contemporaneous with the presence of the ice sheet, deposits like those now forming were laid down in front of its margin, as it retired.†

*The term "boulder clay" is not a very happy one for Huron county for the ground moraine often has not many large stones, and is typically rather a gravelly clay.

†Taylor, loc. cit.

§ 2. Coal measures of Sebewaing. (b)

The formation known as the Woodville sandstone, a reddish sandstone, separated off by Winchell, but not by Rominger, is not represented. It may perhaps once have existed, for we find the unconsolidated deposits resting on an uneven surface with stream valleys cut into it, which now are entirely filled and hidden. Such a surface indicates what is known as an unconformity

between the deposits above and those below. From what has been learned elsewhere we know that this unconformity is a sign that for many more years before the ice period, than have slipped away since that time, this rock surface was a land surface which stood above sea level and was carved and eroded away by running streams. Possibly during that time the Woodville sandstone and others of the uppermost rocks were entirely wasted away.

Passing now to what we have left of the Coal Measures, the well records of Sections 7, 8, 17, 18, of Sebewaing township, from about 50 to about 125 feet down, show the character of the rock. Rominger's remark* is quite applicable; "the whole series is a constant alternation of shale and sandstone beds, and every natural or artificial section teaches us that an immense variety exists in this alternation." It will be observed that red colors do not prevail, but white and bluish to black. The shale is in streaks black and bituminous. At two horizons, at least, occur seams of coal, one of which tends to be about 4 feet thick, but may be somewhat thicker, and often is cut out entirely. Sandstones run from white to gray in color. The whole formation is more or less charged with pyrite. Carbonates of iron, magnesia or lime occur in nodules or thin bands and zinc blende (ZnS) may occur in similar form. The clay beds under the coal are often called fire-clay, but the clays like the other beds vary rapidly in short distances. For example the heavy clay in Bauer's well and that in Miller's well, both in Sebewaing were quite different, the one being much "fatter" than the other. Black bits of fossil rushes are not uncommon in them. There are from 50 to 75 feet of clay above the principal coal deposit and less than twenty below it. I assign to this group, say, in all—75 feet.

At the bottom of the Coal Measures a sandstone is separated off by Winchell under the name of Parma sandstone.† But the dip of 45°, which he gives, shows that there is something abnormal about it, and Rominger fails to recognize it as a separate horizon.‡ Only a trace of it is found in Huron county, e. g., in Bauer's well, Sebewaing, from 101-104 feet, though it seems about Bay City and Saginaw to be well marked, but even there it belongs, I conceive, rather with the next group lower.

*Loc. cit. p. 128.

†Loc. cit., 1860, pp. 112, 138.

‡Loc. cit., p. 128.

§ 3. Maxville limestone of Bayport.

The Grand Rapids Series (c), in Huron county, can be easily divided into two parts: the upper being the limestone of Bayport, equivalent to the Maxville limestone of Ohio.

This formation is composed of limestone, alternating with, and at times frequently replaced by beds of white sandstone, thus resembling the Kaskaskia of Indiana.§ The sandstone is often calcareous and very fossiliferous, and the limestone is inclined to be very cherty with

rounded siliceous concretions. The lower beds are often brown and dolomitic. The first fifty feet of the Bayport limestone quarry section,—on Sec. 5, T. 16 N., R. 10 E. (Fig. 8), is the most detailed division of the formation that we have. It dwindles to some 20 feet around Sebewaing (Sec. 8, T. 15 N., R. 9 E.). As above said, I believe that this formation in its sandy phase is the Parma sandstone, and we have not been able to follow in detail the subdivisions made by Winchell. It is a good source of water. It is the equivalent of the Maxville limestone of Ohio, which has been identified with the St. Louis-Chester (or, as it is now called, the Kaskaskia), as is evident from comparison of the fossils with those of Plates IX and X of Whitfield's paper on the Ohio Subcarboniferous.* For geographic reasons explained a page or two beyond I correlate it with the upper St. Louis, as long ago suggested by Winchell from the palæontology. It is also equivalent to the limestone at Grand Rapids, as is evident from a comparison of their fossils. The most abundant genera are *Allorisma*, *Lithostrotion*† and *Productus*. Good natural exposures are found, as stated by Winchell and Rominger.

It is liable to be eroded by underground water channels, which cause sudden drops in the drilling, as at Sebewaing, Sec. 8, T. 15 N., R. 9 E. For a round number, near the maximum we may call its thickness 50 feet.

§20th Annual Report, State Geol. of Indiana, 1895, pp. 330-331.

*Geology of Ohio, Vol. VII.

†The *Lithostrotion* and *Zaphrentis* have already been figured by Rominger, Vol. III, Plate LV; other forms will be illustrated in reports on Kent county and Arenac county.

§ 4. Michigan series (c, 2).‡

This group of rocks is in general soft and forms valleys in the rock surface, as we see from the map (Pl. VIII), and is therefore little exposed. Just off Oak Point and near Soule the lower part of the formation lying on the more resistant sandstone beneath is brought within reach of erosion, and thus exposed to daylight. Light grey and greenish shales, very fine grained, somewhat sandy or micaceous and pyritiferous, predominate but at various levels as around Soule, at about 70 feet above the coarse underlying Napoleon sandstone, occur beds of impure clayey bluish magnesian limestone, weathering buff, which closely resemble those used at Milwaukee for cement.

‡I would suggest that from Winchell's name the word salt be dropped. While the group is a source of brines, perhaps, rock salt has hitherto been found in it only as a mineralogical curiosity, the really characteristic mineral being gypsum. Moreover, as there is no other group of strata called simply Michigan the term salt is unnecessary. Finally this group in its characteristic gypsiferous facies occurs extensively in Michigan, and, so far as we know, not outside the State, so that the name Michigan series will be very appropriate. If a local name were desirable the town of Alabaster has best claims to the honor of naming it.

Toward the bottom of the series (cf. Dufty's and Sovereign's wells in Lake township) the shales are darker and more bituminous. In the shales also occur lenticular beds of gypsum, which is white when pure, but when impure bluish and hardly to be distinguished from shale. About 80 to 120 feet from the bottom of the formation and not far above the cement rock of Soule is the most marked gypsum horizon (see also well on Sec. 36, T. 17 N., R. 11 E.) and at this level and a little higher the water is very bad. There are signs of another gypsum bed about 20 to 30 feet below the top of the shale. In general the water from this formation is scanty, characteristically highly charged with sulphates, and often cathartic, or almost too salt for use. Unfortunately we have no good characteristic set of samples from the thicker part. Bauer's well, Sec. 8, Sebewaing, from 127 to 249 feet and Deeg's well on Sec. 35, Sebewaing, from 66 to 130 feet, are the most complete records we have, but are from its thinner part. Collison's well (Sec. 14, T. 16 N., R. 9 E.) probably gives only the lower part, while it is probable that under Bayport and to the north this Michigan series is two hundred feet thick and perhaps a little more, with argillaceous dolomitic limestone at the bottom and about one-third the way up, and gypsum beds halfway up and also less marked near the top, being thus quite as thick as at Grand Rapids.*

The base of the Michigan series near Soule appears from the wells to be of micaceous shales like those in the Marshall, while near Oak Point, Rominger describes beds like the Soule cement rock directly above the sandstone. Winchell† seems to include some part of these micaceous shaly beds in the Napoleon.

*Vol. V, Pl. XXI.

†Am. J. S. XXXIII, 1862, p. 353.

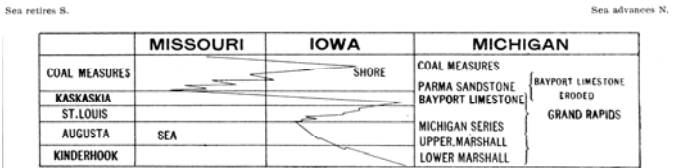


Figure 2. After Keyes (Geol. Survey of Iowa, Vol. II, p. 114), showing how the shore line advances to south and returned north during and before the deposition of the coal measures and connecting the Missouri, Iowa and Michigan beds. The irregular line is as given by Keyes. For the relations of the shore line in Michigan, see text.

The general correlation of this group we can fix very nicely from geographical considerations. The gypsum beds must have been laid down in a nearly enclosed sea. Hence the adjacent country must have been out of water, and our correlation for these beds must be with some series that is wanting in adjacent regions. Now in just the proper part of the geological column in Ohio there is a group which is wanting in northern Ohio and southern Michigan. "By atrophy or overlap" the Logan Group "is wanting in the Cuyahoga Valley, or is at least very inadequately represented there."* Again if we turn to Indiana we find† that the Burlington has not been satisfactorily identified in that state. In each case the

missing part of the column lies close below the St. Louis and Maxville limestones, respectively, which we have identified with the Bayport limestone, and so to anticipate a little we suppose that the general continental emergence which culminated in the heavy sandstones of the Catskill in New York and the Napoleon in Michigan (the former being formed before the latter, as the shore line advanced west and the emergence progressed) finally lifted Ohio and Indiana largely out of water, while part of Michigan remained as a closed basin between these lowlands to the south and the great mass of land to the northeast and (for the indications are that Wisconsin was also out of water) northwest. In the sea thus enclosed the "Michigan Salt Group" was formed, while the Logan Group formed on the other side of the low land which extended through northern Ohio and southern Michigan.

Even as far away as Iowa‡ there are corresponding facts. (Fig. 2.) "In some portions of the Mississippi basin there were very considerable alterations in the coastal contour of this broad shallow gulf during the latter part of the Lower Carboniferous, and it is known that there were even greater changes in the coast line in the other parts of this region during the same period. During the Keokuk the waters over portions of Iowa, Illinois, Missouri and Indiana, became greatly diminished in depth, and the land of the same area was considerably extended. While the St. Louis beds were being deposited the sea again encroached upon the land, extending in some places more than 200 miles northward, beyond the former Keokuk waters."

*Geol. Ohio, VII, p. 32; cf. also pp. 510 and 515.

†Geol. and N. H. Survey, 15th Ann. Report State Geologist. 1885-6, p. 12

‡Iowa Geol. Sur., I, 1892, p. 66.

This is illustrated by Fig. 2 and is in complete accord with what we find in Michigan, only we must remember that the effects of an elevation of the Canadian continent would be felt sooner near by in Michigan than in Iowa farther from the old Laurentian land mass, and the effects of depression later. Thus the Bayport limestone will represent the farthest extension of the St. Louis depression,—the top of the St. Louis,—while the beginning of the Michigan (Salt) Series will be earlier than the Keokuk. In other words the Michigan series is closely equivalent to the Augusta, i. e., Burlington and Keokuk formations which are stratigraphically very closely allied.* The palæontological evidence sustains this conclusion. (See Chapter X, § 4) Its thickness is not out of harmony with our conclusions, for to match with 230 feet of the Augusta in Iowa and 150 feet of the Logan in Ohio, we may estimate the thickness of the Michigan group from the Bayport well, at 232 feet.

*Geol. Sur. Iowa, 1892, I, p. 59.

§ 5. Marshall series. (d)

Beneath the cement rock series comes an extensive sandstone series which forms the points which project from the north shore of the county from the Babbitt sandstone quarries (Lot 3, Sec. 15, T. 18 N., R. 11 E.), to the grindstone quarries. Of these points Hat Point, Flat Rock Point, and Point aux Barques, are supposed by Rominger to represent the same horizon (loc. cit., p. 75), while Winchell supposes a general descent in the series as we go east. The reasons why I consider Winchell's conception of the column to be more nearly correct are as follows:

The coast of Huron county was lined with saltworks, supplied by deep wells which appear to have drawn their brine largely from the same source, namely the Berea grit. If we compare the depths of these wells we find them steadily deepening to the west through the disputed area, as described below under Chapter V, in a way which does not seem to indicate the anticlinal and synclinal supposed by Rominger. Moreover we can trace the individual beds of sandstone in the shallow wells for water until they run under one another, and by thus showing that they cannot be identical, confirm the presumption raised by the salt wells. For example, the heavy sandstones of Flat Rock Point and Port Austin can be traced in wells and by outcrop (Sec. 3, Dwight, T. 18 N., R. 13 E.) to Sec. 13, Dwight, where Robinson's well starting at their outcrop, runs down 101 feet to draw its water supply from the Point aux Barques sandstone, which can be similarly traced through sections 22, 23, 26 and 35, Port Austin, T. 18 N., R. 13 E., and Sec. 1, Dwight, T. 18 N., R. 13 E., to its outcrop on Willow River (S. 28, Huron township).

It is true, indeed, that about Hardwood Point abnormal dips to the northeast and possibly a fault are indicated, and a much greater maximum thickness for the Marshall series must be allowed than was assumed even by Winchell.* Thus we are somewhat puzzled where to put the base of the Marshall, so as to agree best with his idea, who is the geological sponsor for the word. He speaks, indeed, of the fossils of Hardwood Point (Sec. 35, Port Austin) as the first undoubted Marshall fossils,† and in the same report describes the "gritstones" and grindstone quarries (p. 75) in connection with the underlying shales of the Huron group. On page 80 he alludes to the conglomerate 235 feet below the top of the Lower Marshall as containing some of the fossils of the overlying group, and in the table on page 139 he makes this conglomerate the base of the Marshall and separates the Napoleon from the Marshall, placing the former in the Carboniferous, the latter in the Devonian; later, however, he speaks of the Marshall as "outcropping in the sandstone bluffs of Point aux Barques,‡ and on his map and in his fossil lists and publications he includes in the Marshall the fossils of the grindstone quarries of the Huron gritstones. If we put the base of the Marshall at the base of the Point aux Barques sandstone it would be the best place to have it, in order to make his statement hold true that in the

Marshall brachiopods, except *Rhynchonella* are rare. For immediately below comes the zone of [*Camarotoechia R.*] *camerifera* and *Romingerina* [*Centronella*] *julia*, crowded with brachiopods and with a different faunal aspect from the beds above. However, inasmuch as Winchell distinctly includes these and the fauna of the gritstones,** among his Marshall forms, we are constrained to bring the base down so as to include the quarry beds around Grindstone City, with the associated conglomerates.††

These gritstone beds moreover, seem in their outcrop on Willow-River to be coarser and more massive, and more like the Point aux Barques sandstones and in fossils and lithology close allies of the beds above.

Rominger says that Winchell put the base of the Marshall still farther down, just above the conglomerate that underlies the lighthouse (loc. cit., p. 75). This does not appear to have been Winchell's view for we have not only his maps and the numerous references already given, but he distinctly says (Proc. Acad. Nat. Sci., Phila., 1862, p. 406) that the bed in question is intercalated in argillaceous shales of the Huron group and excludes the fossils thereof from the lists of Marshall forms. The other point of Rominger's criticism, that at least 500 feet of rock beds below this horizon present the faunal characteristics of the Cuyahoga shale of Ohio, which forms the upper division of the Waverly group (Subcarboniferous) is well taken, though we must remember that Herrick would divide these shales and assign the lower part of them to the Devonian. There is a practical advantage in drawing the line where we do, in that it may be more easily traced in the well records, and is at the same time of more practical importance. For wells into the Marshall as thus defined are pretty sure to strike good water. Limiting the Marshall thus, it is at maximum 560 feet thick, and we may subdivide it, following Winchell's earlier work into Napoleon or Upper Marshall and Lower Marshall.

*Am. Jour. Sci., 2d Series, Vol. XXXIII, 1862, p. 353, 296 feet; in a later publication 283 feet.

†Report, 1860, p. 80.

‡Walling's Atlas, 1873, p. 41.
3-PT. II.

**i. e. the quarry beds below which were in his time on Sec. 30, T. 19 N., R. 14 E.; cf. Proc. Acad. Nat. Sci. Phila., 1862, p. 305; Am. Phil. Soc. (1870), Vol XII, p. 386; Report 1860, p. 74.

††As he does in Am. Jour. Sci., 1862, 2d Series, Vol. XXXIII, as well as in the latter publications.

§ 6. Napoleon or Upper Marshall sandstone (d 1).

We revive this term from Winchell's report, as being applicable to this county.‡ The Napoleon is typically a white sandstone though often with a faint olive or greenish cast. In well samples it is frequently quite pyritiferous, and to the pyrite is doubtless due small brown mottlings. which appear in it where exposed in outcrop. Hat Point (Sec. 7, T. 18 N., R. 12 E.) seems to

be near the base of the formation; if so, there must be nearly 300 feet of sandstone without important interruption. This is indicated both by such wells as Mr. Dufty's on section 32, and Lonsberry's on section 35 of Lake (T. 18 N., R. 11 E.), and by the considerable breadth of its outcrop. To the southeast under cover its recognizable depth rapidly diminishes to somewhat over 100 feet, as at Bayport (135 feet), Pigeon (110 feet), etc. It yields an ample supply of fresh water when properly cased. The thickness of 300 feet above mentioned is not obtained directly, and may include, as did Winchell, some of the bluish micaceous sandy shales which we have estimated in the overlying group. Thus it is probably near a maximum, but implies a dip from Hat Point to Caseville closely in accord with that indicated in other ways, as shown in Chapter V, § 1.

‡Winchell seems to have abandoned it in 1875. The reason probably was that not finding in the deeper wells of the Saginaw valley any well-pronounced sandstone beneath the 109 feet from 633-742 feet, he concluded as suggested on p. 90 of his 1860 report that this one sandstone represented both his Napoleon and Marshall. Whereas the indications are, as will be shown in the chapter on Stratigraphy, that the lower fossiliferous Marshall of Huron county is there represented by the red shales beneath the sandstone and some of the underlying beds, shown in the record of the Bay City well in Vol. V, Pl. VI. of these reports. Winchell's first thoughts were best.

§ 7. Lower Marshall series. (d 2.)

This group is in rocks and fossils a transition one, and varies from point to point. Lithologically it is a transition from the heavy sandstone overlying to the heavy shale formation underlying. There are three prominent types of rock:

(a) A conglomerate with small very round pebbles of white quartz, and a copious clayey cement—the same material as types b and c—which when fresh may be bluish or greenish, but is reddish when weathered. The rock then resembles peanut candy. We may call it peanut conglomerate.

(b) A fine grained bluish sandstone or grit, impregnated with more or less carbonates, especially of iron, and thus passing into clay iron stone, which often cements the sandstone into rounded balls or nodules. When weathered they become very rusty, brown or red.

(c) Bluish micaceous shale which may be very clayey (a wide spread lithological type in the middle Kinderhook; cf. Missouri Geol. Sur., Vol. IV, p. 51). Gradations and inter-laminations of these types compose the whole formation which has a characteristic bluish to greenish gray color when fresh and a red color when oxidized, and is throughout quite micaceous and ferruginous. These three facies remind one of the Catskill, Chemung and Portage types of New York State. The uppermost beds of the group we find on the hill back of Port Austin on Sec. 31, T. 19 N., R. 13 E., underlying the sandstone which caps the hill and is, we suppose, the base of the Napoleon sandstone.*

These uppermost beds are a series of thin bedded^a fine grained flaggy slabs, greenish when fresh, deep red

when weathered, and contain traces of crinoids, and lamellibranchs. We can trace them in the talus around and down the hill to the southwest, and on the road from Port Crescent they appear somewhat more massive—probably a slightly lower horizon, but the terrace opposite the wave-cut bluff along which the road runs shows a fossiliferous shingle (*Leiopteria torreyi*, Pl. XI, Fig. 2) like that on the hill. Passing next to the shore we find a heavier sandstone and then, some 70 feet below our assumed top, the rocks of Hardwood Point, on Sec. 35, T. 19 N., R. 12 E. These are calcareous flags with *Solens*, *Goniatites marshallensis*, *Orthoceras indianense*, *Nuculana*, and other characteristic Marshall forms. Close beneath, say from 73-75 feet below the top, the rocks become shalier and very micaceous and pass into a plastic blue shale, then becoming sandier and more charged with carbonates they pass into a series of flags which contain a fauna identical with that of Hardwood Point, and in streaks contain abundantly *Solens* and bryozoa, and lie over the more massive sandstones of Flat Rock Point. Next below we have the heavy white sandstones of Port Austin, pure or with small quartz pebbles, highly crossbedded in two or three layers, the cross bedding dipping in the top layer 45° toward N. 38° E., in the layer back of Broken Rocks, 25° toward S. 10° E. and around Kimball Island northeast again. Winchell says that the first of the series is a bluish gray sandrock 12 feet thick, followed by a whitish and grayish, sometimes yellowish, fine grained sandstone, very pure and massive, occurring in beds 10 to 12 feet thick, without pebbles or seams, and moderately coherent. The sandstone appears fairly white and clean along shore, but from some outcrops in section 23, Dwight, of coarse red, friable, highly fossiliferous sandstone with pectinoids, *Athyris* Cf. *ohioensis* and *Centronella flora*, and a small *Schizodus* at the same horizon, and other indications, it is likely that this pure white sandstone is only the result of leaching. Its total thickness seems to be somewhat over 20 feet; our column makes it extend from 85-107 feet below the base of the Napoleon. The Skene well apparently just misses it. Just beneath it, opposite Point of Pines, and rising into sight by a slight undulation to the east of Broken Rocks are some thin-bedded ripple-marked flags with a narrow band of peanut conglomerate, which are the first beds met in the Skene well. We find *Goniatites* again and Rominger says *Rhynchonella camerifera* (Pl. X, Figs. 11 and 12). The beds beneath appear to be fine grained, not porous to water, and soft (not resisting erosion) arenaceous shales, the only somewhat doubtful exposure being along the beach toward Point aux Barques (Sp. 19204), with coaly bits of vegetation and lamellibranchs.

*For it is at least 68 feet, probably more, above the top of the Skene well, Port Austin, or 68 + 1225 = 1293 feet above the base of the Berea. Thus as the top of the Napoleon is about 1750 - 120 = 1630 feet above the bottom of the Berea in the Caseville wells, Sec. 35, T. 18 N., R. 10 E., the sandstone is not probably more than 337 feet below the top of the Napoleon sandstone, and is more likely to be somewhat less, thus bringing it at the base of that formation. Moreover its topographic position, capping the hill, makes it likely to be the relic of a heavy overlying protecting formation.

The picturesque cliffs of Point aux Barques are the outcrop of a sandstone which may, upon weathering, become white and indurated, but is then probably deprived of cement, is somewhat greenish and pyritic in aspect, and in the lower part may appear red and striped. It is highly cross-bedded, and that fact as well as its general aspect is well illustrated in Plate III.

The thickness of this sandstone may be taken as 18 feet, say from 176* to 194 feet below the top of the lower Marshall. Below, the beds become gradually thinner and finer grained, more like the grindstone, with no sharp break, and are exposed in the bluffs just north of the southeast corner of Sec. 23, T. 19 N., R. 13 E., until finally we have a little blue shale, and at 220 feet from the top of the formation† narrow seams of calcareous sandstone covered with *Camarotoechia* (*Rhynconella*) *camerifera* and *Romingerina* (*Centronella*) *julia*. This zone is found just north of the road running northwest from Grindstone City, at 1400 paces north and 900 paces west of the southwest corner of Section 26, T. 19 N., R. 13 E., and also on Willow River, and is one of our datum zones. Underneath it come slabby micaceous green flags and grindstones, with blue shale and perhaps streaks of limestone for some 15 feet until we come, at 235 feet, to a band of peanut conglomerate, probably not persistent, which lies on top of the present grindstone quarries on Sec. 23, whence come the famous whetstones. Fifteen feet below, outcropping near the shore at Grindstone City, seems to be another band, similar but richer in fossils, and the whole thickness of the grindstone beds seems to be about 25 feet, making the thickness of the whole Marshall as we have taken it 560 feet. These last twenty-five feet are generally very even grained, and not generally cross-bedded, though occasionally that defect appears and injures the quality of the stone. Sometimes calcareous concretions, i. e., concretions of sandstone more firmly cemented with carbonates of calcium and iron occur, in which fossils, especially *Goniatites*, may be found. Fish fragments, both teeth and bones and spines are frequent and the surface of occasional seams is strewn with small fragments of woody matter turned into coal, and of fish teeth, which are also blackened.

*From the Skene well 105 feet + 2.63 miles at 27 feet to the mile = 176 feet; similarly from the Carrington well 1330 feet - 1198 feet = 132 feet + 9400 feet distance to Carrington's well X dip of 27 feet to the mile, derived from comparing Grindstone City with Port Austin wells = 180 feet.

†From the Skene well 105 + 4.3 miles at 27 feet dip per mile.

The formation as defined is prevailingly sandy, while the one subjacent is prevailingly shaly. Bits of land plants, beachworn and battered shells, *Solens* and lamellibranchs generally, indicate a littoral fades.

The correlation of the Marshall has been, as previously noted, the subject of much discussion. A list of Winchell's papers has been already given, and he gives an elaborate account of the bibliography up to his time, in the article in Vol. XI of the Proceedings of the American Philosophical Society already referred to.

Rominger, as we have said, refuses to attempt any very exact correlations, and raises objections to those of Winchell. These objections are in part well founded, but in part he mistakes, it seems to me, the drift of the argument in Winchell's mind. Winchell appears to me not so much concerned to disprove the Carboniferous character of the formation underlying the Marshall, as he is to reclaim at least the Marshall for the Carboniferous. Late researches would, however, draw the line* nearly where Winchell drew it. Rominger adduces two arguments against dividing the Marshall from the underlying and assigning the former to the Carboniferous, and the latter to the Devonian.† The first argument which is the conformity of rock material and stratification which he cites, though true, is not sufficient, for we know that in many parts of the Mississippi basin, there is a perfect conformity between the Devonian and Sub-carboniferous (Mississippian). The second argument that the underlying formation presents the faunal characters of the Cuyahoga shales of Ohio is also true, but its weight will depend upon the ultimate disposition of these shales. The latest Missouri reports assign what used to be termed Lower Kinderhook to the Devonian. The more important recent papers for Ohio are by Herrick.**

*C. L. Herrick (Geol. Ohio, VII, p. 510 et seq.).

†Loc. cit., p. 75.

**Geol. Ohio, 1893, VII, p. 495, et seq., summarizing papers in the Bulletins of Denison University, American Geologist, and American Geological Society. See also Bulletin No. 80, U. S. G. S., Correlation Papers, Devonian-Carboniferous, by H. S. Williams.

We find that Herrick subdivides the old Waverly, and assigns part to the Devonian, and part to the Carboniferous. We are able, I think, to make, with the help of Mr. W. F. Cooper, his former assistant, close correlations with his zones,† and thus so determine our strata, that whenever the line between the Devonian and Carboniferous shall be finally fixed in Ohio, which is a question for the general palæontologist, it may be easily extended.

Our section is more complex and thicker than his, and he mentions that the fauna of the first fifty feet of the shale below his conglomerate I contains many Michigan Marshall forms, though his list of freestone fossils seems more akin to ours, even to those of the *C. (R.) camerifera* zone. His next fauna is obtained largely from calcareous nodules in the Cuyahoga shales, some seventy feet more or less below his Conglomerate I and contains a *Proetus missouriensis* found at the Point aux Barques lighthouse, numerous *Spirifers* and an assemblage Devonian in habitus, compared with those above.‡ This lighthouse stratum we make to be some 175 feet more or less below the bottom of the Marshall or about twice as far down as the nodule band in Ohio, but the whole formation down to the Berea black shale we find to be thicker (868 feet) than in Ohio (Geol. Ohio, VII, p. 32; 300 or 400 feet thick), in about the same proportion, so that the base of our Marshall might perhaps be coeval with Herrick's base of Division II,

though the Schizodus zone of the lighthouse fauna is more like that of the Waverly freestone as a whole, and Mr. Cooper takes the lighthouse conglomerate to be Herrick's No. 1.

Concerning the climate of the Marshall as thus defined we may note, somewhat in contrast to the group lying immediately above, that the abundance of mica and sand, feldspar and small pebbles, shows rapid land waste and rock decay while the abundant bits of vegetation show that there was abundant plant life. Both facts point to a relatively humid climate. The abundance of iron suggests that the land waste was from a region full of basic rocks.

†See Chapter X.

‡This fauna has been recognized by W. F. Cooper at Rock Falls with the characteristic nodules.

§ 8. Coldwater shales. (e, 1)

The term Coldwater is nearly equivalent to Winchell's Chemung shales and to the Cuyahoga of Ohio, but as the New York and Ohio names are receiving remodelling, it may be well to cling to the name used in Vol. V, a while longer. Lithologically it corresponds to the Portage shales, for as the formation above is prevailingly sandy though with occasional minor streaks of blue shale, so, conversely, this formation is prevailingly blue shale, with occasional streaks of sandstone, not generally very persistent nor coarse, and when struck under cover salty. Hence as a recent well in Grindstone City shows, not much water can be obtained from it. The base of the bluffs, south of the old grindstone quarries on Sec. 30, T. 19 N., R. 14, shows the top of these blue shales. After about 30 feet the formation is sandier, as found at the top of the New River well.* These flags also seem to form the crest of the bluffs south of Huron City. We seem to trace this horizon in the Port Austin well at 204 feet depth, which our computations make 49 feet below the top of this group. Of these sandier beds there are according to the Eagle Bay well (Sec. 23, T. 19 N., R. 13 E.), some 24 feet, according to Rominger some 20 feet on the hill, and then we get blue clay shale again. Rominger recognized (*Nucula*) *hubbardi* therein. Willow Creek, at Huron City, exposes a section about 89 feet below the top of the Coldwater formation.†

*1750 - 1029 = 41 feet; by the Eagle Bay well, Sec. 23, T. 19 N., R. 13 E., 54-78 feet below surface is grindstone.

†In placing this section at this point in the column some account is taken of altitude, and a dip is assumed of 55 feet to the mile for a strike of N. 26° W., which dip is derived from comparing Grindstone City and Port Hope wells. The strike is probably veering—more to the north and the dip is less in proportion, but so long as we compare two points whose distance apart along the strike is not large relative to their distance at right angles thereto, the error involved will not be great, and checking up on the (*Centronella*) *Romingerina julia* zone where it crosses Willow Creek—it is found near by in the bottom of a well,—we have the position of the Huron City outcrops in the geological column thus determined: 220 (the depth of the *Romingerina julia* zone below the top of the Lower Marshall)—(1.4 miles which is the distance perpendicular to the strike from the outcrop of *Romingerina julia* on Willow Creek to the Huron City bridge outcrop X 55 feet per mile dip)—

(the difference in altitude above lake of the two outcrops just mentioned, viz. 60—10)—260 (which is the thickness of the lower Marshall) = 87 feet for the distance of the section above mentioned below the bottom of the Lower Marshall, which checks very well with other computations.

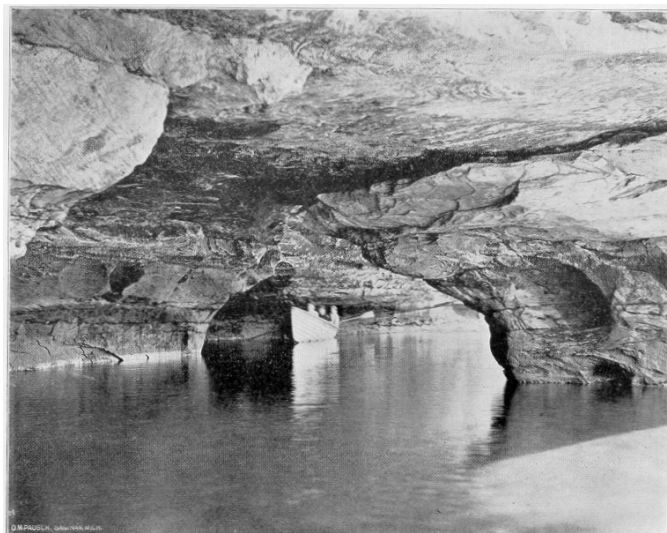


Plate III. Illustrates the appearance and cross bedding of the Lower Marshall sandstone at Point Aux Parques; also the undercutting action of the waves and formation of caves. (Reproduced through the courtesy of the F. & P. M. R. R.)

The lower part is blue shale with compressed lamellibranchs, while the upper part has several sandier seams of dark greenish blue flags, which show their high per cent of carbonates of iron, etc., by weathering very rusty. We measure, beginning at the top:—

6 inches, dirt;

3 inches, red sandstone seam, with *Rhynchonella*, Sp. 19036, *Productus*, and *Pleurotomaria*, Sp. 19039, etc.;

3 inches, barren;

6 inches, sandy;

3 feet blue shale, sparingly fossiliferous; Sp. 19043;

2 feet blue shale; no fossils found.

Below we have arenaceous shales with small seams of sandier nature, fairly continuously exposed until we come to the section given below at the bluffs south of the lighthouse (Fig. 5). I take my section about where the east line of Sec. 11, T. 18 N., R. 14 E., strikes the bluff. Winchell gives slightly different measurements, and his section may have been taken somewhere else.

Moreover 40 years has doubtless made a difference in the bluffs, but both sections agree in giving an intermediate portion with a number of seams of sandstone up to two and three feet thick, while blue shales lie above and below. I consider my section of 32 feet to be from 156 to 188 feet below the top of the group as follows:*

A. 11 feet, 3 inches, blue shale;

B. 3 inches narrow band of calcareous sandstone, brown in weathering;

C. 3 feet blue sandy shales;

D. 14 feet 6 inches to 14 feet 10 inches; a compact brown very fossiliferous sandstone, the *Schizodus* sandstone, which seems to be the principal source of the extensive fauna here collected, Sps. Nos. 19044-19067; at 170 feet from the top of the group;

E. 1 foot 3 inches, blue shale;

F. From 16 feet 1 inch to 19 feet 9 inches, the main bed of sand-stone, conglomeratic (pebble of coal!), pyritic, especially the top which is almost a solid layer of pyrite, enclosing and replacing many fossils; at times very calcareous, and again appearing as a white sandstone, the pebbles appearing as small rounded grains of quartz. Sp. 19074 shows the pyritic facies, and Sp. 19068 the conglomerate, and Sp. 19073 the sandstone facies; from 173 to 176 feet from the top of the group;

G. About 12 feet of blue shale to 188 feet below base of Marshall; fossils very rare, but occasional *Producti*, and *Spirifers*, and minute forms, (? trilobite larvæ) are to be seen, as illustrated by specimens, Nos. 19076-19084. We may compare the fauna with that of the *Romingerina julia* zone, etc., and find corresponding forms but in the upper zone they are all smaller.

*From *Romingerina julia* zone (3.05 miles X 55 feet deep = 168) + 220 + 60 (altitude of *Romingerina* zone) - 260 = 188. Compare Port Austin 336 + 105 - 260 = 181, and Caseville 800 to 900 - 120 - 560 = 120 to 220.

4-PT. II.

Winchell's section is given on page 75 of the 1860 report.

Though this stratum is so thin, the richness of its fauna, and its apparent persistence and thickening under cover, if, as seems probable, it is the same as that found at 336 feet under Port Austin, and somewhere between 750 and 800 feet under Caseville, in which event it is very likely still more widely recognizable,* make it important, and suggest its correlation with one of Herrick's zones, viz.: Conglomerate I.

Below this the formation grows more and more shaly, with fewer sandy streaks. The outcrops, along shore and south of the mill at Port Hope, of sandy shales, with a fauna like that at Sand Beach seem to be about 283 feet from the top of the formation, and a greenish micaceous sandstone found at 16 feet depth in the Port Hope well may be at 299-305 feet from the top of the formation.†

We may place the horizon of the top of the Sand Beach well near 400 feet below the top of the Coldwater.‡

At about this point in the column are the greenish and bluish micaceous, more or less sandy, shales of the creeks near Sand Beach with *Chonetes* mentioned by Rominger, (*scitulus*? apparently *pulchella* Win.) and a little lower, 454 to 464 feet below the base of the Marshall, the section of similar shales and shaley sandstones with *Chonetes*, *Goniatites* and a *Conularia* at Rock Falls may be placed. Similar sections are

exposed respectively one mile and 4 miles farther south. This is correlated by Mr. W. F. Cooper with the Moots Run section of Ohio. The fauna all along the east shore seems identical, the *Chonetes* being the most abundant form. The top of the White Rock well must correspond to about 505 feet of the section,§ and this determines the approximate place of the clay bluffs of arenaceous shale to the south with the indistinct casts of fossils—*Goniatites* and the like,—which were mentioned by Rominger. To our search they were unfossiliferous and well exposed in a stream bed. They look as though they would make good cement clays.** The well at Forestville, about two miles south of the county line, encounters the Berea at 465-505 feet down and hence its top may be placed at a horizon about 555 feet below the top of this group. But the blue arenaceous shales continue without material change until within some 100 feet of the Berea grit and hence are the lowest rocks outcropping in the county. The rest of the column, Plate I, is only struck in the deeper wells, but to get the full thickness of these bluish green shales we must add to the 396 feet above the Sand Beach well, 500 feet more recorded in the upper part of that well, making 896 feet. Lithologically the rock is equivalent to the Cuyahoga group of Ohio and the shales of Branch county in this State, and is the counterpart of the Portage group of New York, with its sandier beds above and black shales, etc., below, but lying farther westward it doubtless represents a later time when the Michigan part of the continent was undergoing a similar stage of development to that which occurred earlier in New York.

*Vol. V, Pt. II, p. 20

†1750 - 787 - 680 = 283, or 1680 - 716 - 880 = 284, comparing the Port Hope and Caseville wells, or comparing the Port Hope and New River, 1029 - 787 + 41 = 283, in each case + 16 feet for depth in well.

‡The reports as to the depth of the Berea in this well vary a good deal; a place for the top of the well 368 feet below the base of the Marshall is obtained by correlating 702 feet Sand Beach well with 1750 feet Caseville. Wright's figures, 715, would give 355. Similarly correlating Port Hope 716 with 633 of Sand Beach gives 366 feet, or with 603 feet gives 396 feet, while comparing 787 with 664 would give 406 feet. 664 feet seems to be the more precise figure for the depth of the base of the sandstone in the Sand Beach well, which would make the horizon of the well 406 feet down in the coldwater shales, but it is doubtful if in other wells some 10 feet or so below the sandstone has not also been included in the depth.

§The depths to the different horizons in this well are also variously given. We correlate the bed at 555, White Rock, with that at 664, Sand Beach, making the former 109 feet the lower. If the depth should more correctly be 550, White Rock, we should have the top of the White Rock 114 feet, below the top of the Sand Beach well and correlating the top of the Berea, 450 or 495, with 633, of Sand Beach, we have similarly 117 feet or 183 feet for the difference in horizons between the tops of the wells, while a correlation with the bed at 1225 of the Port Austin well of the bed at 555 feet at White Rock, would give the top of the White Rock well as 142 feet below the horizon of the Sand Beach.

**See Vol. VII. Part I, by H. Ries, for views of and reports of tests on these clays. See also Part III of this volume, on Sanilac county, Plate III.

§ 9. Formations not exposed at surface.

Berea shale (e, 2).

The Sand Beach well gives from 600-603 feet as black shale, with a few feet more of transition, above the Berea grit. The "rotten bad-smelling soft rock" from 800-900 feet of New River doubtless represents the same horizon, and the dark blue shales of Port Hope, from 533 feet down, and the 40 feet of chocolate colored shales above the Berea in the Port Austin well may mark the same horizon. In the Caseville wells it is not reported, but should come, according to our data, from 1548 feet down to the Berea, say 102 feet. This is probably rather more than it really is, though it doubtless exists there, for we find it recognizable in Bay City. But the less we make it, the more we must make the overlying Cuyahoga.

Berea grit (f).

It will be noticed that we assume this famous producer of oil and gas and brine to have been struck in almost all the wells that have been put down for salt, and from it we have computed our fundamental dips. That we are justified in correlating the wells in this way is shown. (1) in some cases by the correspondence of other strata, the Berea shale, the lighthouse sandstone horizon, etc., (2) by the correspondence in the character and thickness of the rock itself, which has been so repeatedly pierced, at such short intervals that there can be hardly a chance for it to escape, as shown by the following succession:

Forestville, 465-505;

White Rock, 495-555;

Harbor (Sand) Beach, 603-664?;

Port Hope, 716-787;

New River, 929-1029—(well penetrates the shales a few feet);

Grindstone City, 1010-1080;

Carrington, Port Austin, 1198 (1100-1200);

Learned, Port Austin, 1160-1225 (well penetrates the shales a few feet);

Hazard, Port Crescent,—1250;

Crawford, Caseville, 1650-1750 (the figures for the base at Caseville vary from 1735 to 1770);

Bayport, 1900 + ? (not reached).

(3) We have also the indirect but most convincing argument that the assumption of this continuous stratum, makes all the other wells and outcrops fall into place as a consistent whole, while the dips derived from this correlation check with those derived independently. (4) The quality of the brine is uniformly better than in strata above or below.

The rock is almost invariably reported as a white, gray or brown sandrock with a plentiful supply of brine. The more reliable measurements show a thickness less than 100 feet, but so near it that in round numbers that figure is generally given. We make it in our column 70 feet.

Only three wells have penetrated deeper than this stratum. From the Caseville well all we learn with any degree of certainty is that between 2200 and 2300 feet, most probably at about 2270 feet, it struck another brine more impure than the one they had been using. The chances are that this is in the top of the Traverse or Hamilton group. So we continue our column with the aid of the Harbor (Sand) Beach well.

Ohio shale (Saint Clair, Huron black, or Black). (g)

(1.) *Bedford shale.* Below the Berea we have in the Sand Beach record 186 feet of light colored shale. In the White Rock record, however, there is given a three foot stratum of gaseous black shale, which if we take it to be the Cleveland shale would then leave about fifty feet above it to be assigned to the Bedford. This we will accordingly do, and this thickness corresponds very well to that assigned to the Bedford shale by the Ohio geologists.

(g 2.) Cleveland shale.

The narrow belt of gaseous black shale of three feet between 600 and 610 feet, in the White Rock record is at the proper place in the column for this shale.

(g 3.) Erie shale.

The underlying light colored shales, for the remainder of the 186 feet ($186 - 53 = 133$) through which they occur in Harbor Beach well, may be assigned to the Erie shales, being of the proper color and position. It is highly probable, however, that these alternations of blue and bituminous shales are very inconstant. Still, the Bay City record shows a somewhat similar group in a similar place.

(g 4.) Huron shale.

The next 270 feet from 850-1120 of the Harbor Beach well is said to be a dark brown or black slate, which corresponds very closely to Newberry's Huron shale, is the great Devonian Black shale, and is one of the most widespread of lithological datum-planes.

Traverse group (h).

We next have, from 1120-1725, some 605 feet of light slate or "soapstone," i. e., calcareous shales, with 1.5 feet of extremely hard rock at 1400 feet. This appears to be the Traverse group, which has already thickened enormously, judging purely by lithology, from what it is in the southern part of the state, but this thickening is a characteristic of our column generally. Somewhere in this series which is 456 feet and more below the Berea, the deepest Caseville well may be supposed to obtain part of its brine.

At 1400 is a belt of extremely hard rock, probably a cherty limestone, possibly a pyrite nodule, a premonition of what we are to find below.*

*The "granite" in the Churchill well at Alpena, from 145-153 feet down, seems to correspond. It may be the horizon of the Encrinal limestone.

Helderberg limestones (i, j).

At 1725 feet we seem to have reached that series of limestones which lie at the base of the Devonian and top of the Silurian. At 1844, 119 feet below, where it seemed to be lime and sand mixed, we may possibly be near the horizon of the Oriskany or perhaps the Sylvania sandstone, but the limestones were penetrated 86 feet farther down, to 1920 feet, the rock growing coarser, dolomitic (?). If we may venture a prediction, some 500 feet farther down—2400 feet—would carry the Harbor Beach boring well down to the rock salt formation struck in the deep wells at Goderich, Canada, and in the deep wells of the Saint Clair River. It would probably be not less than 1300 feet farther down to the Trenton. We thus finish our geological column, or account of the rocks of the county in descending order. It may be remarked in conclusion, that since the thickness of the beds varies from point to point, no such column is exactly accurate anywhere. We have tried to make ours fit as closely as possible to the section as it might be found by a shaft at Caseville. It must be remembered, however, that for the Marshall and the formations generally the coast of the adjacent land was to the northeast, so that as we go to the southwest there will be less variety and in general less thickness to any division of our geological column.

The plate of our Geological column, Plate I, which may be compared with Plates VI and LXXIII of Vol. V, and uses the same symbolism for the lithological character of the beds, is constructed by combining the record of the Sand Beach well below the Berea, with that of the Caseville well, filled in with local observations, as far up as it goes, then using the record of the Bayport quarry's deepest boring, and finally that of the Bauer well at Sebawaing, thus covering the whole of the column in as great detail as possible, consistent with any accuracy in summation. It is obvious in constructing the column in this way that if for instance we have overestimated the thickness of the Napoleon sandstone beneath Caseville, we shall have to increase some other formation by the amount that this sandstone is in excess and similarly in other cases.

CHAPTER III. PHYSICAL GEOGRAPHY OF HURON COUNTY.

§ 1. Introduction. Relation of physical geography and geology.

Physical geography and geology are kindred sciences, in fact inseparable. Physical geography is the geology of the present, while one branch of geology is the physical

geography of the past. But as the biography of a man usually and rightly begins with some account of his ancestors, so we can only understand physical geography rightly when we have some idea of the origin of the present forms of the earth's surface. On the other hand we use the present as the key whereby we may unlock the past. One of the marked features of the last decade is the expansion of the science of physical geography under the influence of geological ideas, and a correlative development of geology, which now endeavors to read the history of the carving of the land surfaces of the earth, as well as the history of the filling up of its sea bottoms. No farther apology is needed for introducing some account of the physical geography of Huron county into this report. I trust it may aid the teachers of the county to make their instruction more real by the introduction of familiar illustrations.

We have already described the general location of Huron county as lying at the end of a peninsula, bounded on the one side by Saginaw Bay and on the other by Lake Huron (Pl. VIII). The effect of the neighborhood of so much water in mollifying the climate is plainly to be noticed. This advantage it shares with Michigan generally and the subject has been quite fully developed by A. Winchell.* His climatological maps show that in January the temperature is about 24° to 25° F., and in July .68° to 69° F., i. e., some 3° warmer in winter and 3° colder in summer than in the middle of the state, and some 6° warmer in winter and 6° colder in summer than at a corresponding latitude in Minnesota. These figures are sufficient to show the effect of the lakes in producing a semi-insular climate, while the effect in checking extreme temperatures for few hours, e. g. frosts, is yet more marked. For example, the first autumnal frost at (Sand Beach) Harbor-Beach in 1894 (the latest date conveniently accessible) was on October 12, while in Adrian, Lansing and Howell it was September 25, and most of Indiana was visited by frost before October 12. The mean annual temperature would be according to Winchell's maps a trifle under 45°; from 1899 to 1900 it averaged 46.0° at Hayes, 44.4° at Harbor Beach, and the weather service data furnished to U. S. G. S. paper No. 30 make it the same. This is practically the same temperature which obtains at points at a corresponding latitude on the great plains. We see thus that the effect of the lakes is to check oscillations and extreme variations of climate, rather than to change the average temperature for the year.

*1871, Harper's Monthly, XLIII, p. 279, 281; also Walling's Atlas.

The following reports furnished us by C. F. Schneider, director of the State Weather Service, show the temperatures and precipitation for the past ten or twelve years in two stations within the county, and agree probably as well as observations of short period and of thirty years ago could be expected to, with Winchell's results.

PRECIPITATION AT HARBOR BEACH (SAND BEACH), HURON COUNTY, MICHIGAN. OBSERVER: W. NIMS TO FEBRUARY, 1896, SINCE THEN N. P. ARNOLD.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1887.....						3.66	1.66	1.49	1.16	3.22	1.13	1.89	.....
1888.....	0.48	0.50					1.30	3.44	0.76			0.40	.....
1889.....	1.98	1.39	0.30	0.85	3.23	5.59	1.81	1.92	0.89	0.97		3.25	.....
1890.....	1.41	2.34	0.72	1.86	3.30	3.34	4.27	3.40	0.82	7.37	2.54	2.60	34.93
1891.....	2.40	1.80	2.02	1.45	0.52	0.66	2.96	4.85	1.92	2.08	6.03	2.01	28.20
1892.....	6.27	1.85	1.20	1.08	2.61	3.55	1.72	2.86	4.77	3.46	2.95	2.02	34.34
1893.....	1.20	3.90	1.51	4.14	4.25	2.13	2.02	2.17	2.05	5.94	2.57	2.90	24.77
1894.....			1.95	1.82	4.11	4.48	1.10	0.77	3.12	3.37	1.32	0.90	25.40
1895.....				2.10	2.14	0.96	1.92	3.60	3.43	0.77	2.31	2.87	19.20
1896.....		0.38	0.35	1.49	2.73	3.72	0.93	3.99	5.56	0.62	1.50		21.27
1897.....			2.30	35.4	37.4	0.79	3.02	2.56	0.83	3.07	1.50	2.55	23.90
1898.....	1.30	1.40	1.85	2.27	1.82	4.9	0.20	3.89	1.05	3.98	3.08	0.67	25.70
1899.....	1.41	0.95	2.47	0.88	3.22	3.14	2.05	0.19	2.84	3.09	1.63	2.16	24.03
1900.....	0.60	2.37	2.25	1.65	2.11								.....
Mean.....	2.06	1.61	1.47	1.95	2.88	3.02	1.83	2.91	2.20	3.17	2.49	2.01	27.98

TEMPERATURE: SAME STATION AND OBSERVER.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average.
1887.....						64.2	74.2	66.2	59.4	45.1	36.0	28.9	.....
1888.....	16.3	21.4					68.0	67.0	59.1			31.8	.....
1889.....	27.6	16.5	32.3	41.6	51.8	57.2	69.0	66.4	62.0	43.8		34.6	.....
1890.....	27.9	27.3	24.8	39.8	47.5	64.8	66.8	63.7	56.6	40.4	37.6	24.1	44.0
1891.....	26.8	26.5	26.0	41.8	48.8	60.5	62.7	64.7	61.6	45.6	32.4	29.3	43.9
1892.....	15.6	21.8	23.7		48.4	63.5	65.7	64.3	61.2	49.0	35.8	24.8	43.1
1893.....	14.5	17.6	29.3	39.6	49.5	64.0	68.7	67.0	59.6	52.6	35.4	24.7	43.6
1894.....	26.0	21.7	39.1	43.0	50.7	60.6	70.6	67.4	64.0	50.2	33.2	31.8	47.3
1895.....	19.4	15.9	24.0	40.0	56.5	65.2	64.5	65.8	63.6	44.5	36.1	28.7	43.7
1896.....	23.2	23.2	26.2		60.2	61.9	68.6	68.6	58.0	50.1		28.2	46.8
1897.....	23.0	27.2	29.0	40.2	50.4	56.0	67.0	63.2	62.2	51.6	36.6	25.4	44.3
1898.....	24.0	20.8	33.3	39.0	52.0	63.4	69.4	67.4	63.4	50.9	36.2	26.1	45.5
1899.....	21.0	16.4	24.3	42.8	53.2	63.0	65.6	67.9	57.4	52.8	41.7	27.4	44.5
1900.....	25.6	18.5	23.0	43.0	54.0								.....
Mean.....	22.1	21.4	28.4	40.9	51.7	62.5	67.9	66.0	60.9	48.3	35.5	28.2	44.4

PRECIPITATION AT HAYES, HURON COUNTY, MICHIGAN. OBSERVER: C. F. LEIPPRANDT.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average.*	Total.
1889.....	1.40										2.59	3.36	.....	.....
1890.....	1.41	1.00	0.98	1.61			2.17	2.86	0.28	4.98	2.02	1.46	2.04	24.47
1891.....		3.50	1.70		0.84		1.49	9.47	2.91	2.17		0.60	2.32	27.82
1892.....	2.50		0.30		2.45	4.84		2.32		1.18	1.57	1.61	2.08	24.96
1893.....	2.90	2.50	1.40	4.35	3.36	1.25	2.65	1.13	2.11	2.76		2.95	2.44	29.25
1894.....	1.14	1.22	1.70	1.60	3.77	1.27	2.06	0.14	3.11	2.17		0.50	1.67	20.07
1895.....	4.23	0.60	0.80	1.15	3.08	1.18	2.15	1.93	2.60	0.80	1.86	2.36	1.89	32.74
1896.....	0.94	0.78		1.25	2.14	0.78	0.67	2.44	6.05	0.85	2.28	0.46	1.71	20.48
1897.....	3.93	1.09	3.80	3.08	4.09	2.23	3.74	1.53	1.13	2.72	1.83	1.51	2.52	33.24
1898.....	1.84	1.82	2.36	1.44	2.00	3.27	1.01	3.57	1.26	5.20	1.09	0.32	2.09	35.18
1899.....	0.90	0.70	3.54	0	2.66	3.00	3.73	Tr.	2.91	3.19	0.75	1.11	2.304	.....
1900.....	0.68	4.68	3.00	1.11	3.10								3.22	.....
Average	2.21	1.46	1.84	1.81	2.79	2.23	1.99	2.82	2.43	2.54	1.89	1.51	2.16	25.88

*Average per month or total per year in feet and decimals of a foot.
5-Pt. II.

TEMPERATURE: SAME STATION AND OBSERVER.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average.
1889.....											39.2	35.6	.....
1890.....	30.3	30.5	28.3	45.6	54.0	68.4	68.4	63.2	57.6	48.1	39.5	26.7	46.7
1891.....	26.5		29.5	49.4	53.3	64.4	66.0	66.4	63.6	46.8		35.5	46.7
1892.....	19.2		29.2		52.0	66.5		66.7		49.0	35.3	25.9	45.0
1893.....	13.8	17.1	27.9	41.0	52.5	68.4	68.2	65.8	59.0	52.1	37.7	26.2	44.1
1894.....	27.1	21.3	40.0	44.5	54.1	67.4	68.5	63.4	62.2	54.2		32.2	47.7
1895.....	17.8	15.2	24.6	43.2	56.4	70.8	69.4	66.0	67.4	44.4	36.3	27.8	44.9
1896.....	24.6	23.7	27.2	49.2	61.7	65.6	70.8	69.2	57.0	46.7	39.4	27.8	46.9
1897.....	24.2	26.1	30.4	42.0	52.8	64.2	70.8	66.6	64.2	52.8	36.6	27.0	46.6
1898.....	25.0	21.6	36.3	41.7	54.4	63.9	67.5	65.6	63.4	49.6	36.3	26.2	45.8
1899.....	22.0	15.0	22.8	44.0	57.6	66.0	67.8	67.2	58.4	49.8	40.4	27.9	44.9
1900.....	24.3	17.2	22.0	44.4	56.2								.....
Mean.....	23.0	21.3	29.6	44.5	54.9	66.6	68.7	65.9	61.8	49.3	37.5	29.1	46.0

Precipitations and temperatures.

When only two or three months are missing from a year, the yearly average has been found by using the means for the missing months. The general average is the average of the monthly average, and is liable to vary slightly from the average of the yearly averages. Hayes is, I think from its position, a truer representative of the county in general.

The prevailing winds are westerly, though they are modified by the usual system of land and lake breezes, by which in the summer time, on the afternoons of hot days there is a tendency for the heated air over the land to rise and draw in a cool breeze from the lake. A rider on a bicycle quickly notices a head wind and it was quite noticeable that in riding back to Port Austin in from the south after a hot day, one was very liable to encounter a head wind.

In accord with the prevailing west wind the prevailing surface drift of the Great Lakes is eastward, as is indicated on the chart of the Great Lakes issued by the weather bureau. This general character of the lake currents and winds seems to have a marked effect on the character of the shore lines, making those facing west seats of deposit, and accelerating erosive action on those facing east by removing the debris of erosion. This is well illustrated on Lake Michigan, where the shore from Evanston to Manitowoc is eroded away at an average rate of about 5.28 feet a year,* while around New Buffalo, and thence north the sand is piling high. The same antithesis may be observed between the two sides of Huron County, as will be later seen.

*E. Andrews, Trans. Chicago Acad. of Sciences, 1870, Vol. II, quoted by Crosman.

§ 2. Level of Lake Huron.

The level of Lake Huron varies in a very complex way. Eliminating the waves of various causes which are of reasonably short periods, we find fluctuations, dependent either on the direction of the wind which may cause a very noticeable rise of level lasting over a day or two, or on the height of the barometer or on the tidal

attraction of the moon, and also on the general relations of rainfall, freezing and evaporation.

Other causes, change in earth level, downcutting of outlet, etc., may have their part in affecting this level. Before we can consider these latter causes which will take us back into the realm of geology almost before we know it, we should consider what fluctuations we really have, and how far they may be accounted for by climatic considerations. Plate IV shows the effect of the fall of lake level from 1886 to 1896 in the line of undermined but deserted cliffs. This inquiry is of great practical consequence, as affecting the depth of harbor improvements, etc., and also as affecting the use of the lake as a datum plane in leveling.

Plate V below, compiled mainly by Mr. M. L. Fuller, under my direction, shows the variation of the lake level during the past century fairly completely. We are indebted to Mr. Charles Crosman for permission to extract a large part of it, viz., from 1858 to 1887, from his chart. We have brought this down to date by appending the records of the Sand Beach (Harbor Beach) gage in the Annual Reports of the U. S. Engineers, and added the earlier part from data in Foster and Whitney's Report on the Geology of the Lake Superior Land District, 1851, Chapter XIX, on the observed fluctuations of the surface of the lakes by Chas. Whittlesey. This quotes from Douglass Houghton's observations in his early reports of the Michigan Geological Survey in 1839 and 1840, so that we are but continuing researches begun by the first Geological Survey. We have also used some data from the Lake Survey.

A comparison of the recorded fluctuations of the monthly mean water level as shown in appendix SS of the Annual Report, upon the Surveys of the Northern and Northwestern Lakes,† shows that the fluctuations are within a small fraction of a foot the same at Milwaukee and Sand Beach, and at Point aux Barques, and Port Austin. The records are from 1859 to 1882. See also § 5.

†Annual Report of the Chief of Engineers, 18S2.

In the 18th Annual Report of the U. S. Geological Survey, Part II, p. 624, the altitude of the Port Austin gage was studied by G. K. Gilbert of the Survey to determine if there was any relative change of level, i. e., any elevation of the land. He chose a period in July and August, 1876, when the weather and wind were not likely to produce local disturbances of level, to compare it with the gage at Milwaukee. He found that the Port Austin gage zero, which was about 7.4 feet above the water level was on the average 5.21 ± probably .013 feet, above the Milwaukee gage, which was about 2.2 feet above the water level. This Port Austin gage zero was originally placed on a level with the main or Wisner benchmark (590.53 A. T.), but Gilbert says that Mss. records of the Engineers office state that in July, 1875, it was 0.003 foot too low, and on Oct. 18, 1876, it was 0.040 too low, having settled in the meantime. As the readings studied by Gilbert were during the time of

settling he was obliged to apply a correction, which he took to be 0.034 foot, but applied in the wrong sense and found the gage zero to be 7.460 above a check point at Port Austin, to wit, the top of an iron bolt driven into a vertical face of bed rock on the west side of a promontory opposite the residence of J. W. Kimball," i. e. 590.570 A. T. instead of which it should be 7.39 above the check point (590.50 A. T.). Mr. Gilbert had a new series of observations made at Milwaukee and Port Austin in the summer of 1896, with the help of Mr. John P. Smith of the Port Austin News, using a new gage which he established with its zero 5.125 feet below the check point (577.985 A. T.), and about 1.2 feet below the water level of that time. Assuming the lake level to be the same at Milwaukee and Port Austin he found as the result of a series of readings that the gage zero was now 6.875 feet ± 0.019 foot below the Milwaukee gage zero. Correcting and tabulating his results we have:

	1876.	1896.
Mil. check point above Mil. gage zero.....	0.843	1.206
Mil. gage zero above or below Port Austin gage zero.....	—5.210	6.875
Gage zero above or below check point, Port Austin.....	7.390	—5.125
Check point at Milwaukee is above that at Port Austin.....	3.023	2.956
Difference.....	0.008 ft.	.....

which is what Port Austin has risen relative to Milwaukee in the last 20 years, a quantity within the range of possible though not of probable error. The slip of the gage in 1876, which seems to be the most uncertain element, could not make the result more than .006 foot less and if all the change took place after August, 1876, the elevation would be greater.

Prof. Gilbert concludes that the land is rising to the N. W. at a rate that would produce an apparent fall of the lake in Huron county of 0.2 foot per century.

It may be worth while some time to test some of the other bench marks left by the Lake Survey, to wit:

Bench mark near Station D at the mouth of Willow River was 5.65 feet above mean water level in June, 1857.

On overhanging rock near Station No. 30, Point aux Barques, 16.8 feet above water surface in 1857.

Bench near triangulation station M, Partridge river was 5.3 feet above water surface in 1857.

Bench mark 300 feet east of triangulation station L is marked with a cross on the top which is 9.6 feet above mean level of water surface for season of 1857.

In the curves of lake level fluctuations published in the report of the Chief of Engineers, U. S. A., e. g. Appendix SS in 1882, the plane of reference for water levels on Lake Huron is taken by assuming that during the months of June, July and August, 1874, the waters on Lakes Huron and Michigan were level and that the high Water of 1838 was at either Port Austin or Milwaukee at the same distance above that level.

The Point aux Barques curve was adjusted to the others by assuming that during June, July and August, 1860, Lakes Michigan and Huron were at the same level.

In studying the records plotted in Plate V we see plainly that there is an annual fluctuation of about a foot to a foot and a half.* The effect of the melting of the winter snows, and the spring rains is not fully felt in making the maximum of high water in Lake Huron until June or July. From this time, under the influence of the increasing evaporation and the shrunken inflow due to midsummer heat, the lakes dwindle and their levels fall. The approach of autumn with its cooler weather checks evaporation, the autumn rains begin and the fall is checked somewhat, but is resumed, as Mr. Fuller suggested to me. when the ground freezes and rain changes to snow and the lowest water is in the latest winter months.** Beside this annual fluctuation there is also one of greater period, dependent upon the mean rainfall of the previous years, but lagging behind the rainfall curve. Thus the high waters of 1876 and 1886 were both coincident with periods of extra rainfall. Again, in the earlier part of the century, "from the low water of 1810 to the high water of 1814 there fell in Pennsylvania 34.54 inches of rain more than from the years from 1815 to 1819." So too, the rainfall of the 11 years prior to the flood of 1838 is very large, averaging 41 inches per annum or 11 inches per annum greater than that of the preceding low water of 1819. The signs of the fall of water level since 1886 were in 1896 everywhere evident along the coast. Around Bayport the slope of the land is so gentle that some 400 feet had been added to the shore of Wild Fowl Bay for quite an extent. North Island was joined by a neck to an islet northwest of it, and northwest of Point aux Barques Gull Island had developed from a shoal. The water is said to have been somewhat higher in 1896 than in 1895, and Was distinctly higher in 1897. Trespassing a little farther into the past, Mr. Webber informs me that having occasion to have Sec. 17, T. 17 N., R. 10 E., on the shore of Wild Fowl Bay resurveyed in 1895, the surveyor found the meander stakes as called for by the notes of the old Government Survey to be just at the water line. The water was lower than normal in 1895 and in the head of a bay near the mouth of a stream like Mud Creek one would expect to find the shore built out, if anything, so that such observations would indicate no considerable rise of land on lake. We hear indeed of traditions from the Indians around Saginaw Bay, of a time when the Indians could go with their canoes where it is now dry land, but a high water like that of 1838, nearly 6 feet above the recent low water, would give abundant opportunity for such a tradition, when, we consider also the out-building of the coast by the accumulating sand, and the extremely gentle slope of the land. On the other hand while the water was in 1896 abnormally low, and we may expect to see it rise again, the water during the summer of 1883 to 1886 was extra high, so that we need not expect it to return to that level permanently. Moreover the last report of the Chief of Engineers, for 1899 (Appendix DDD, p. 3858) reports that the head of the St. Clair has scoured materially since 1867. The indications are that this deepening started about 1887.

*Crosman says 1.34 ft. See also article by A. J. Henry, National Geographic Magazine (1899), Vol. X, p. 404, and Lieut. Col. H. M. Chittenden, Transactions Am. Soc. of Civil Engineers, Vol. XL (1898), No. 839.

**Low water is later in Lake Superior, March having the lowest average level, and high water is not until August or September.

The fluctuations of the water level are one of the sources of embarrassment in obtaining very exact altitudes in the county or preparing a contour map, which is the subject of the next section. Before leaving the present subject, however, we must allude to the theory of Spencer,* who, while he also believes that in the more remote past the lake has subsided, believes that at present it is rising again. If there had been any considerable rise of the lake, there would be a tendency to flood the river valleys and lower their grade, causing them to build up near their mouths. Any marked effect of this sort in Huron county is inconsistent with the rock beds of Allen Creek, Willow Creek, Pinnebog and Shebeon rivers, close to their mouths. In counties farther south such flooded river valleys are plainly visible. During the past few years many wells that once flowed, have been ceasing to flow, and in general the water level in wells has lowered. This fall may be due to the settling up of the country, clearing the forests and draining the swamps, and allowing the water that falls upon the surface to run off more rapidly, and also in part to the greater demands upon it by the more numerous wells, and may also be due to such local causes as the draining of the coal mines, but it must also be affected by the unusually dry weather of the past few years. The accompanying fall in the lake level is but an index of the general lowering in ground water level, so that it would not be surprising if the water level in the wells rose again somewhat in the next few years. There are also more temporary fluctuations of the ground water level or head peculiar to individual wells which seem to correspond to the more temporary fluctuations of lake levels. (See Chapter VI.)†

*Popular Science Monthly, June 1896.

†This section was written in 1897. There has been no chance to see how much the recent rainier seasons have raised the level of the ground water.

§ 3. Types of shore line.

When we study the shore lines of Huron county we find three different types, which though more or less intermingled, nevertheless predominate respectively on the western, northern, and eastern sides, and depend partly on the slope and nature of the shore, and partly on its relation to the currents and waves.

(a). The first type, the mud flat type, is pronounced along the shore from Sebewaing up to Sand Point (Point Charities). The slope of the land surface is so gentle that the force of the waves is thoroughly broken ere they reach the shore. There is, therefore, little beach ridge or crest, though the spring ice may shove up and strand many boulders. The contours of the land sweep out under the sea with scarce a break at the shore line. The prevailing wind and currents beat back the mud brought

down by the streams against the shore and the reeds and sedges creep out over the muddy flats and catch both it and the driftwood that is brought on higher stages of the water. The winds blow back into "dunes" the sand from the shore and thus little by little the land creeps out in a series of mud flats or swamps and low sand ridges.

(b). The second type, the sand beach type, occurs all along the shore at intervals, but is dominant from Sand Point to Hardwood Point close to Port Austin. From it the town of Sand Beach, now Harbor Beach, took its name, as being, so it was said, the first appearance of this type of shore line from Port Huron north on the west side of the Lake. This type of shore line occurs (Plate IV) where the water deepens more rapidly, allowing the waves freer action so that they wash away the mud from the beach, while the sand is piled up. Where such shores face the west the prevailing west winds catch the sand and throw it back above the reach of the waves, where it forms rolling ridges of shifting sands "dune sands" for these rolling, wind-built sand hills are called "dunes" and are admirably developed from Port Austin to Port Crescent, and thence to Caseville, and in fact at intervals, all along the western shore. The prevalence of this shore type on the northwest coast is due partly to the supply of sand furnished by the underlying rocks, partly to the more open sweep of water, and partly to the prevalence of on-shore winds.

In this type of shore line the land is not gaining so rapidly on the sea, though it is probably gaining somewhat, but it is the favorite type of shore line where the lake is evening off the irregularities of the land, cutting the points and filling in the heads of the bays and coves. Plate IV is taken from the bay between Point aux Barques and Burnt Cabin Pt.



Plate IV. Illustrates the transition from the cliff and shingle to the sand beach type of shore line at Point Aux Barques; also the resemblance of the cliffs to boats drawn up on the beach; also the undercutting action of the waves, producing sea caves now abandoned by the water; the top of the cliff is the level of the Algonquin terrace.

(Reproduced through the courtesy of the F, &P, M, R, R.)

(c). The third type may be called the cliff and shingle type. It alternates with the second type, but grows more and more prominent toward the southeast. In this type there are unmistakable signs that the lake has been wearing the land back, making cliffs which rise up to 40 feet high, and face a bench made largely of their own debris, and in general more stony than the sand beach type proper, though if the rocks are sandstone, the transition to the second type is easy. For example, Plate IV might illustrate this type, except that the beaches in front of the cliffs are quite pure sand. The third type is typically represented near the Point aux Barques lighthouse (Fig. 5), and around Grindstone City. The stony beach deposit in front of outcrops of rock, composed of fragments torn off by waves, is called shingle. Often such a bench is strewn with boulders. These are perhaps in part as suggested by Spencer boulders left by the washing of the finer part of the boulder clay deposit, but are undoubtedly very largely left stranded by the melting of the spring floes of ice. We are informed that at the Oak Grove resort near Sebewaing they picked up all the stone from the beach one year, but the next year a broad winnow was piled in by the storms breaking up the ice. The ice in the bay is even now, often four feet thick, and the stones left by melting are often bigger than a man can carry, even, as reported up to a ton weight. Such observations throw considerable light upon the rapidity with which the beach accumulations may be formed, and upon the depth below the water level at which such boulder benches may be formed. It may be noted that since the lakes are lowest in winter, such large stones frozen into the ice will be subject to a powerful lifting action when the water level is raised by the beginning of the spring rise. The level of the boulder bench in front of Port Austin seems to be four to six feet below present summer water level. Houghton noted concerning White Rock that it was "about 20 feet in horizontal dimensions and 8 feet high with crust on top; it is cracked in all directions, and pieces lie all around it; water 5 feet deep; siliceous limestone and probably a boulder; distance from shore 1,900 feet." In the original Lake Survey sheets this is given as 1,460 feet from shore in 6 feet of water.

On the eastern shore the winds and currents and spring ice help to bear away part of the material which the waves have beaten from the cliff, and thus prevent them from being clogged in their activity as they are on the west and northwest, while the coarser shingle left behind serves as a weapon for new onslaughts.

The contrast thus emphasized between the shore facing west, which is in general growing, and the shore facing east which has been in general retreating, is like that already mentioned in § 2 as also occurring around the lower end of Lake Michigan. While an elevation of land to the northwest and a relative down sinking to the east might accelerate this contrast between the east and west sides by making deeper water and hence more forcible waves on the east side, and vice versa, it seems probable that the lake currents and prevailing winds have been the determining influence.

§ 4. Explanation of contour map.

We find the features of the present shore lines repeated at higher levels, repeated in such a way as to assure us that although the lake has not fallen appreciably during the period of accurate records, yet it has fallen in recent times. Basing our division partly upon the modification of the surface and soil thus produced, but also upon other facts, we may divide the county into four districts, topographically distinct, but before we begin to describe them, we must first explain the contour or topographic map (Pl. VIII), which we shall use in the description.

As we have just said, in 1896, Lake Huron had been retreating. Imagine the process suddenly reversed, and the lake suddenly raised ten feet and the new shore line marked upon the map. Suppose the lake raised ten feet more, and the resulting shore line marked upon the map of the county. Such lines would be called contour lines, and all points of a given contour line are obviously at the same level above the lake. We could find such lines if we could by surveying and leveling find all the points in the county which are exactly 10 feet above the level of the lake and join them by a line. All the country lying between the 10 and 20 foot contour lines would be between 10 and 20 feet above present lake level. The lines drawn upon our contour map are the best approximations to such lines that we can draw. But as the lake level fluctuates so much they are not referred to lake level, but to an assumed level on the Atlantic Ocean, the average level of Lake Huron being between 581 and 582 feet above the sea. The United States Geological Survey has published a dictionary of altitudes of points all over the United States, referred to this level, from which we have taken the altitudes of all points that were in Huron county.* With these as starting points, the profiles of various surveyed lines, furnished by Mr. Webber, gave a great many others. The county drains furnished the relative elevations of many more points, and finally barometric readings were taken as we went over the roads, checked up on points more accurately determined as often as possible, and the weather fluctuation as far as possible eliminated. Thus the altitudes of a great many other points were determined from those already given. At the same time the depths of stream valleys, and general character and slope of the country were noted. Finally the contour lines were drawn so as to harmonize with this accumulation of data. They have been constructed to determine primarily the relative positions of outcrops and of the strata intersected by the wells, and must be judged accordingly, but it is believed that they are not more than ten feet out, one way or the other, except in the hilly part of Verona, Bloomfield, Sheridan and Paris townships. Moreover, it must be understood that on our map we have adapted the river valleys between section lines to the stream as they are found on the county atlas which we have used as a base in all cases except where it is known to be wrong, so that if any stream as laid down on the map, proves to be out of position, the stream valley contours are correspondingly incorrect. With the time and means at our disposal, it was impossible to meander

the streams. The expense required to produce a thoroughly accurate contour map, would be prohibitory with present Survey appropriations.

*Bulletin No. 76, and third edition, No. 160, by H. Gannett.

The present map cannot be depended upon for final location of railroads or drains, though it may be useful in their preliminary location. For example, it suggests that a very practicable line from Badaxe to Harbor Beach may be found by going north or northeast and then following the center line of the north tier of sections in Verona, Sigel and Sand Beach townships. But it is in the first place for geological use. It suggests, as will be hereafter shown, the gathering places for artesian water supply, and removes the mystery as to the origin of the head of water at the Badaxe flowing well. It helps us to make due allowance for the differing altitude of outcrops in estimating strike and dips, etc., and also aids us in tracing the ancient history of the lakes, and their abandoned shores. Without its help, too, the map showing the general conformation of the rock surface beneath (Pl. VII.) the drift mantle could not be constructed.

§ 5. Tables of altitudes.

(a). Lake survey bench marks. The most accurate leveling done in the county is presumably that of the Lake Survey.

The present plane of reference of the U. S. Lake Survey for their gages on Lakes Michigan and Huron is known as high water of 1838. This is 8.33 ft. below a bench mark on Dr. I. A. Lapham's house in Milwaukee, according to Plate III of Appendix SS of the Annual Report of the Chief of Engineers for 1882. This bench mark according to Professional Paper of the Corps of Engineers, U. S. A., No. 24, p. 609, is 592.67 feet above mean tide at New York ($577.94 \pm .36$ feet above coast survey bench mark at Greenbush, N. Y.). The plane of reference of the U. S. Lake Survey which is also that of our Plate V is therefore 584.34 feet above tide (A. T.). According to the same reference the mean surface of Lakes Huron and Michigan from Jan. 1, 1860, to Dec. 31, 1875, was $11.39 \text{ feet} \pm 0.10$ below the Lapham bench mark, i. e., 581.28 above tide. According to Crosman the mean water surface from 1860 to 1888 was 2.82 feet below the plane of reference i. e. 581.52 feet A. T. This is 0.24 foot higher than the mean level for 1860 to 1875, and most of the time from 1875 to 1888 the lake level was unusually high. A check point at Port Austin is the top of an iron bolt driven into a vertical face of bed rock on the west side of a promontory opposite the residence of Dr. J. W. Kimball, which was* 1.23 feet below the plane of reference, i. e., 583.11 A. T., and in July, 1875, and October, 1876, 7.424 feet below the Wisner bench mark, which is 6.19 feet above the plane of reference, i. e., 590.53 feet A. T., or 7.424 feet† above the check point.

*Annual report of the Chief of Engineers for 1876, HH., p. 84.

(b). Altitudes from Gannett's dictionary of altitudes in the U. S. Bulletin No. 76 and 130 of the U. S. Geol. Survey. The last column is the distance as there given above tide, the second column is obtained by subtracting 582, the elevation of Lake Huron according to Gannett, while the first column gives the distance from the starting point of the railroad survey. Some stations are interpolated by profile combined with repeated barometric readings.

(b1) Port Austin Division

PERE MARQUETTE (PORT HURON AND NORTHWESTERN) R. R.

(b1) Port Austin Division.	Miles from Port Huron.	Above Lake Huron.	Above tide.
Tyre.....	59.9	199	781
Ubley (Ubyl).....	62.9	203	785
Highest Point.....	64.7	232	814
Wadsworth.....	66.4	199	781
Badaxe.....	70.2	169	*751
Rapson's Siding, Secs. 31 & 6.....	73	2102	744
Clarks, Secs. 19 & 30.....	75	1146	728
Filion, Secs. 18 & 19.....	76	139	†721
Creedy Siding, Secs. 7 & 16.....	77	1134	716
Kinde (Dwight), Secs. 31 & 6.....	79.6	130	701
Johnson, Secs. 18 & 19.....	82	73	645
Port Austin.....	87	15	597

(b2) Harbor Beach Division

(b2) Harbor Beach Division.‡	Miles from Port Huron.	Above lake.	Above tide.
Harbor Beach station.....	70.4	18	600
Lowest point of track on section 12.....		8	590
Shore Road crossing.....		16	598
Bridge over Allen Creek.....		44	626±6
Crossing east road between Sec. 24 and 25, T. 16 N., R. 15 E.....		76	658±2
Crossing north road between Sec. 20 and 20.....		94	676±3
Crossing east road between Sec. 26 and 35.....		121	708
Crossing north road between Sec. 34 and 35.....		124	706
Crossing east road between Sec. 34 and 3.....			
Helena.....	64.7	134	716±2
Crossing east road between Sec. 4 and 9, T. 15 N., R. 15 E.....		149	731
Crossing north between Sec. 8 and 9.....		105	747
Crossing east between Sec. 8 and 17.....		169	751
Five feet below top of ridge just west, i. e.,.....		174	756
Crossing east road between 20 and 29 <i>Ruth</i>	60.0	172	754
Minden City, near S. O. P., T. 14 N., R. 14 E.....	56.4	235	817

*This is exactly the same union station as the Badaxe of the Saginaw, Tuscola and Huron Railroad for which Gannett gives the altitude 758 feet, agreeing with the levels obtained in the office of the Railway Company. The weather service altitude is also 758. The preliminary and final line agree and for this and for various reasons I consider the Saginaw, Tuscola and Huron levels the more trustworthy, and have made them the base of my work, but I have not changed the other levels of the Port Austin Division other than at Badaxe, because the level given for Port Austin station seems too high now. According to profile obtained from the office of the Flint and Pere Marquette Railroad, Port Austin is 33 feet, Kinde 131 feet and Wadsworth 208 feet above Lake Michigan, i. e., Lake Huron, but according to letter of Chief Engineer W. B. Sears, Oct. 10, 1896, these profiles compiled from old data are certainly wrong, Port Austin being about 14 feet above lake. The fluctuations of the lake level make this reference somewhat uncertain. I should take it to be about right for 18% lake level, but about a foot or two too high if referred to the mean height of the lake from 1860 to 1875, which is the altitude taken by Gannett. The altitude of Badaxe is by the same profile and letter 193 feet. If we subtract 18 feet from the Port Austin elevation of the profile and from the Badaxe elevation also, it will bring the latter nearly the same as the Saginaw, Tuscola and Huron elevation, and the former also nearly correct, and the same as given by Gannett. But an equal subtraction would make Kinde 113 feet above lake or 7 feet lower and Wadsworth 10 feet lower than given by Gannett. Going south into Sanilac county a similar subtraction would leave Palms 238 feet above the lake, still higher than it is given by Gannett (812. A. T. or 213 above lake). Such discrepancies cannot be satisfactorily adjusted. We have used Gannett's figures, except for obvious misprints, e. g., Port Austin = 696, with some regard to repeated barometric measurements.

The last edition of Gannett's dictionary has lowered altitudes on the S. T. & H. and P. O. & N. seven feet. This is apparently to make the reading on Saginaw Bay of the latter line agree with the level of Lake Huron, but it seems to produce many discrepancies elsewhere and our work is based on the second edition.

†740, as given in Bulletin 130, is a misprint for 720.

‡Interpolated by repeated barometric readings, assuming Badaxe = 758.

§The town of Sand Beach has received the name of Harbor Beach quite recently. The maps were printed with the old form, but I have tried to replace the old form by the new in the text. Badaxe is also written thus by the post office authorities, but by others is often written Bad Axe.

Altitudes between Harbor Beach and Minden City have been interpolated by triple barometer readings. Bulletin No. 130 gives the altitude of Harbor Beach Station as 599, and of the cisterns of the weather service barometer as 600.

(b3) Pontiac, Oxford & Northern (Pontiac Oxford & Port Austin) R.R.

	Miles from Port Huron.	Above lake.	Above tide.
Saginaw Bay.....			*588
Caseville.....	100	12	594
Pigeon River.....			588
Pigeon River (Sec. 25, Caseville).....			605
Berne (misprinted Barnes).....			627
Berne Junction, S. & T. H. R. R.....			630
Pigeon River (Sec. 14, Winsor).....			617
Center of Section 23.....	90	†62.5	
Winsor (misprinted Winsor).....	87	66	648
Owendale.....	69	69	651
Creel.....	73		655
Gagetown.....	80		754

Gannett's figures (in No. 76) agree exactly with those obtained by adding 582 feet to the altitudes of the profile, with the one exception of Bayport, for which he gives the altitude of 604 feet. We use therefore, the profile of that line, as obtained from the railroad office, more in detail. In No. 130 he has subtracted 7 feet straight through, which is a mistake.

*The reference to Saginaw Bay is uncertain as we do not know at just what level the Bay may have been at that time. But it is not likely that the water was six feet above the 582 feet datum though if the time was the summer of 82-83 it well may have been a foot above, i. e., 583 A. T., and consequently the altitudes given below should be reduced, but when we come, to the junction with the Saginaw, Tuscola and Huron railroad at Berne Junction, now called Pigeon, we find the altitude given by the Pontiac, Oxford and Northern railroad three feet below that given by the S. T. and H. (633), so that we should not be justified in subtracting from the altitude given by the P. O. and N. right along. I think, however, that the altitude of the Caseville Station is some 3 feet too high. If we should take off three feet from all the P. O. and N. altitudes and then 6 feet from all those of the S. T. & H. to make a match, the difference between the altitudes of the Badaxe station as determined from the S. T. and H. and Port Huron and Northwestern according to Gannett No. 76 would also disappear. The third edition No. 130, subtracts 6 or 7 feet from all the P. O. & N. altitudes which is probably too much. The reading on Saginaw Bay was probably when the water was at about 583 ft. Also at the junction point of Pigeon and Clifford the P. O. & N. altitudes are low when thus corrected.

†Altitude determined by preliminary survey for S. T. and H. given below.

(c) Saginaw, Tuscola and Huron Railroad Recently Leased by Pere Marquette.

(c.1). Preliminary line from Sebewaing to the center of Sec. 20, T. 16 N., R. 10 E., thence by quarter line to Badaxe.

Remarks.	Station of survey.	Alt. above lake.	A. T.
Union Street, Sebewaing.....	1950	8	590
N. line of Sec. 8, T. 15 N., R. 9 E.....	1996.58	9	591
Ridge Road.....	2000	14	596
West side of ditch.....	2022	24	606
Ridge Road.....	2037	29	611
2096	28	610	
Town line (168 feet E. to corner between Secs. 3 and 4, T. 15 N., R. 9 E.).....	2074.35	35	607
Creek (bottom at alt. 25 ft., country 27 ft.).....	2097.50	35	607
Road between Secs. 34 and 35 (270 feet to the quarterpost).....	2137.39	32	614
Road between Secs. 25 and 26, T. 16 N., R. 9 E., then almost dead level.....	2196.81	45	617
Ditch with banks at alt. 43 feet.....	2250.50	40	612
Shebeon Creek (alt. of banks 42 feet.).....	2269.50	40	622
Near center of Sec. 20, T. 16 N., R. 10 W.....	2348	45	627
(Course thence N. 88° E.)			
Line between Sections 20 and 21.....	2370.90	52	634
Creek, valley about 70 feet wide, (bottom of creek at an altitude of 46 feet; flood plain at 50 feet; general country level at 55 feet.).....	2425	54	636
Offset of 239 feet N. 1° 30' W. to quarterpost between Sections 22 and 23.....	2476.62	59	641
Creek.....	2490	60	642
Intersect P. O. and P. A. R. R. (at Sta. 539.39).....	2503.78	62.5	644.5
Country level.....	2529.85	62	644
Section line road (Secs. 23 and 24).....	2537	61	643
Pigeon river and road, top of west bank.....	2537.40	58	637
Flood plain.....	2537.50	50	632
River bottom.....	2537.50	50	632
Top of east bank.....	2537.50	63	645
25 feet S. to quarterpost between Sections 24 and 19, T. 16 N., R. 11 E., 2½ miles S. to Kilkenny.....	2582.18	68	650
2929	70	652	
2631.20	72	654	
Section line between 19 and 20.....	2683.81		
21 feet N. to quarterpost between Sections 20 and 21, T. 16 N., R. 11 E.....			
Angle thence N. 88° E.....			
Creek in flooded woods.....	2696.70	70	652
Offset S. 0° 30' E. 940 feet on Section line.....			
Road, Sections 21 and 22.....	2719	80	662
2736.59			
2767	90	672	
2810.50	100	682	
2817	104	686	
River road, west bank of Pinnebog.....			
Flood plain.....	90	672	
Bottom of river.....	84	666	
East bank, front of terrace.....	100	682	
Section line between 23 and 24.....	2838.33	108	690
Creek.....	2844	106	688
2845	110	692	
2870	120	702	
113 feet north to quarterpost between Sections 24 and 19, T. 16 N., R. 12 E.....	2891.27	125	707
2905	130	722	
2930	140		
2945	147		
Section line between 19 and 20.....	2975	157	739
Road N. E. and S. W.....	2985	169	742
2990	164	746	
After 2992 very flat for quite a way.....			
103 feet N. to quarterpost between Secs. 21 and 22.....	3050.08	162.5	744.5
From here course N. 63° 27' E.....	3076.55		
Section line road, 1349 feet S. to quarterpost between Sections 22 and 23.....	3105.58	165	747
Change course to N. 88° 35' E.....			
3142.50	167	749	
3142.50	182	764	
3143.50	177	759	
3213.70	181	763	
Creasant avenue, Badaxe, section line.....			
Road between Sec. 24 and Sec. 18, T. 16 N., R. 13 E.....			

Comparing this profile with that of the Pontiac, Oxford and Northern or with that of the Saginaw, Tuscola and Huron hereafter given, it agrees very well. It does not agree with the profile of the Goodman Logging Road, if this be located as given on the town map of Oliver in the county atlas. This was a logging spur, however, and is now torn up, and is given otherwise on the map of the county.

(c. 2). The following gives the main topographic data of Goodman Logging Road:

Main track of S. T. and H. taken as beginning of Survey and at 100 feet altitude.

	Station No.	Elevation.
(Compare altitude of Goodman (=Grassmere) as given by Gannett, i. e., 686 A. T., or 104 above lake.)		
	5	97.6
	8	101.1
	40	108.1
	49	104.6
Crosses previous profile (c.1) near its station 2870, i. e., about 120 feet above lake.		
	51	108.6
	76	117.4
	78	113.7
	91	123.4
	100	120.5
Bridge abutment over Pinnebog.....	102.70	112.9
Bottom of river.....		92.4
River valley, flood plain.....	about	93
Inner valley bench.....		113
Outer bench.....		120

It seems likely that the assumed 100 feet is about 590 feet above tide, and more than 100 feet above Lake Huron.

(c 3) Main line of Saginaw, Tuscola and Huron Railroad.

	Station number of railroad survey.	Elevation of railroad track.	Elev. of surround- ing country.	Above tide.
Base about 11 feet above Lake Huron.....	100 ft apart			
Sebewaing.....	1958	15.00	13	593
2320				597
Sand ridge road.....	2345	23.00		605
Bayport Junction.....	2354	25.50	24	607
Bayport Station.....	2372	29.00		602, (604)*
Bayport dock, north end.....	2388	13.00		605
	2413	30.00		612
	2448	40.00		622
Quarry Junction.....	2482	46.00	46.5	628
Rock.....	2486		at 46.6	
	2487		up to 50	
Leave rock.....	2493		at 47.7 ext.	
Level of ground, 54 ft.....	2515.5		up to	
Mud Creek.....	2506	45.00	42	627

* Gannett.

	Station number of railroad survey.	Elevation of railroad track.	Elev. of surround- ing country.	Above tide.
Cut (the rest is fill) from 2,506 to 2,560.....	2538			
Road, east line Sec. 4, T. 16 N., R. 10 E.....	2550	44.00		625
Pigeon River bridge, above bottom of valley, 12 feet deep, i. e., altitude 35 ft., with river 3 feet deeper, i. e., altitude 32 feet.....	2585	47.00		629
2583 to 2588				
P. O. & N. R. R. Pigeon. Compare altitude on P. O. & N. R. R.....	2640	51.50		633
2819	71	74		653
Culvert; wet marsh.....	2856	68	63	650
Elkton.....	2874	68.50	66	651
Pinnebog R., 3¼ ft. above bottom.....	2906	70.00	66.5	652
2940	30			612
2970	90			672
East line Sec. 14, T. 16 N., R. 11 E.....	2981	95.00	94	677
3009			100	682
Goodman.....				686
3030			110	693
(Grassmere) East line Sec. 13, T. 16 N., R. 11 E.....	3033	112.00		694
Nettle Run.....	3068	124.50		697
3080			120	702
East line Sec. 18, T. 16 N., R. 12 E.....	3086	133.50		715
3114			143	725
3133			150	732
Bottom of Silver Creek.....	3163	156.5	151.5	739
East line Sec. 16, T. 16 N., R. 12.....	3193	161.25	160	743
3230			163	745
3244			170	747
About 2 ft. below railroad.....	3283			752
East line Sec. 14, T. 16 N., R. 12 E (highest).....	3297	177.60	180	759
3311.5			179	
3352.5			164.50	746
Lowest point between Sec. 14 and Bad Axe sta.....	3354	164.00	162.5	746
Northwest end of curve.....	3370	167.00	163.5	749
South end of curve.....	3380.5	171.00	171	753
Badaxe yard.....	3390	172.00	170	754
Badaxe depot, junction with P. M. R. R.....	3400	176.00	178	758

(c 4.) A compass line northerly from Sebewaing to the quarry of Sec. 5, T. 16 N., R. 10 E., gives some additional data important as to the lower lake ridges.

	Station of railroad survey.		
Main line near Sebewaing.....	1,966	8+	582=590
Ridge road.....	2,000	14	596
Ditch, bank 20 ft. on one side and 24 ft. on the other.....	2,022	18	600
Mound sloping down to 23 ft. on the other side; bottom Ridge road; west side of ridge 20 ft., east side 24 to 25 ft.; top.....	2,037	29	611
Country level is 27 feet above base at summit.....	2,070.35	35	609
Town line road.....	2,070.35	25	607
Creek.....	2,137.39	32	614
Line between Secs. 34 and 35, T. 16 N., R. 9 E.....	2,197	42	624
Line between Secs. 25 and 26.....	2,197	43	625
Surrounding country of Shebeon river.....	2,270	40	622
Shebeon river.....			
Angle to due north on Sec. 20, T. 16 N., R. 10 E.....			
South line of Sec. 5.....	2,490	44	626
Highest point on compass line.....		49	631
Town line road (north line of Sec. 5).....	2,541	42	624
	2,574	37	619

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(c 5). A survey from Sebewaing to Kilmanagh and thence to Caseville gives probably (the datum is uncertain).

	Station No.	Elevation above lake.	Elevation above tide.
	2000	11	593
	2010	21	603
Line between Secs. 3 and 4, T. 15 N., R. 9 E.....	2030.50	20	602
	2046	17	599
Creek (banks at 23 feet).....		21	603
Line between Sec. 2 and 3.....	2085	30	612
Line between Secs. 2 and 35, T. 16 N., R. 9 E.....	2116	35	617
	2107.25	38	620
Line between Secs. 35 and 36, T. 16 N. R. 9 E.....		40	622
Line between Sec. 36 and Sec. 31, T. 16 N., R. 10 E.....	2196.50	40	622
Line between Secs. 29 and 30.....	2304	50	632
Line between Secs. 29 and 23.....	2305		632
Line between Secs. 21 and 28.....	2360	45	627
Line between Secs. 16 and 21.....	2414	45	627
Line between Secs. 16 and 9.....	2468	44	626
Line between Secs. 9 and 4.....	2522	42	624
Line between Secs. 4 and 3.....	2523	41	623
Thence all the way a beaver swamp to line between Sec. 3 and Sec. 34, T. 17 N., R. 10 E.....		34	616
Line between Secs. 27 and 34, and between Secs. 27 and 23, T. 17 N., R. 10 E.....	2776	33	615
From 2705.50 to 2735 altitude the same.....		34	616
Line between Secs. 15 and 23.....	2735		
Line between Secs. 11 and 14.....	2790	32	614
Watery all the way from.....	2798	25	607
to.....	2848	23	605
Course changes at.....	2912.47	22	604
Creek (banks at 17 and 19 ft.).....	2923.70	23	605
Line between Secs. 2 and 35, T. 18 N., R. 10 E.....	2940	14	596
Road (center line of Sec. 35) running east.....	2927.50	20	602
Caseville.....	2940	18	600
		20	602

The altitudes above agree very well with those of the Saginaw, Tuscola and Huron R. R., where this line crosses the latter on Sec. 4, T. 16 N., R. 10 E., but are a little lower than that of profile ((c.1). Preliminary line from Sebewaing to the center of Sec. 20, T. 16 N., R. 10 E., thence by quarter line to Badaxe.) where this line crosses that on Sec. 21, and seem rather low near Caseville, but nearly right.

(d). Miscellaneous data from Mr. W. L. Webber.

The east part of Sec. 5, T. 16 N., R. 10 E. has been contoured and at the center of the northeast quarter the altitude is 56.4 feet (638.4 feet A. T.) the altitude of Mud Creek on the north line of Sec. 4 is 37.4 feet (= 618.9 feet A. T.), on S. line, 41.8 feet (= 623.3 feet A. T.). Farther altitudes will be found in connection with coal explorations in Secs. 17 and 18, T. 15 N., R. 9 E., and in Sec. 5, T. 16 N., R. 10 E., Secs 35 and 36, T. 17 N., R. 9 E.

(e). Abstract of cross-section leveled with wye level at Port Austin, on August 6, 1886, by A. C. Lane and C. A. Davis, south on center line of sections 30 and 31, Port Austin Township, T. 19 N., R. 13 E.

From water's edge.	Chains.	Alt. above lake.	Above tide.
Water level that day.....	0.00	0.00	578
Top of old beach crest.....		4.03	582?
Level of Spring street, and usual datum for our barometric work, assumed as 592 feet above tide, i. e., 10 feet above lake datum, but very probably nearer 12 feet.....	3	13.91	592
	4	14.75	
	5	13.64	
	6	14.00	
	7	20.97	598
First dune line or ridge (height of instrument when on this bench, 30.80).....	8	25.25	603
Hollow back of first ridge.....	9	23.21	601
Level of dunes to east and west.....	10	35.42	612
	11	27.07	
		31.10	609
Bench back of dunes, water line at level of Lake Algonquin.....	12	25.98	604
Front of back bench.....	13	24.18	602
End of sand.....	14	30.43	598
Washington street.....	15		
Bottom of flat swampy plain.....	19	14.16	
The instrument is about on level of the Broken Rocks bench at a height of.....		36.72	615
	24		
		23.26	
		27.37	
At 39.49 a fence.....	39	42.02	
Bench mark on beech tree at 47.28.....			
No higher land east or west.....	45		
Crest of little beach-ridge, shingle.....	46	57.27	635
Hollow back of same.....	47	56.63	635
Slabs of rock at 54.50 chains.....	50	60.03	
Instrument on a beach line at an altitude of.....		69.15	647
All along here woodchucks throw up slightly fossiliferous flagstones.....	56	68.17	
	57		
	60	73.36	
	68	80.32	
	70	80.83	
Sandstone outcrops on hill west.....		91.97	670
Height of instrument on top of hill is 99.71, i. e., top of hill is about.....		94	

Another line of levels referred to below was run by Locke level near Bayport up to 40 feet, and gave practically the same altitudes for terraces, etc.

(f). Altitudes obtained by barometer.

	Above lake.	Above tide.
T. 19 N., R. 13 E., Port Austin, N. E. cor. Sec. 27.....	60	642
T. 18 N., R. 14 E., Huron, bridge over Willow creek, S. line of Sec. 8.....	33	615
N. W. cor. Sec. 31.....	116	608
N. quarter-post Sec. 33.....	68	681
T. 18 N., R. 13 E., Dwight, N. W. cor. Sec. 36.....	119	701
N. W. cor. Sec. 21.....	71	653
N. W. cor. Sec. 31.....	108	690
T. 18 N., R. 12 E., Hume, E. quarter-post Sec. 12.....	57	639
S. E. cor. Sec. 13.....	75	657
N. E. cor. Sec. 31.....	37	619
S. E. cor. Sec. 34.....	85	667
T. 18 N., R. 11 E., Lake, N. W. cor. Sec. 36.....	46	628
T. 17 N., R. 15 E., Rubicon, S. E. cor. Sec. 33.....	96	678
T. 17 N., R. 14 E., Bloomfield, N. quarter-post of Sec. 9 (Redman) State road on N. line Sec. 29.....	131	713
S. W. cor. Sec. 31, Rapson.....	130	712
T. 17 N., R. 13 E., Lincoln, N. W. cor. Sec. 7.....	160	742
N. W. cor. Sec. 18.....	126	708
N. W. cor. Sec. 18.....	133	715
N. W. cor. Sec. 30.....	143	725
N. W. cor. Sec. 31.....	163	745
S. E. cor. Sec. 31.....	166	748
T. 17 N., R. 12 E., Meade, S. E. cor. Sec. 6.....	68	650
S. W. cor. Sec. 36.....	146	728
T. 16 N., R. 14 E., Sigel, N. W. cor. Sec. 18.....	146	728
Verona Mills, W. quarter-post Sec. 10.....	192	820
T. 16 N., R. 13 E., Verona, E. quarter-post Sec. 10.....	168	750
N. W. cor. Sec. 7.....	166	748
N. W. cor. Sec. 18.....	188	770
Summit of hill on N. E. & Sec. 23.....	273	855
Bridge over Willow creek, Sec. 23.....	182	764
W. quarter-post Sec. 22.....	200	782
W. quarter-post Sec. 21.....	185	767
S. W. cor. Sec. 35.....	234	816
S. W. cor. Sec. 31.....	177	759
T. 16 N., R. 12 E., Colfax, S. E. cor. Sec. 6.....	111	693
T. 16 N., R. 11 E., Oliver, S. W. cor. Sec. 1.....	82	664
S. W. cor. Sec. 35.....	141	723
T. 15 N., R. 16 E., White Rock, S. W. cor. Sec. 7.....	72	654
T. 15 N., R. 15 E., Sherman, crest of ridge east side of S. E. cor. Sec. 35.....	174	756
	98	680
T. 15 N., R. 14 E., Paris, S. W. cor. Sec. 3.....	195	777
S. W. cor. Sec. 18.....	222	874
S. W. cor. Sec. 19.....	216	808
S. W. cor. Sec. 18.....	196	776
T. 15 N., R. 13 E., Bingham, S. W. cor. Sec. 14.....	225	807
S. W. cor. Sec. 31.....	254	836
T. 15 N., R. 11 E., Grant, S. W. cor. Sec. 7.....	80	662
S. W. cor. Sec. 15.....	125	707
T. 15 N., R. 10 E., Sebewaing, Voltz creek bottom, on E. side of Sec. 14.....	48	630
N. side of Sec. 14.....	41	623

The altitudes of the points given below were obtained by barometer in the course of our bicycling trips, but are picked stations which have been occupied at least twice, with harmonious results after allowing for the weather

variation. The altitude is not supposed to be more than five feet out, one way or the other, supposing that the nearest railroad levels are correct.

§ 6. The hill district.

Glancing upon the contour map previously described it will be apparent that Huron county may be divided into two districts, the hill district and the plain district. The latter may be subdivided into still smaller districts, but the former makes a well denned core or back bone to the county. It occupies, as is apparent from the map, a roughly triangular area extending from the north part of Verona township south-southeast to Parisville and west-south-west to Gagetown. In it head all the important streams of the county. It is higher to the east than to the west and while the valleys range from 165 to 213 feet above lake or 745 to 795 feet above tide, the hills rise frequently to some 850 feet above tide (occasionally some thirty feet more), or up to 100 feet above the valleys. It is characteristic that it is not flat like the surrounding plain, whose smooth slope indicated by continuous contours is only broken by stream valleys, but that it has hills of gravelly clay or till, whose contours may have been cut into by running water, but are not principally determined by it. The streams which flow between them often flow in valleys which are ridiculously large for the present size of the streams. This is particularly true of Cass river and Willow Creek. Sometimes* undrained hollows will be found on the top of the hills with pools of water standing in them in the wetter part of the year.

Frequently these hills are terraced on their sides with sand and gravel, and especially as we go toward the margin of the district the clay ridges become lower and lower and are gradually buried under a mantle of gravel and sand which marks the boundary of this region. These till ridges, as may be seen at a glance at the map (Plate VIII), are the chief watersheds in this region. In several places the main ridges border upon swamps which are long and narrow like river valleys. In other cases the ridges may actually enclose quite considerable marshes without any outlet. Such a case is seen on Sec. 18, Sheridan, T. 15 N., R. 12 E., and these sand plain gravels or ridges are also well developed on Sec. 30 and elsewhere in the same township, where gravel also occurs in the form of eskers. Beside the hills of gravelly clay and these gravel deposits, this region contains also considerable swamp land. The streams have not had time to cut proper drainage channels, but it is all easily drained, and such old swamps, with a soil composed of muck underlain by shell marl are most fertile land. The shell marl points to a time when these swamps were lakes, and one such lake is left in this district—Mud Lake—on Sec. 32, Grant, T. 15 N., R. 11 E. Apparently it would not be difficult to drain this off into the Shebeon or into the Pigeon. Probably the shortest way of draining the whole lake would be into the former. This district is particularly ill adapted for the system of rectangular roads which obtains, as it involves a great

deal of unnecessary up and down hill. It is easy to see valleys on the map which would make easy grades between the important points. The kames and askers furnish excellent road material, in their gravels, and are Very porous so that they dry easily.

*e. g. on top of a hill on Sec. 34, Verona, T. 16 N., R. 13 E.

§ 7. The plain district.

Around the rolling nucleus of low hills just described sweeps a great plain, which includes most of the county. While to the eye it often appears perfectly level, except for the stream valleys carved in it, in reality it falls gently but steadily with no prominent exceptions, in all directions away toward the lake, until it is about 20 feet above it on the west side and about 40 on the east side. The stream valleys are usually not over 20 to 30 feet deep, growing deeper toward the margin of the plain, and not over 500 feet wide, and have steep sides showing their youth. It is a typical coastal plain.

The soil is usually a calcareous gravelly clay, diversified with low ridges of sand and gravel, or bouldery streaks which run in a general way parallel to the contour lines. To one standing on a prominent hill near Verona, and looking east the contrast of the two districts is as plain as in the diagram in Frye's Physical Geography, p. 12.

In this plain the streams have not developed marked ox bows and the only thing that can be called lake is a small body of water on the south side of Sec. 11, Chandler, T. 17 N., R. 11 E., which will doubtless soon be drained into the Pinnebog or otherwise. As the streams cut through these surface sands, which usually also line the borders of their valleys as a continuous fringe of delta deposit, down to the underlying clay, springs are likely to appear along the point of contact of overlying sands and clay. Excellent examples of this action may be seen on the road along the west line of White Rock township, T. 15 N., R. 16 E.

Along the upper part of this district some stimulus to the stream drainage is required, and so we find from Brookfield around through Lincoln to Paris, a strip of country which is artificially drained. As we get toward the margin of this district the trenches cut by the streams deepen. The Pinnebog and Pigeon have both cut down about as far as possible and are now vigorously at work lowering their grade by lengthening their course by enlarging their curves, swinging from bank to bank of the flood plain and cutting away at the bluffs which border it. Compare Sec. 26, Chandler Tp. and Sec. 25 Winsor. On the east side of this district, the streams flow, "in their narrow U-shaped trenches, quite regularly down the slope direct toward the lake." There are an extraordinary number of nearly parallel streams. This is also true on the west side for the upper part of the slope, but then the streams are all deflected to the north. This deflection is probably in part due to the tendency already noticed for the sand to work back against the shore and along to the northeast on this side of the county (§ 3) so that there was a tendency to deflect the streams with the

sand that they themselves bear down and turn their mouths northward. When, for example, the mouth of the Pinnebog was near Elkton the sand brought down by it and by its neighbor the Pigeon and by other streams immediately south, was deposited abundantly where we now find it on Secs. 16 and 17, Oliver, and may have assisted in turning its course northward. There are, however, faint irregularities of the old plain, undulations in the ground moraine, as it is called, which have also assisted in this action.

Some of the exceptions to the general slope of the plain deserve notice. There are a number due to the outcrop of the Marshall, sandstone. Section 31, Port Austin, and Secs. 3 and 13, Dwight, Secs. 6 and 15 Meade, and perhaps also the southeast part of Lake show low rises due to this cause. Certainly in the southeast part of Huron and Bloomfield townships the eastern border of the Willow valley is marked by the buried sandstone escarpment. The limestones of the Bayport quarries are also marked by a ridge. In the northwest part of Rubicon township a number of streams seem to have been grouped together behind the heavy gravel ridges between 128 and 108 feet above the lake. Finally through the central part of Chandler and the northwest part of Oliver is a low ridge of the ground moraine.

§ 8. The eastern shore.

Sometimes, as just north of White Rock, we find the plain descending until it drops off to the lake in a single bluff, but more often we find a narrow zone with a stairlike structure, a sea cliff and a bench, then another cliff and another bench. The top of the first cliff is from 30 odd to nearly 100 feet above the lake (Sec. 3, Huron township)—but its bottom is pretty uniformly about 25 feet above. The bench slopes from this level pretty gradually, though with lesser breaks down to about 17 feet above the lake. Often there is a sheer cliff from this level down, but at times there is another bench 10 feet above lake (592 feet A. T.). The risers of this flight of stairs are often too steep for cultivation, and often stony. The benches also are often stony, especially toward Point aux Barques, but were originally marshy. "The upper terrace follows the shore line closely nearly all the way. About three-fourths of a mile north of White Rock the lake has cut away the intervening space and is now undermining and cutting back the bluff, which is here about 40 feet high, composed entirely of clay. The section shows about 35 feet of typical till,—blue clay, filled with pebbles and cobble stones; above this three to five feet of yellowish clay stratified, includes some sands; above this about one foot of soil." This upper terrace is cut by numerous short streams "which set back but a little into the uplands, and cut steep narrow channels in the edge of the plateau. The principal shore road runs generally just above or at the foot of the upper bench."*

*Quotations are from notes of C. H. Gordon.

§ 9. The western shore.

This district is much more important than the eastern, but has about the same limits of altitude. Beginning at the north extremity of the county around Point aux Barques, there is a practically continuous ridge of knobs of shifting dune sand, which continues, swinging from point to point, like draped festoons, clear to the southwest edge of the county. Exceptionally high knobs rise more than 40 feet above lake (620 feet A. T.), but in general the top of the ridge is a little above 30 feet above lake level. The ridge road crossed by the railroad lines, § 5. Tables of altitudes., ((b1) *Port Austin Division*) and ((b3) *Pontiac, Oxford & Northern (Pontiac Oxford & Port Austin) R.R.*), at 29 feet is on the lower part of this ridge. On the landward side this ridge is backed by extensive swamps, now rapidly being artificially drained, at an altitude of 20 to 24 feet above lake (606 feet A. T.). On the lake side we find a series of sand and gravel beach ridges, interspersed with swamps. Their altitudes are quite various, depending somewhat upon how far the ridges pass into dune sand aggregates. There are in places at least four or five distinct strand lines. Occasionally, as around Sebewaing, on very gentle slopes the sand ridges are spread so far apart that the normal soil of gravelly clay appears between them, but in general the soil of this district is too sandy to be good, except in the swamps, and the roads are very heavy in dry weather, and best mended by clayey material such as the burnt waste from the coal mines. A characteristic feature of this district is the number of ponds. These are of the lagoon type, i. e., originally portions of the lake shut off by barrier beaches. Such was Bear Lake, near Port Austin (now drained, by cutting through the barrier beach) on the south line of Sec. 25. Back of Hat Point was one, and a filled up cranberry bog indicates another. Rush Lake is the largest of this type. Around Oak Point are about three more. Around Sand Point some seven more, while beds of calcareous marl under some of the swamps point to the former existence of others. Probably before this report is printed some of those enumerated will also be converted into marshes by nature, or into fertile meadows by man. On Charity Island was one of these ponds which had temporarily disappeared, when I visited it, leaving a bare expanse of cracked and treacherous mud. Were Lake Huron to remain at its present low level a few seasons more a growth of vegetation would cover the pond permanently. In all we may reckon some sixteen of these "lagoon" ponds at least, in altitudes ranging from 22 feet above the lake (604 feet A. T.) down—quite a contrast to the practically pondless condition of the other districts described.

The origin of these ponds were very beautifully shown in revisiting Oak Point in 1897, and the effect of the oscillations of lake level on a growing shore. The fall of water level culminating in 1895 had added a broad smooth slope some 400 feet wide to the shore of the southwest side of Oak Point. The recent rise had not gained on this smoothly, but had rolled up a ridge ahead of it, two feet high or so, behind which shallow ponds

were formed, and the indications were that the lake would never regain what it had lost, but that a new ridge at about equal height would be added to the shore and would be separated from the old shore ridge by a swamp and by shallow ponds quickly converted to swamp. The whole space back of Oak Point to the road is filled with alternations of ridge and swamp to be explained this way, though mainly referrible to the higher 20-25 foot level. These ponds are a great resort for wild fowl. The soundings of the Lake Survey show that if Lake Huron were to drop 12 to 18 feet, several more similar ponds would be formed.

In this district the principal streams, the Pinnebog, the Pigeon and Sebewaing wind round in oxbows characteristic of streams which have had much time for lateral erosion and the stronger streams of the eastern side had time while the lake stood at the 25 foot level to cut their main valley down to this level and are also winding in oxbows, for instance the Allen on Sec. 24; Sand Beach Tp.

South of Sebewaing and for a short distance on the road from Port Austin to Port Crescent, the dune line is interrupted and the shore type is rather that of a cut terrace like that on the eastern shore.

CHAPTER IV. FORMATION OF THE SOILS AND SUBSOILS (PLEISTOCENE).

§ 1. The preglacial surface.

The materials of which the earth's crust is composed are in Huron county so sharply divided into consolidated and unconsolidated shale, sandstone or limestone rock, on the one side, and soils and subsoils, i. e., gravels, sands, hardpan and the like on the other, and the physical geography just described is so dependent upon the latter that it seems wise to invert the historical order and describe the latter first. During the interval between the formation of the latest rocks represented, and the earliest of the unconsolidated deposits of the Pleistocene, a long time elapsed. Geological periods passed away, and the surface of the rocks, after having been buried beneath we know not what other sediments, was for a long time a land surface. By subtracting the depths to rock in different wells from their altitudes as obtained on Plate VIII, we are able to get a number of altitudes of the rock surface, and thus draw a contour map of that surface, which is naturally much more hypothetical than the map of the present surface. This is illustrated by Plate VII. Though the present hill district is supported upon an elevated sandstone platform of underlying rock, we notice some other features of the rock surface which are not at all indicated by the present topography. One such completely disguised feature is the old river valley which runs through the township of Winsor and the southwest part of Sebewaing. While the exact location of the river valley is somewhat uncertain,

its general course is not and is quite in accord with numerous other river valleys of similar nature known elsewhere in Michigan, and indicated by sudden irregularities in the drift.*

*In Hillsdale county, H. P. Parmelee, has noted such a river valley and described it in a paper read before the American Association and from the records sent us by well-drillers another passes close to Jonesville in the same county. Farther indications of such valleys are found near Alma, Midland, Saginaw, Unionville and elsewhere.

§ 2. The ice age. (Glacial epoch.)

We can see from these valleys that at one time the base level of erosion, i. e., the water level down toward which the streams were cutting, was much lower than the present lake surface. Such buried river channels taken together with others outside the county, raise in the mind the strong presumption that the land at one time stood higher than at present. This higher elevation may have had some influence, as well as a number of other causes which have been suggested, in bringing on the accumulation of ice that followed. Even in the tropics high mountains are now covered with perpetual snow, and as we pass north to the temperate regions this perpetual snow line lowers. If now a large portion of a country is raised up to this level of perpetual snow and the precipitation is greater than that gradual wasting which takes place even in the coolest, dry winter days, we have the conditions necessary for producing a vast ice sheet, for, once such a state of things is established, the white surface of the snow tends to reflect the arrows of the sun's heat like a polished buckler, and thus perpetuate its own existence. In other words, perpetual snow once established will tend to accumulate, and slowly compacting into ice will creep like a vast flood of stiff treacle far beyond the original area, just as it now does in Alaska, Switzerland and Greenland, until it meets a climate mild enough to melt it away as fast as it advances. Now, we find that over the surface of Huron county there advanced such a sheet of ice from the north, filling up and evening off the valleys with a mass of miscellaneous material derived from farther north, and dragged along or carried with the ice. The rocks and sand in the base of this moving sheet of ice scratched, or polished and grooved the underlying rocks (Pl. IX). Evidence concerning the motion of the ice is derived from two sources: (1) the direction of the striæ,—N. 10° W. at the Bayport quarries (observations around Port Austin are not so trustworthy as they may be due to shore ice). (2) Character of transported material. The boulders on the surface, e. g., the chistolite schist on North Island, and the material of beach sands and gravel are not to be implicitly trusted, since they may have been transported by floe ice (§ 3. Types of shore line.), when the lake was at a higher stage. For example, in the collection of Mr. Webber, there is a small piece of native copper, which is said to have been obtained from the stripping of the Bayport limestone quarry, and most likely was thus transported. But the boulders of the till and the high level gravels, the over-wash of the moraines and

kames, and the very first lake beaches formed at the immediate margin of the ice are more valuable.

Important observations are:

Sec. 23, Verona. Altitude 857, A. T. hornblendic rocks, quartzites, granites pink and white, also white chert apparently from the Corniferous or Upper Helderberg, black calcareous shales, with trilobites apparently *Phacops bufo* of the Traverse, reddish-green sandstone, like the grindstone, etc.

Sec. 35, Caseville, *Atrypa reticularis* in blue shale;

Sec. 4, Winsor, and Sec. 26, Caseville, gypsum in drift. According to Davis on northernmost ridge are granite, volcanic and trap rocks, pyritiferous quartz, also found near Badaxe and now in Post and Seeley's bank; jasper conglomerate quite frequent.

This sheet of ice extended, as we know from the reports of adjacent States, down to the Ohio River, carrying with it fragments from the Laurentian highlands of Canada, whence it is called the Laurentide glacier.* Fragments of Canadian rock are frequent in Huron county, and the Corniferous cherts and Hamilton rocks which outcrop north of the county, beneath Lake Huron as well as in Canada. Such a glacial ice sheet would naturally be very much affected by the weather, the front being wasted away, or retiring during a series of dry seasons, or hot seasons, just as present glaciers are found to be advancing and receding. In this respect it would be like the lakes whose fluctuations extending over a series of years we have already described. Such fluctuations have been, noted extending over many miles by geologists who have followed along the margin of the glacier. One evidence of such recession and re-advance is found in forest beds, i. e. indications of soil and wood, between two beds of gravelly clay or till, laid down beneath an ice sheet. Huron county is, however, far back from the ice front and we have no clear indications that such a retreat of the ice occurred until after the last period of farthest advance, which has been called the Wisconsin advance or stage.†

*Maps of the extent of this glacier are very numerous. One of the more recent is by Leverett and Taylor in the Inland Educator, August, 1896, p. 29, American Geologist, Vol. XXIV, Plate II.

†Leverett Inland Educator, loc. cit.

In a few well records as in Secs. 11, 17, 18, 30, Sebawaing, beds of sand or gravel are reported under hardpan, i. e., till or gravelly clay, but in many cases these are just above the rock and may have antedated the first advance of the ice sheet. In Sec 3, Brookfield, chips were brought up at 130 feet and in boring some other wells chips have been found. This is again near the bottom, and may have antedated the glacial period, as it is in a well in an old valley, where the soil and trees before the ice would be especially likely to be overridden. A piece of wood was taken from the pump of the Badaxe waterworks, but all the experts to whom I have shown it unanimously agreed that it must have found its way there accidentally.

§ 3. The ice retreat. (Early Champlain or terrace epoch.)

The ice period is then, as regards Huron county so far as we know practically a unit, and we cannot here learn how long the ice rested upon the county nor what was happening in the meantime. History is a record of current events, and there can be no history when nothing happened, while the county slept beneath the white sheet of ice. History begins again when the ice retired from the county. But to make the story clear we must begin before the retiring ice front had reached Huron county. For our knowledge of the course of events at this time we are much indebted to Mr. F. B. Taylor,* from whom we thankfully borrow a plate of the thumb region to illustrate the course of events of this epoch,—the Champlain or Terrace epoch,—Plate VI.

*A very clear and popular resume is "A short History of the Great Lakes," No. X of the Studies in Indiana Geography, issued by the Inland Publishing Company, Terre Haute, Indiana, May, 1897, well illustrated, and especially to be recommended to teachers. See also article in American Geologist, Vol. XXIV, July, 1899. This report we in general follow. A technical paper, with references to the earlier literature, is in Vol. 8, of the Bull. of the Geol. Soc. of America, Jan. 1896, pp. 31-58. This paper contains the plate of the thumb region, which we reproduce in Plate VI. Numerous earlier papers of Taylor, Leverett, Upham, Tarr, Gilbert, Spencer and others will be found scattered through the American Geologist, Bulletin of the Geological Society, and Am. Jour. of Science. Particular attention may be called to Spencer's popular paper in Appleton's Popular Science Monthly, June, 1896, "How the Great Lakes were Built." It will be noticed that his views do not agree with Taylor's, but the views of the latter were based particularly upon studies in Huron county and neighborhood, and I consider them decidedly more nearly correct in reference to this region. For a fuller description of the earlier stages of the ice retreat see also Sherzer's report on Monroe county, Part I of this volume.

As the sheet advanced, it followed the low grounds like a river and as it melted back it lingered in the valleys longest. One lobe of the ice went down Saginaw Bay and another down Lake Huron, and they met in a thinner sheet over the sandstone ridge which projects into Huron county. Lakes formed in front of the melting ice and drained off to the Mississippi. In front of the Saginaw lobe a lake formed, called by Taylor, Lake Saginaw, which passed over the watershed between Ashley and Bannister, and flowed down the Grand River to a larger lake, which lay in front of another lobe, covered somewhat more than the southern part of Lake Michigan, and near Chicago drained off to the Mississippi.*

Some old shore lines of this old lake are indicated on Plate VI. Gradually the ice retreated, and Lake Saginaw grew toward the northeast, and the streams began to work their way down to it from east, south and west.

But before this, another lake had formed in front of the Erie Huron lobe of the ice front, called by Taylor, Lake Maumee, which drained off past the town of Fort Wayne, down the Wabash. As the ice front retreated it was only a question of time when these two lakes would mingle, and it is easy to foresee that their meeting point would be in Huron county or just south of it. But the level of these two lakes was not the same. As we find their

water marks at the southwest and southeast ends of the hill district respectively (Plate VIII), Lake Saginaw was some 75 feet below the highest watermark on the other side.†

As Lake Whittlesey and Lake Saginaw were independent the beaches of the one cannot be closely parallel with those of the other,—at least it is not to be presumed without proof that the permanent water stages of the one were correspondent to those of the other. In a general way, however, the two lakes were coeval. Taylor gives for altitude of the Forest Beach at Gagetown 765 feet, but I think that the gravels he probably had in mind were deposited before free water communication was established around the point. The beaches around the outlet of Lake Saginaw Taylor gives as 750 or 746 above tide or 100 feet above the channel floor at Pewamo. The highest point of the channel floor of the outlet must be, by levels of the Ann Arbor line which is about 65 feet above Lake Michigan between Ashley and Bannister (according to Spencer quoted by Taylor, not over 100 feet above Lake Huron), about 647 feet above tide. Adding about 100 feet for the depth of water in the channel, will bring the altitude to that of Lake Saginaw as above given. The Lower Forest Beach is given by Taylor as only about 700 ft. above tide around Chapin and the outlet, in which case the correlation with the terraces in the Pewamo channel would not hold. But as we shall later see, there are a number of marked water levels, below the Forest Beach, especially the Grassmere Beaches, and it is possible that Taylor has lost track and jumped over to the Grassmere Beaches in going between Gagetown and Chapin, as he could not follow the beach continuously. The high beaches of the Pewamo channel may correspond with some stage of Lake Saginaw during which the ice had not melted back as far as to Huron county. This subject will be considered later.

*Leverett, Bull. No. II, Geol. and Nat. Hist. Survey, Chicago Academy of Sciences.

†Note the change of topography at the 820 foot, respectively 740 feet contour lines, more particular observations are: Cass City, Tuscola County, on broad terrace (probably stream delta), 742 to 748 feet A. T.; west line, Sec. 29, T. 15 N., R. 11 E., Grant, highest gravel deposits, 744 feet A. T., same section, centerline, top of gravel bench, 740 feet A. T.; same section, 500 paces E., 1,500 paces N., 747 feet A. T., also gravel bench on south line of Sec. 21, 750 A. T.; on west line of Sec. 31, 727 feet A. T. On the other side of the hill district the beach line is by no means so well marked, but compare in Paris Township: Sec. 18, north line, front of gravel bench, 809 feet A. T.; Sec. 20, north line, top of gravel bench, 819 feet A. T.; Sec. 31, sandspur from east. 827 feet, A. T.; Sec. 34, north line, river channel, swamp, 811 feet A. T.; Sec. 34, in Bingham township (see below), sand spit, 809 feet, A. T. Average for Lake Saginaw about the time it reached Huron County, 744 feet A. T. According to Taylor, by the evidence of the Duplain beach it was at one time 20 feet or more higher. Probable altitude for Lake Whittlesey (large successor of Lake Maumee). 809 ft.

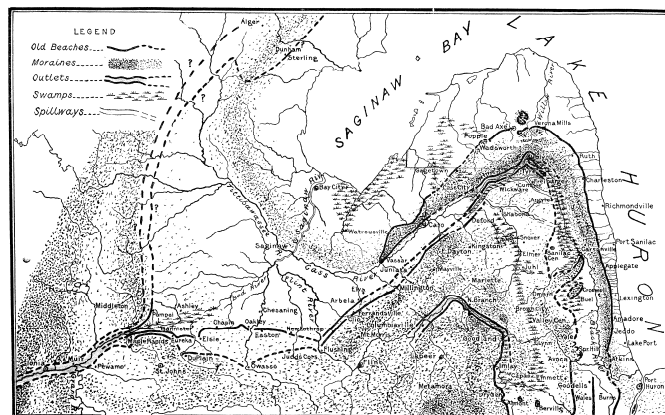


Plate VI. Erie-Huron beaches in southeastern Michigan and their related outlets and moraines, Bull. Geol. Soc. Am., Vo. 8, Pl. 2.

On the east side of the Hill district, Taylor saw no signs of lake level above 775 feet above tide, but he will remember that the character of the topography changes at some distance above the Forest beaches, later to be described. It is probable that the ice retreated rapidly from the heavy moraine which has its apex in the northeast corner of Bingham, that the water extended on the east side only for a short time as a long narrow sound in front of and between the ice and its recently deserted moraine, so that there was no pronounced beach line, and the gravels would be hard to distinguish from overwash gravels. I frankly confess myself unable always to discriminate between the two. On Sec. 34, Bingham, i. e., on the old channel connecting the two lakes, there is a hill (267 feet above lake) 849 feet above tide on which is a well marked spit 809 feet above tide. This is quite certain. According to Taylor the earlier stage of Lake Maumee was about 795 feet above tide, while the later Lake Whittlesey, at the time when it reached nearly to Huron county was 800 feet plus on the Tyre Ugly outlet, while other beaches were found at 817 feet near Berville, 825 feet near Almont, 849 feet near Imlay (p. 18). Taylor leaves the question of the exact correlation of these beaches open, and owing to the fact that the beach lines of these old lakes cannot be supposed exactly even, and that the Port Huron and Northwestern E. B. levels are, as above mentioned (§ 5. Marshall series. (d)), not as accurate as could be wished, it will probably be some time before the exact correlation of these beaches can be established with any certainty. Taking the observations on Sec. 34, Bingham, in connection with that on Sec. 31, Paris, and those further south quoted by Taylor, there seems but little doubt that while the water level on the eastern side was still considerably above 800 feet, the ice front had melted back to the southern verge of Huron county. Then we may suppose Taylor's Arkona Beach to be a faint subsequent stage, probably marking a time when the channels across the point south of Verona Mills had lowered the waters of the lake on the east, Lake Whittlesey, so much that their own capacity for discharge was cut down and a state of equilibrium was temporarily established. The level of the lower lake,

Lake Saginaw during all this time, like that of most lakes with large inflowing and outflowing stream, would fluctuate according to the climate from month to month and, from year to year, without much changing its general level. Hence there would be a tendency for the waters to find their way across the "Thumb" from the waters on the east to those on the west. That was exactly what happened. The waters found their way along the valley now occupied by Black River in Sanilac county (see Plate VI) and across the divide by various shifting channels in Sanilac county, described by Taylor, and more fully noticed in Gordon's report on Sanilac county,* which we need not therefore mention further. They are shown in part on Plate VI. The first channel that particularly interests us is one of the strongest and most permanent of all and just enters Huron county. The rush of waters came up past Palms and Tyre, scouring away the surface "till" down to the sandstone floor, up through sections 34 and 35, Bingham, cutting a bench on the sharp hill on section 34 on the west side of the channel, and drawing it out in a long spit with an altitude of about 809 feet. The water level of the lakes at those times undoubtedly varied from year to year, and from month to month as it does now, probably in even more marked degree, as the cold of winter would have even more effect in checking the flow of water from the ice sheet. But we may safely take the average stage of water in the river between the two lakes at this point as somewhere about 810 feet. But since the stream had had to flow 30 miles or more up north, following the Black River valley, the level of the lake corresponding to this outlet, may have been a couple of feet higher, if the grade was the same as that of the present Saint Clair River. The waters thus running north probably met on Sec. 22 a large stream issuing from the melting ice sheet at the angle between the Saginaw and the Huron lobes, and were deflected south so as to follow along the margin of the Saginaw lobe down the present valley of the Cass River. Any one standing on any one of the hills overlooking this valley, will recognize at once that it is a great stream valley, vastly too large for the little Cass. In the mean time the ice front remained nearly stationary long enough to pile up on the Huron side the ridge of gravelly clay and boulders, called a terminal moraine, which runs up in Bingham township from the south part of Sec. 36, into Sec. 22; on the side of the Saginaw lobe it piled up a similar ridge from the south part of Sec. 31 into Sec. 21. These moraines do not meet, and the presumption is that the gap was in the first place occupied by the stream from the ice sheet, though at a later stage in the ice retreat a channel was found in this direction also for the waters of the eastern lake. The height of the moraine (about 844 ft. above tide) and the pronounced character of the Tyre channel, shows that this line was held for some time, but at length the ice of the Huron lobe retreated some four miles and took up a new position, extending from Sec. 33, Paris, into Sec. 2, Bingham. It does not seem as though the Saginaw lobe retreated at the same time nearly so much, as on that side the morainal ridges are piled close behind one another (Plate VIII). On the east side there are also

numerous isolated rounded hills between the two main lines, which may be remnants of moraines overridden in a temporary advance.

*Part III of this volume.
9-PT. II.

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

The swamp lying in the old channel is now drained by a county drain. The swamp level is now about (213) 795 feet above tide, or somewhat higher than the Tyre channel (782 feet A. T.), and the water level was at least 801 feet A. T. and probably more.* It may have caused slight drop from the level when the south or Tyre channel alone was working, but it is within the range of error of our barometric observations. The water still had to find its way up by way of the Black River, and a heavy moraine ridge was built along this line,† rising to about 864 feet above sea level. But finally the ice front was withdrawn from this line. The ridge of till or gravelly clay strewn with boulders was‡ more or less covered, "aproned," with gravels washed on to it from the ice, and the water either gathered in pools, like the Merjelen See of Switzerland, between the ice sheet and the moraine ridge, or worked in from Lake Whittlesey on the south. At this time the ridges marking the stages of retreat of the ice seem to have been out of water to the northwest and to have passed under water to the southeast, for these ridges seem much sharper when laid down in the air than when laid down under water, and we have for example a hill on the south line of Sec. 6, Paris, which is continued to the southeast only in a very gentle undulation. When the ice sheet, with its front thus in the water, and its flank just out of water, forming land-made ridges near the corner of Verona, Sigel, Paris and Bingham townships, retired a little farther, there was left open a channel through Sec. 6, Paris, and Sec. 1, Bingham, around to Sec. 35, Verona. This is not, however, much lower than previous outlets (780 feet A. T.), and as we find it in distinct sand and gravel deposits on Sec. 35, Verona, about 800 feet above tide (219, 216, 217 feet above lake, according to different readings), the opening of the channel could have made no, material change in the lake level. It could hardly have led the water off down the Cass valley, for the lowest point on the channel on the south side of Sec. 2, Bingham, appears to be at least 805 feet above tide and I think that any discharge directly west was blocked by the Saginaw moraine and the ice. The channel on Sec. 35, above mentioned, might even have been an outlet westward of the great glacial river from the north,

already mentioned, into the eastern lake, Lake Whittlesey, though we have not supposed so. Can it be shown that the current was that way?

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

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

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

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

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

It is probable, therefore, that so long as the whole current had finally to pass down the valley of the Cass through Sec. 32, Bingham, the level of the eastern lake, Lake Whittlesey, remained practically constant, no matter how many different channels there were by which it started to leave the lake. This level so many observations point to as being between 800 and 810 feet above tide that we may be reasonably confident of those figures, the latter figure being probably the maximum. But when the lobe of the Saginaw moraine melted back so as to let the waters around behind the very heavy series of ridges which run north northeast from the southwest corner of Bingham the lake discharge found its way across the northwest corner of Bingham, half burying the clay ridge on the north side of Sec. 4, Bingham, in sand on the east side, and making heavy gravel deposits along the north side of Sec. 3, Bingham, then as the ice retired sweeping sand and gravel over

numerous places in Colfax, Bingham and Sheridan, and passing southward out of the county in some well marked channels,** the new and independent outlets probably lowered the waters rapidly.† The first gravels on the back of the moraine are not very much lower than those previously mentioned, but as we go northwest in Sheridan the gravels appear at lower levels, down to 770 feet, in a long ridge on Secs. 9, 10, 11, and 12.

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

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

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

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

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

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

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

number of possible causes to account for it,* but the gravitative attraction of the ice sheet, which would have its greatest effect on a body of water lying between two lobes of the ice front, seems quite sufficient to account for the rise so far as seen in this Forest Beach in this county. When we trace this beach level off from Verona Mills to the southwest we find it again falling slightly. We can trace it quite well, as shown on the map, through Sec. 12, Verona, and across the northwest corner of Sec. 14, faintly up the valley of the Willow, very well marked in a little bay on Sec. 21 and clearly marked on a slope well sprinkled with boulders across Sec. 20, to the southeast corner of Sec. 19, near Badaxe. Here there seems to have been an opening into a large lagoon or sound in which marl was deposited, shallow and not over fifteen or sixteen feet deep for the most part. The altitude of its bottom is 754 feet above tide. A low island with marked dune sand ridges rose above the lagoon in the northeast corner of section 34, Colfax, and from Badaxe to Popple, followed by the old State Road, runs a moraine ridge, which rises somewhat above the Forest Beach level in the northern part and is flanked by well marked terrace gravels at the level of the Upper Forest Beach (765 feet A. T.), and often buried by them. The level of Webber's gravel pit near the southwest corner of Sec. 13, Colfax, gives a good opportunity to obtain the level of the beach here quite exactly with reference to the Saginaw, Tuscola and Huron R. R.** Down near Popple we find a number of hills, which appear to have protruded above water, and the bench marks of the first beach are scored upon their flanks.† Thence the Upper Forest Beach can be traced through Secs. 11, 14 and 13, Grant, down to another sound, a remnant of which is Mud Lake. It reappears again on Secs. 28, 29 and 81, where the moraine once more was above lake level, and where it is at an altitude, as previously stated, of about 744 feet above tide.

North of Badaxe, running from the southwest corner of Sec. 1, Verona, through Secs. 8, 9 and 10 to 11 is a low clay ridge, heavily aproned with gravel on the south side, which rises a little above the Forest Beach level, and seems to mark the line of the ice front at one stage in the time of the Forest Beach. This seems to be practically the same moraine which passes north and west of Popple and northwest of Mud Lake. At the beginning of the time of the Upper Forest Beach this moraine was probably largely under water and kame gravels were extensively formed in a broad shallow sound which faced it and was later resolved into a series of lakes (indicated by shell marls under the present swamp) of which Mud Lake is the only surviving representative. By the end of this time the connection between the two sides of the "Thumb" was so open, that the water level was practically identical in both, as is shown by the fact that the gravels at the foot of the ridge north of Mud Lake are at practically the same height on each side. Hence the retirement from this ridge, the last place in the county where the ice front kept above the water, made no material difference in the lake level. I was at one time inclined to think that the retirement from this point might

have caused the slight drop to the Lower Forest Beach level, but the double beach line appears well marked on the northwest flank of the Mud Lake ridge.

*The following are some of the causes:

- (1) The ice sheet may have attracted the water toward it, just as a plumb line is deflected by a mountain near by. This would give a slope relative to the present level increasing to a maximum at the margin of the ice front, and not over 1.8 ft. per mile for a sheet 10,000 feet thick (the Greenland ice sheet is about 9,000 feet thick) while the average slope for 69 miles from the border might easily be 0.4 feet per mile. See Woodward in sixth Report U. S. Geol. Sur., 1884-1885, p. 295-296, also U. S. G. S., Bull. 48, p. 66. It is found generally true that the slope of the old shore lines rises toward the ice. It is to be observed that in the case just before us of water lying between two lobes of the ice, we have a case of maximum effect something like that discussed by Woodward of a canal in the ice sheet near the margin, where the equipotential surface within the ice sheet is to be considered.
- (2) The shifting of the volume of the ice sheet, if not symmetrical to the pole would displace the earth's axis of rotation, relative to the solid crust, but a rough investigation shows that this would have a negligibly small effect.
- (3) The weight of the ice cap may have bent down the crust upon which it lay during the ice period, which may be supposed to have been uplifted again when the ice retired. But here it is to be noted that we cannot compute this effect as independent of effect No. 1. If the ice sheet depressed the earth beneath it it would have a correspondingly less effect in drawing the water up toward it. In a certain sense the first and third agencies might be inferred from, the same phenomenon, by two different ways of looking at it, for the raising of the water surface by ice attraction, would produce an apparent subsidence of the land. The test between the first and third effects would apparently be the rapidity of the apparent uplift of the land. If it continued after the ice sheet had disappeared, it must be really a land uplift. Cf. Upham (23d Annual Report, Minn. Geol. Sur., 1895, p. 162) on Epeirogenic Uplifts. So far as the difference in level of the old water levels and the later water levels is concerned, this effect would be practically the same, to the order of approximation of Woodward's solutions.

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

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

This Lower Forest Beach is at times somewhat more than ten feet below the other, and can be followed around with it very well, and the two beaches may mark merely two high water stages easily due to climatic variations. Through Sigel township the lower follows the upper beach quite closely, but extends out over the flat lands of Lincoln township much farther in long sand spits or barrier beaches at an altitude of about 757 feet above tide (on the south side of Secs. 20, 21 and 29 and 35, Lincoln, on the east side of Sec. 31, with a spur also, and on the east side of Sec. 33, Lincoln). Through Colfax township there is a broad sandy terrace whose upper margin is at about 749 feet above tide. This second terrace is clearly marked in the north corner of Grant township at 739 feet above tide, and about 6 to 18 feet above the general broad sandy level over which it looks.

The lake thus formed by the running together of Lake Saginaw and Lake Whittlesey has been called by Taylor, following Spencer, Lake Warren. In all probability for quite a while after communication was opened around

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

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

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

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

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

A temporary halt in the subsidence of Lake Warren seems to be indicated at about 725 feet above tide, after which the lake seems to have sunk more rapidly than before down to about 700 feet above tide. Then the subsidence must have been slower and sand ridges are numerous down to 680 feet above tide. It must have been held at this general level for quite a while, for we find in front of the 680 foot beach line that the drift has been scoured away in many places down nearly to the rock, so that the 670 foot to 690 foot contours are

crowded together and a series of terrace benches have been cut on the east side of Robinson's hill on Sec. 13, Dwight. Sand ridges at about this level, i. e. 98-108 feet above the lake were found almost invariably where these contours were crossed, also delta sands near the rivers on both sides of the county. Most of the outcrops, except those immediately adjacent to the shore, are connected with this level. Frequently there are numerous boulders covering the surface of the lower land immediately to the west like the boulder pavement figured by Spencer.†

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

†Loc. cit. in Pop. Sci. Monthly.
10-PT. II.

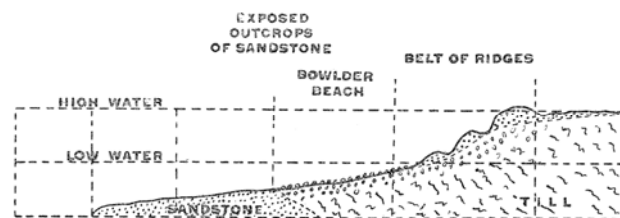


Figure 3. Illustrates the relation of sand and gravel ridges, boulder benches and flat sandstone exposures to ancient water levels. South line of Sec. 3, Meade Tp.

Fig. 3 Illustrates the boulder bench which lay just below low water and the series of ridges, the highest of which was, of course, somewhat above highwater, of Lake Warren at this level. The fact that the lake was thus held for quite a while from 672 to 692 feet above tide may be connected with the fact that that is about the lower limit for the Pewamo outlet. After free connection was established, it is natural to suppose that the lake would wear down the outlet, and its own level fall until the outlet had shrunk so as to be only sufficient to carry off the annual supply of water, after which the lake would remain relatively permanent. We call these beaches the Grassmere beaches since this general level is most accurately determined where it crosses the Saginaw, Tuscola and Huron R. R. near Grassmere, but it seems to be quite horizontal in its course around the thumb. From this level Lake Warren dropped rather suddenly to an altitude of 647 feet above tide.* What caused this drop, whether the opening of a channel around by Mackinaw into Lake Chicago, or some outlet across central New York down the Mohawk I would not dare to say definitely,† but the subsequent pause in the fall of the waters is well marked and we may follow it, from the swamps of Brookfield township past Elkton, where the beach gravel wraps around a low waterlaid moraine ridge of till, which runs from the northwest of Oliver to the northeast and is the last relic of the ice front that we

notice, on to Port Austin where the beach skirts the hill on Sec. 31. This level is also visible on Sec. 3, Dwight, and probably the prolonged lake action during this pause had something to do with exposing the outcrops on Sec. 1 of the same town. In Huron township a well marked bar at this level connects the hills on Sec. 3, and it is apparently a prominent sand and gravel beach below the Forest beaches on the eastern side, being traceable quite continuously down to the southeast, until near White Rock it is only three-fourths of a mile from the Lake.

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

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

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

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

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

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

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

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

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

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

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

he calls Nipissing, since the present Lake Nipissing (northeast of Georgian Bay, Lake Huron) was at that time part of the Great Lake system, the land was so depressed to the north that the lakes drained to the sea through North Bay and the Mattawa valley, and owing to the tilting necessarily implied deserted the southern part of their basins. Huron county lies near the dividing line

between the region where the old level of Lake Nipissing extended less far on the land, and the region where the level of Lake Nipissing was above the present level. If the lake level during the period of Lake Nipissing was lowered in Huron county it could have been but slightly lower, for if there had been a long lower stage we should find the rivers near their mouths had cut down to it, and then the rise of the coast would flood their valleys, producing such a type of coast as we have in Chesapeake Bay, or on the southern shore of Lake Michigan or in Monroe county on Lake Erie. See Part I of this volume. Of such a shore there is no evidence. On the contrary many of the streams, the Shebeon, Willow, Diamond, Allen and others flow on rock bottom close to their mouths. In fact this is the rule rather than the exception, and at other points, as at Caseville, dredging has shown that rock is close beneath, and had the streams been flowing down to a much lower level any length of time, they would have cut back rock channels farther inland. On the contrary the geological evidence is that the latest movement is what Prof. Gilbert has recently shown by measurement, to be still in progress,* viz.: an uptilting of the lake shores to the north-northwest. By carefully comparing the elevation of certain fixed points with the mean water level for the season in the summer of 1897, with the elevations of the same points above mean lake level determined by the Lake Survey years ago, he found the northeastern points relatively higher now than then in a way that indicated a rising of the earth's crust in a direction N. 27° E. about 0.42 of a foot per hundred miles per hundred years.† For instance, "Between 1876 and 1896, a point at Port Austin, Michigan" i. e., in Huron county which we are studying, "on the shore of Lake Huron as compared to a point in Milwaukee, on the shore of Lake Michigan" rose 0.127 of a foot or one and a half inches.‡ The distance between these two points is 259 miles, or, in the direction N. 27° E., 176 miles. Huron county is distant fifty miles more or less in the direction north-northeast from the outlet of Lake Huron at the Saint Clair River, so that such tilting would produce along the shores of Huron county a rise of the land upon the lake of about 0.2 of a foot per century. We do not know how long this rate of tilting has continued, nor whether it is increasing or decreasing, but the fact above cited that so many of the streams have rock ledges close to their mouths seems to confirm the belief that the latest motion of land relative to lake in Huron county has been an uplift. Possibly more detailed study may lead Mr. Taylor to shift the nodal line for Lake Nipissing a little to the southwest.

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

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

‡Loc. cit. p. 244.

§ 5. Time estimates.

We have now finished our account of the various stages in the retirement of the lake. By comparing amount of cutting on the one side, and amount and volume of

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

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

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

For the eastern shore of Huron county we have no such close estimates. In fact the general impression is that the shore has been gaining upon the water. But as Plate V shows, for the ten years before 1896, the waters had been lowering rapidly. Again opposite Harbor (Sand) Beach the shore is protected by the great artificial breakwater erected by the government at a cost of \$2,000,000 and a filling in has been caused. Mr. Geo. W. Jenks says that a strip of an average width of 50 to 100 feet has been added in his recollection,—the last twenty years or so. A large double tree, which in his boyhood was on the crest of the beach not over fifty feet from the water, is now 140 feet from the limit of vegetation or 145 feet from the water's edge according to measurements that I made in Sept., 1897. The old Land Office notes make the distance along the north line of Sec. 12, T. 16 N., R. 15 E., 50.25 chains, i. e., 3316.5 feet. The county atlas gives by scale 3560 feet, and the careful plan of Sand Beach harbor prepared in 1889 by the U. S. Engineers from work between 1885 and 1888 makes the same distance 3600 feet, showing a decided gain of land over lake, especially as the lake was highest in 1885. But this line is close to the mouth of a stream, and perhaps influenced by its delta. The various successive blue prints by the United States Engineers show plainly the accretions year by year. But when we come to compare with more distant times and especially with the records of the first Land Office surveys, which are not very accurate, however, in 1834 and 1835, when the water was as low as in 1896, we find a very different state of affairs. The indications are of greater or less erosion not of gain. Let us cite a few facts. Mr. J. H. Tucker, one of the oldest surveyors of the county, reports a general erosion of the land; that to the north on the town line where the quarter post originally stood on the land the shore now comes 40 rods this side of it.*

The elder Mr. Jenks bought a lot which, according to the government notes, contained 65.50 acres. By 1880 this lot (3, Sec. 36, T. 17 N., R. 16 E.) had dwindled on resurvey to 54 acres, implying if both surveys were accurate and took the shore line in the same way a retreat of 380 feet or 8.43 feet per annum. To the south of the breakwater near the summer resort, on the west line of Sec. 7, T. 16 N., R. 16 E., the line from the corner to the water was in February, 1896, 1730 feet to the edge of the bluff plus about 30 feet to water, a loss from the original survey of 50 links. On the south line of the same section, 7, the line was 20 to 30 links short. This loss in spite of the low water of 1896 and the recent accretion due to the protection of the breakwater shows that there must have been considerable cutting before, amounting to between 100 and 200 feet, i. e., for the fifty years, 1835-1885, from 2 to 4 feet a year.

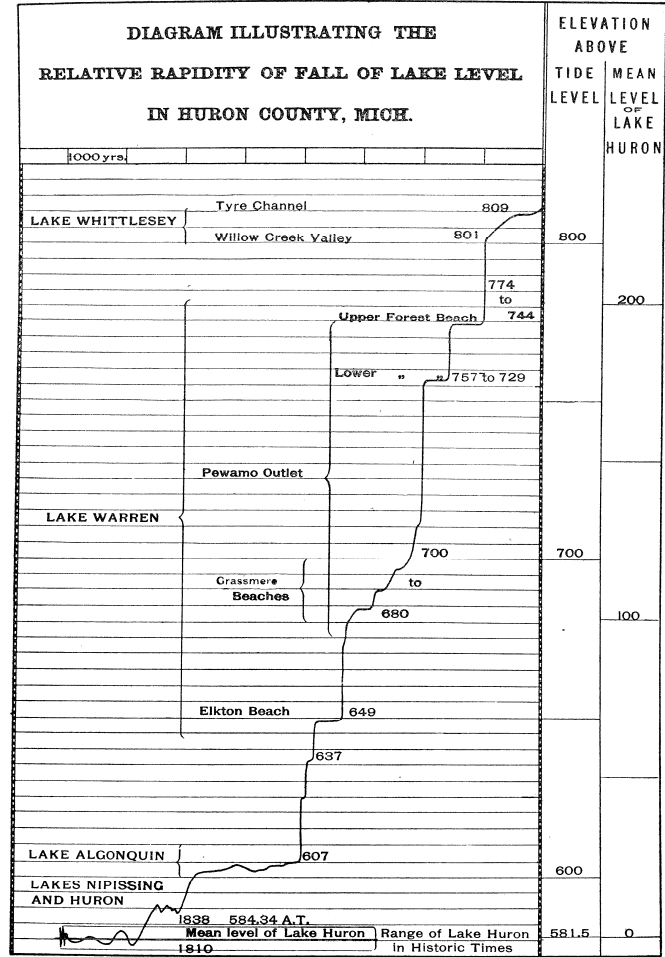


Figure 4. Illustrates the relative strength of the water lines at various levels in Huron county, Michigan. The altitudes given at various parts of the curve are above tide, lake level being 582 feet above tide, according to Gannet. The altitudes are indicated on the vertical scale while the horizontal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

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

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

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

Thus, as the general situation of the eastern shore of Huron county is not unlike that of the eastern shore of Wisconsin, so the rate of erosion, judging from the scattering and not very reliable figures above given,

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

If we look at the Lake Survey chart of Saginaw Bay and part of Lake Huron, or at the field sheets of Sanilac county, we shall see the Algonquin 25 foot bench well indicated and running from half to three-quarters of a mile back of the present shore line. But as it is so much higher than the present bench, it would cut the grade line perhaps a mile nearer the shore, so that the total breadth of the notch cut at this level may have averaged a mile or less, not far, perhaps, from the average breadth of the notch cut at the present level, as the notch at White Rock is probably extra deep. We may also compare the breadth from the present shore line out to the three fathom line. If an equal amount of erosion has been done at each of these levels, and the mean rate of erosion was the same, and we see no reason why it should have been materially different, say 3 feet a year, each notch of a mile or less at a rate of 3 feet a year would have taken somewhat less than 1,760 years. This would imply a rate of $4\frac{1}{2}$ feet at White Rock to produce strict accordance.

Taylor's estimate for the duration of the present lake system from the rate of erosion of Niagara is 2,700 years. In order to bring our figures into any accordance with his (the factor of safety which he introduces by increasing 2,700 to 5,000 to 10,000 seems to be unnecessary), we must assume that the Nipissing erosion was at a slightly lower level and has been hidden by the debris from the later cut at a higher level, so that the time of the Nipissing Lake is not accounted for in our study, just as it is omitted in the work of Dr. Andrews who gets for the duration of the present Lake Michigan at various levels, from 13,000 to 3,000 years, or in another way, using the rate of erosion determined by the Wisconsin Survey, some 4,700 years. I must confess that the character of the stream valleys and the frequent rock exposures near their mouths leads me to believe that in Huron county, Lake Nipissing and Lake

Huron were at nearly the same level, and that the cut at White Rock includes the efficiency of them both. In that case the total time since the fall below the 40 foot level in Huron county could be confined within 4,000 years in accordance with all we yet know. A certain check on our results may also be derived from Gilbert's measurements of fluctuation of relative level aforesaid. From the relative strength of the beach lines, we may feel sure that the lake level has remained more than ordinarily constant within the range through which it has fluctuated in the century. Therefore the rate of change of land level must have been below the average. Thus, unless the rate of change found by Gilbert is abnormally high for the century (which of course it may be) it must be below the average rate of change during the emergence of Huron county from under water,* and then supposing that no oscillations of lake level which have occurred have checked its efficiency as a cutting agent, according to the figures at the end of the preceding section the emergence of the last 25 feet must be confined within the past 12,500 years ($25 \div 2$ feet per century). We may note that Gilbert's rate of tilting would, if uniformly continued back into the past, change the present lake level into that of Lake Nipissing (7 in. per mile rise N.) in about 14,000 years. In the same way the apparent rate of lowering of the water at the mouth of French River would point to 14,400 years since the water stood at the level of the Nipissing Beach there, and that was the outlet of Lake Nipissing.

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

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

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

*Dr. Andrews also finds that around Chicago the combined bulk of the beaches of Lake Chicago, which, in our diagram, correspond to all above the 40 foot level, and a little more, are about equal to those of the present shore line taking it out to where the water reaches a depth

of 24 to 36 feet. Here, however, again according to Taylor the Nipissing is far below present lake level at Chicago, and hence the time of its work should be deducted.

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

The most uncertain factors in the discussion above are:

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

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

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

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

CHAPTER V. STRATIGRAPHY, DISTRIBUTION AND STRUCTURE OF THE ROCKS.

§ 1. The Cuyahoga or Coldwater shales.

We have in a previous chapter described the character of the rock column. It now remains for us to consider how these rocks are distributed through the county, what modifications they undergo, and what the indications are of their geological history, and, without trespassing too much on the material of a later chapter, what are their characteristics from a practical point of view. In this history we begin with the underlying oldest exposed beds, the blue shales of the eastern coast. Occasionally thin seams of sideritic grit are intercalated, which grow

thicker and more abundant near the top. They are at present exposed only near the eastern shore and in the Willow Creek section. Under the cover of drift or in deep wells they are characterized by the lack of good water from the rock. Speaking generally, it may be said that within the region colored on the map (Plate VII) as of this formation, wells in the rock do not yield a satisfactory supply of water, either in quantity or quality, for it is often brackish. The dip* of this formation estimating from the correlations of the deeper wells, is not far from 40 feet per mile and is in a general way on the west, but the line of strike shows a veering from about S. 31° E., which is the strike of the *Romingerina julia* beds from near Point aux Barques, down to the Willow Creek to the south. The dip seems to be greater toward the east. The character of the sediments is quite uniform, as mentioned above, and with what is known of similar deposits elsewhere, we may infer that they are composed of the finer detritus brought down by sediment-laden rivers from the Laurentian highlands of Canada, and from regions which contained much iron, i. e., region of hornblendic rocks. The sea was not very deep and the shore was either not very steep or was yet quite a distance from the present limits of Huron county.

*Dips: From New River to Grindstone City (1010 - 900 or 1080 - 1000 to 1029), is 47 ft. per mile. From White Rock, which is 560 - f 505 feet below the top of the Napoleon, to Sec. 35. Sebewaing, is 39 miles; altitude of the top of the Napoleon in the well there 502 A. T.; altitude of the well at White Rock, 592 (?). Whence $(560 + 505) \times (592 - 502) \div 39$ is 29.6 feet per mile dip from White Rock to Sebewaing. From Sebewaing to Ruth, taking the top of the ridge or rock escarpment near Ruth to be the grindstone or the Point aux Barques sandstone, 70 feet above the bottom of the Marshall, we have $505 \text{ perhaps } + 70 - (592 - 740) \div 6 = 59.5$ to 71 feet per mile. If we take the bottom of the Marshall series in the flowing Badaxe well, Sec. 19, Verona to be at 320 feet down, i. e. 437 feet A. T., subtracting this from $592 + 396$, since the Harbor Beach well begins about 398 lower, we have 551 feet in 16.8 miles, or about 32 feet per mile. Similarly to the edge of the rock escarpment at Sigel or Allen Creek would be $(750 - 437) \div 11 = 29$ feet per mile. The strikes are indicated on the map, Plate VII, with the dip assumed in finding them in feet per mile.

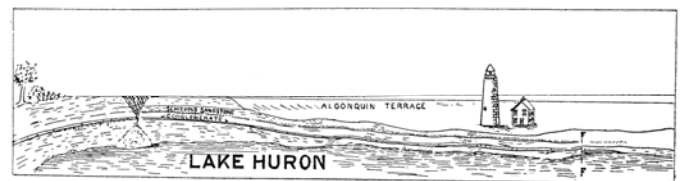


Figure 5. Ideal view of Point aux Barques lighthouse, showing the conglomerate and the fault. The lighthouse stands on the Algonquin terrace, but to the left, south, the present lake has cut back farther than Lake Algonquin.

The indications are that the rock surface in this region is nearly a plain, or rather a gentle slope from the ridge or watershed made by the more resistant rocks of the next overlying series. The more important wells that strike this formation, are those at White Rock, Harbor Beach, New River, Grindstone City, Port Austin, Port Crescent, Caseville, Bayport, and Badaxe. The more important outcrops are already partly described in the geological column; additional notes are as follows:

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

(2) The Point aux Barques section (see geological column, Plate I, and Fig. 5. Specimens No. 19044-19083). In this section we see as we go north and northwest that the beds run downwards from 15 feet at the south end of the bluffs to 6 feet above lake, near the lighthouse. Just beyond the lighthouse the calcareous conglomerate disappears, and is replaced by another layer farther down, the exact and critical point not being exposed when we were there. But this is probably the point spoken of by Winchell where there is a fault, the most extensive dislocation seen south of Mackinac," as he says. The neighborhood of the fault would account for the abnormal dip of 1° to $1\frac{1}{2}^{\circ}$ to the northeast. The general relations are illustrated by the perspective diagram, Fig. 5, which is not drawn rigidly to scale. There are some errors in Winchell's account, as where he speaks of the lighthouse being one mile east of Willow Creek, instead of 2, and of the dip of the sandstone being southwest instead of northerly, which it is in reality. Southwest is of course the general direction of dip in this region. Rominger's description is more accurate (Geol. Sur. Mich., Vol. III, p. 73). The palæontology of this very important section is given at length in Chapter X, § 3. The shales of this section are also visible farther south in a number of ravines in Secs. 12 and 13, Huron, cutting the bluffs which are at an altitude of 30 to 39 feet above lake and overlook the Algonquin terraces.

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

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

(5) Rock Falls. "The same beds with *Chonetes* and impressions of *Goniatites* are well exposed at Rock Falls, the ripple-marked surface of the ledges * * * being covered with *Caudagalli* fucoids in relief, as well as other singularly-shaped prominences of organic origin."* At the mouth of the stream (N. E. quarter Sec. 19, T. 16 N., R. 16 E.) the water flows over a ledge of shale, and shaly sandstone in alternating beds, with a fall of three feet. The full section exposed was about ten feet. A similar exposure was observed about a mile below this.

(Gordon.) The fossils from this locality are Nos. 19146-19150, and palæontologically it is said by Mr. Cooper to be equivalent to the Moot's Run section in Ohio. These same beds occur obscurely at the base of the Algonquin bluffs on and near the north line of Sec. 31, T. 16 N., R. 16 E.

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

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

§ 2. The Marshall sandstones.

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

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

A. Character of rock.	B. Number of survey specimen.	C. Sp. Wt.	D. Weight wet.	E. Weight dry.	F. Porosity.
Napoleon sandstone: Babbit quarry.....	19161	2.8	2,339 ±27	2,067 ±57	27.2 ±3.0
Hat Point.....	19087	2.8	2,718 ±800	2,615 ±800	10.3 ±2.5
Do.....	19102	2.8	2,308 ±52	2,040	26.8 ±5.2
Grindstone (scythestone of the Hu- ron Grindstone Co. volume com- puted from dimensions).....	19017	2.61	2,420 ±50	2,280 ±20	14.0
Cass river grindstone.....	19152	2.57 ±.04	2,290 ±40	2,070 ±20	22.0
Arenaceous shale.....	19092	2.64	2,500 ±120	2,360 ±90	14.0
Fine grained conglomerate of Wil- low Creek.....	19108	2.59	2,520 ±240	2,480	4.0
Sandstone near Point aux Barques lighthouse.....	19046	3.18	2,850 ±50	2,700 ±50	15.0
Bayport limestone.....	19006	2.69±	2,690 ±350	2,690 ±350	.....
Bayport limestone.....	Report Vol. V.	2.72	.....	2,720 170 bbls.	.....

The physical characters and subdivisions as they are shown along the north coast between Oak Point and Grindstone City are quite fully described in connection with the geological column. The Badaxe well affords the most detailed account to the southeast on Sec. 19, Verona. As we go southwest the lower part of the series seems to become less sandy, showing that we are going away from a shore line to the northeast, along which this formation was deposited, and the whole Marshall appears in the drillers' records as a hundred feet or so of white sandstone at top, very full of water, representing the Napoleon, or some part of it, and below this, "red rock," "paint rock," "iron ore" and similar expressions are used in describing it. We can trace this red rock so continuously along* that there can be but little doubt that it represents the Lower Marshall of the north coast. Bed rock also occurs so constantly (separated by about 18 feet of blue shale), under the salt rock of the Saginaw River, that as I am informed by Mr. J. Coreyell, it is often referred to in contracts for boring wells. That the Marshall should be represented by red shales as we pass from the shore is quite natural, when we consider the very ferruginous character of this lower Marshall, due as I have suggested it may be to the fact that there were large areas of basic greenstones, hornblende schists, and similar ferruginous rocks in the region from which it was derived. In Winchell's 1861 report (p. 91) he was in doubt as to how the Saginaw well section should be correlated with the coast, and at that time he was inclined to regard the shale reached in the Saginaw well immediately under the brine sandstone as the "thickened separating shale lying between the Napoleon and Marshall Groups." In this I believe he was right. Later and very likely properly, in view of the evidence then before him, perhaps also influenced by Rominger's erroneous views as to the Huron county stratigraphy he seems to have swung to the other conclusion, and to

have thrown together the Napoleon and Marshall, as one group under the name of Marshall. With the evidence before us I believe that the other alternative must be taken that the whole Marshall of Huron county is not represented by a hundred feet of sandstone beneath Bay City and Saginaw, but that the lower part becomes shaly, and not distinguishable from the formation beneath. In my report, Volume V, I followed Winchell's later view, but I would now draw the line, for example, in the Bay City well (Pl. VI) of that volume for the base of the lower Marshall as we have defined it in Huron county somewhere near 1285 feet.

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

Though the dip of the Marshall is in a general way like that of the underlying formation, it has several minor undulations at least in the top of the formation (see Fig. 6), and it is probable that these are, like those at Point aux Barques lighthouse and the Sebewaing coal mines associated with faults of small throw. The capping of Learned's hill on Sec. 31, Port Austin, seems to be left as a small synclinal, since we find on Sec. 35, 800 paces N. and 135 paces W., that the Leiopteria beds exposed in the bluffs of the Algonquin level, to the east of the road dip as much as 5° to northeast and along the shore we find between Hardwood Point and Flat Rock Point a blue shale which seems to be mixed with a breccia of angular pieces of the sandstones with which it is associated. It, too, seems to dip about 4° E.

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

of the bank and gradually working down. The *R. julia* zone can also be plainly recognized in a well sunk near the north quarter-post of Sec. 21, Huron, and gives our opportunity of most accurately determining the general strike for this region, viz., N. 31° W.*

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

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

He describes it as follows: "From a consideration of the well-records it is evident that a concealed rock escarpment representing the eastern limit of the Marshall occurs along a line approximately corresponding to the township line between Sand Beach and Sigel townships. At M. Cowper's, N. W. Cor. Sec. 19, Sand Beach, this sandstone comes within 6 feet of the surface, while R. A. Brown's well, 660 paces east and north, shows 48 feet to rock, which is a shale evidently belonging to the Coldwater shales. Again in Sec. 1, Paris, at Susalla's, the rock is but 6 feet below the surface, while a short distance, ten to fifteen rods, north of this the rock comes within 2 feet of the surface, and at Lock's farther south, it is but 12 feet to rock.

Toward the east within about half a mile it is said wells fifty feet deep do not reach rock. In Sec. 12 of Sherman township, at Hoeldke's it is 54 feet to rock. At Parisville it is 90 feet. Wells to rock are not numerous enough to trace the line accurately, but the line drawn on the map approximately represents this concealed escarpment. No indication of this ledge appears in the surface configuration. East of Ruth no wells are found that reach rock. Several wells occur toward the south and west. Those to the southwest show that the eastern limit of the sandstone found at Susalla's, northwest of Ruth, passes to the southward of the latter place, crossing the county line into Sanilac county near the southeast corner of Sec. 31, T. 15 N, R. 15 E."

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

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

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

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

The fossiliferous series on Sec. 35, Port Austin, T. 19 N., R. 13 E., the Marshall *par excellence*, palæontologically speaking, can be traced down into Sec. 20, Hume, and the isolated outcrop, Sp. No. 19100, which is found on Sec. 10, Hume, at Port Crescent, seems to belong in the same series. The sandstone of Hat Point can be followed some distance south-southeast from the shore in bluffs in Sec. 7, and reappears in Sec. 20, Hume [Sps. Nos. 19096, 19097] thus giving us a good strike similar

to that around Point aux Barques, but more to the north [N. 15° W.] The escarpment fronts east and all the indications are that the dip is the normal one to the southwest. But it is obvious that if the marked easterly-dips which we had around Hardwood Point were long continued, we should have the Port Austin sandstone, which ran below the water line at Flat Rock reappearing from the waves. As already suggested, there is probably a little fault, enough only to counterbalance the abnormal dips in part, for we find the Port Crescent well only 25 feet deeper than those at Port Austin. The dip from Port Crescent to Caseville is, according to the wells, about $(1750-1250 \div 11.7)$ 43 feet per mile on an average. This dip is probably a little steeper than that for the middle of the distance.*

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

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

Thus we find it continuing into a ridge in the rock surface, which extends on toward Tyre, a ridge which underlies the higher part of the county, though the rock surface is not anywhere near so irregular as the present surface, since wells upon the ridges of till strike the rock deeper down than those in the valleys. And finally just outside the county we find outcrops of sandstone once more, near Tyre where the old channel between the lakes around the Point has scoured down to rock. But to get the most close parallel to these Tyre outcrops, we must retrace our steps, and begin at Little Oak Point where, exposed in the Babbitt sandstone quarry and not at present worked, we have a coarse and porous sandstone. There is also sandstone on the south shore of Rush Lake, and we can trace the sandstone along, very near the surface in Sec. 6, Meade, exposed on the Pinnebog in Sec. 5 adjacent, extensively exposed along the road in the ditch on the north line of Sec. 16, Meade, and making a marked ridge which runs southeast through Sec. 15, Meade. The samples taken here are extremely like those from the Babbitt sandstone quarry. (Sps. No. 19101 and 19102 like Sp. No. 19161.) These sandstones are evidently near the center of the Napoleon sandstone and the summit of the prominent ridge in the rock surface. Hence we may obtain from it some idea of the general course of the strike which evidently veers from southeast to south. We do not

know just how far this sandstone horizon lies below the top of the Napoleon sandstone but wells like Sovereign's on Sec. 30, Lake, Lounsberry's on Sec. 3, Chandler and the Badaxe cemetery well on Sec. 24, Colfax, make it obvious that there is a considerable thickness of sandstone and nothing of importance but sandstone between it and the top of the Napoleon. This latter we assume to be near Oak Point where the coarse water-bearing sandstones are overlain by bluish drab-colored limestone ledges of dolomitic or partly arenaceous character, fossiliferous, as described by Rominger (Vol. III, pp. 70, 103), and apparently similar in character to outcrops found on Secs. 18 and 19, Meade (T. 17 N., R. 12 E.). This line seems to be a well defined one in almost all the wells, being generally the one where a flow of water, or a new flow of water was struck. The Napoleon sandstone is much more porous than the overlying beds of the Michigan series. (Cf. Table II.) Tracing the top as best we can in the records of the wells, we have platted the observations in Fig. 6 and sketched in contours accordingly. The numbers of this map are of practical importance, for by subtracting the nearest one from the altitude of any point above tide, as given in Plate VIII one may form an estimate as to how far drilling should be carried for the best results. It will be noticed that the surface of the top of the Marshall as thus delineated is not accordant with, and is much more irregular than, the bottom of the formation in dip and strike. It is thrown into a series of gentle folds pitching toward the northwest and corresponding in a general way to that slight fold which we have spoken of near Port Austin and also to the fold in the coal mine at Sebewaing. As there may be some hesitation in admitting such a comparatively complex stratigraphy on the somewhat uncertain evidence of drill records, it may be well to mention some confirmatory facts:

- (1) The dips of the Bayport limestone on North Island, on Big Charity Island and at the quarries are, as indicated on Plate VII, in harmony with the structure assumed.
- (2) At a nearly uniform distance above the top thus determined there is a gypsiferous zone, so that the deep rock wells in the area where the top of the Napoleon is less than 550 feet above tide, are pretty apt to be strongly mineralized. In fact the tracing of the gypsum had led me to some such stratigraphy long before the contours of Fig. 6 were drawn.
- (3) The records of the Caseville and Bayport deep wells show that there is nowhere near the usual grade per mile between these wells.
- (4) The old rock surface as given on Plate VII seems to show that the streams which cut it were adjusted to some such structure as here indicated.

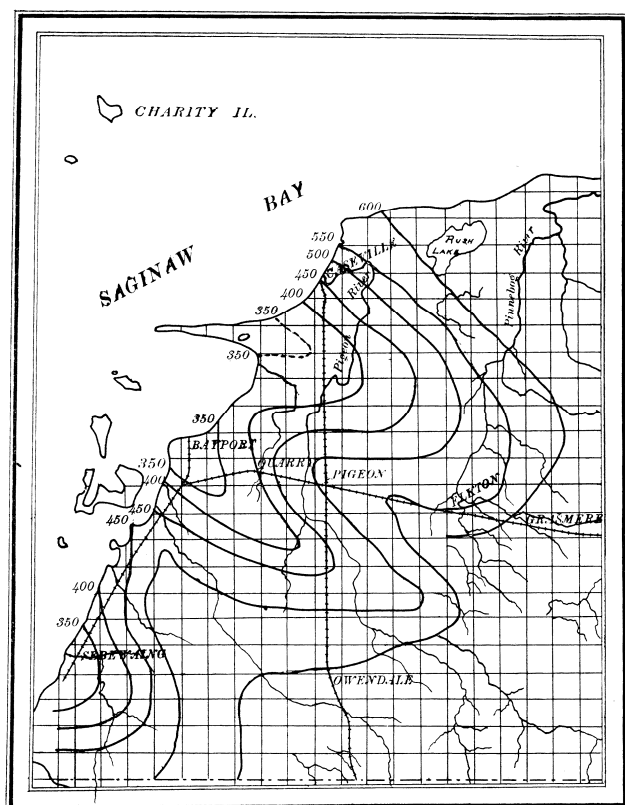


Figure 6. Contours showing the elevation of the top of the Upper Marshall above sea level.

§ 3. Lower Grand Rapids, Michigan series.*

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

*In Volume V, I included this series in the Grand Rapids, rejecting the term Michigan Salt Group as used by Winchell, because there are well founded and generally accepted objections to such terms as Salt Groups as applied to groups of rocks, and especially since we have in Michigan another formation much richer in salt, which material is, so far as yet known, merely a mineralogical curiosity in the "Michigan Salt Group." I then proposed to replace "Michigan Salt" by "Grand Rapids," a place identified with the manufacture of plaster from gypsum, so characteristic of this formation, including also in this term the limestones which were according to Winchell and Rominger equivalent. But I have on farther consideration decided that I ought to have retained the part of Winchell's name which was open to no objection, viz.: Michigan, and especially because during the formation of the series in question Michigan was a separate province to which these rocks were confined. I used the term Grand Rapids group in a more inclusive sense than the "Michigan Salt Group" of Winchell to include also the overlying "Carboniferous limestone" of Winchell, the Bayport or Maxville limestone of this report, which has also been well exposed at Grand Rapids. Since that time, however, the records at

Alma and Midland and South Saginaw (Salina) with the samples preserved, together with the older records recorded in Vol. V, have shown that the gypsum beds and the characteristic shales associated are widely persistent and need not be confounded in one group with the limestone above, and at the time of formation of this group Michigan was a separate geological province, through which these rocks were quite uniformly developed in the basin in which they were formed. Their correlation with the Burlington and Keokuk, i. e., Augusta limestones of the Mississippi I have already mentioned (§ 4. Michigan series (c. 2).‡).

The Marshall was, as we have remarked, a period of uplift and at least for the earlier part of the time a period of rapid degradation of the land, i. e., of wet climate. Toward the end of the time the climate may have become dryer, for the Napoleon is freer from mud, and more of the nature of a glass sand, with the grains of quartz well rounded and freed from foreign ingredients. I dwell upon this point because it has some bearing upon the coal question. Coal has been reported below the coal measures in a well on Sec. 2, Dwight, T. 18 N., R. 13 E.* and from the Michigan series in Sovereign's well on Sec. 30, Lake, T. 18 N., R. 11 E., also on Sec. 21, T. 15 N., R. 9 E. about 75 feet above the white sandstone of the Napoleon.

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

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

repeated with variations until a depression let in the waters of the open sea once more.

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

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

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

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

†Sovereign's well on Sec. 30, Lake.

Not far above the Soule limestones, near Soule, about 100 feet above the bottom of the formation is a gypsum bed, which grows less and less to the southwest. We may infer this position from the facts reported that gypsum was dredged from the river at Caseville and found in shallow wells and was first encountered in Codey's well in Sec. 24, T. 17 N., R. 11 E., and in shallow wells on Sec. 25, immediately south, whereas in Collison's well, Sec. 15, Fairhaven, the gypsum is probably not so far above the Napoleon sandstone, and in Bauer's well, Sec. 8, Sebewaing, I can find no trace of it, the whole thickness of the formation having dwindled from about 200 feet to 125 feet. Supposing it to be a hundred feet above the Napoleon, and that is about the relative position at Alma and Midland, we may trace its outcrop on the rock surface of Plate VII, by seeing where a surface 100 feet above the surface outlined by the contours on Fig. 6, would cut the surface indicated by the contours of that plate. For example, the surface of the Napoleon is about 500 feet above tide near the southeast corner, Sec. 5, T. 17 N., R. 11 E. and hence the gypsum bed should be about 600 feet above tide there. But the rock surface, cf. Plate VII, is also about

600 feet above tide. Hence the gypsum should strike the rock surface there. Thus we can follow point by point the extension of the gypsum bed. We may control and check this somewhat theoretical location by observations upon the character of the well water. For not only is gypsum somewhat soluble, so as to strongly impregnate the well water of any well which strikes it, but the evaporation went on so far as in some cases probably to throw down a little salt, for from only 100 feet depth Mr. Leipprandt on Sec. 13, T. 17 N., R. 10 E., gets a very strong brine. If rock salt was not formed, the sea water must have been at any rate a concentrated brine, which would be more or less entangled in the pores of the rocks laid down. Hence wells drawing water from this formation, would be strong of sulphates (gypsum is sulphate of lime) and very probably salty.

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

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

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

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

Then apparently it follows down the old river valley which is quite natural as it would easily be dissolved and eroded, but finally extends over it, as we find highly mineralized wells on Sec. 23, and at Winsor, and finally one on Sec. 10 near Owendale, which only penetrates a short distance into the rock. From a well on Sec. 33, Oliver, a foot of plaster is also reported, but none of the waters in that region indicate any such extension. In fact

as to the extension in Sec. 23 and Winsor, it must be remembered that it is by no means necessary that wells strong in sulphates should have their sulphates derived from gypsum, or from sea-water at all. Sulphates may be derived from the oxidation of sulphides of iron pyrites, etc., which are abundant in the rocks of this and the over and underlying series. Hence sulphated water can be used readily only as confirmatory of evidence which in the direction of Owendale is scanty. But turning northward again as is required by the anticlinal indicated by Fig. 6; in the Napoleon, we find in Secs. 28, 29, 30, and in the north part of Secs. 31, 32 and 33, Winsor, T. 16 N., R. 10 E., a group of wells very strong in sulphates and cathartic. This group we can trace on through Secs. 25 and 26, Fairhaven, and here we are quite near to Collison's well on Sec. 16, from which we have seen samples of gypsum. This well is in the midst of a group of wells which all are heavily charged with sulphates.

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

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

Concerning the fossils of this formation, see Chapter X.

§ 4. Bayport (Maxville) limestone.

This is one of the best exposed and most fossiliferous of the formations of Huron county. It is the only characteristic representative of the great series of limestones of the Mississippi valley. As I have mentioned in my account of the geological column, in CHAPTER II. GEOLOGICAL COLUMN., it represents the Maxville limestone of Ohio, and the Upper St. Louis limestone of the Missouri Survey, and probably marks the epoch of depression which admitted the open sea once more into the basin of Michigan (Fig. 2), and put an end to the separation of that basin into a distinct province by itself that characterized the epoch of the Michigan series. The deposition of gypsum might have been terminated in two ways,—either by an increase in the precipitation and supply of fresh water, or by an opening to the sea. The characters of the Bayport deposits, clear limestones and dolomite, and limestones, and white sandstones, crowded with life, and yet comparatively free from mud, indicate that the climate remained dry,—that it was not the former alternative but the latter that took place. This formation is characteristically full of chert, chalcedonic and clay nodules, often a genuine limestone, about 95% Ca CO_3 with little magnesia but generally impregnated with silica, and it abounds in corals, which generally prefer clear water. Signs of vegetation are rare. From all this we may infer that at this time the climate continued dry and hot as in the previous epoch, but that the Michigan basin became an arm of the great interior sea. The thickness of this formation around Bayport is about fifty feet and the indications are that there is a considerable thickness all along that edge of the basin, but as we go southwest it seems to diminish considerably in thickness, until around Sebewaing we cannot safely assign more than 27 feet to this formation. Brown, yellow and white, not blue nor black, are the more characteristic colors for this formation. On Charity Island the formation is quite well exposed, and has been described both by Winchell and Rominger. Winchell gives the section on the north side of the island as follows:— C. Limestone, arenocalcareous, containing Bryozoa, Cyathophyllida, and Allorisma 10 inches. B. Limestone with cherty nodules 10 inches. A. Sandstone, calcareous, obliquely laminated 4 feet. "Some portions of A are well characterized sandstone of a whitish or grayish color. The laminae extend from top to bottom of the mass, dipping northwest at an angle of about 45°. They are quite undulating and even contorted, and the whole mass shows something of a rude concretionary structure." This cross-bedding of the sandstone is like that met with in a sandstone in similar relation to the limestones on the Bayport quarry on Sec. 5, T. 16 N., R. 10 E., at a depth of from 26 1-3 feet to 29 feet [Fig. 9]. It also reminds one of the abnormal dip of the lamination in the type exposure of Winchell's Parma sandstone (Report, 1860, p. 113). The "rudely concretionary structure" is evidently the same as the anticlinal of

Rominger's description (Vol. III, p. 119), who describes the section as follows: Upper horizontal beds, a pure lime rock, free of sands, with numerous flint nodules, and interlaminated with thin seams of calcareous shale with *Lithostrotrion proliferum*, *Syringopora ramulosa*, *Fenestella*, *Polypora*, *Productus flemmingii*, *Allorisma clavata*, and fish teeth not abundant, 8 feet. Lower beds lying in a discordant stratification beneath the upper in an anticlinal, the higher ledges arenaceous but with lime prevailing, with flint concretions, *Zaphrentis spinulosa*, *Lithostrotrion proliferum*, ripple-marked, 5 feet. Lowest beds a light colored ripple-marked calcareous sand rock about one foot above the water level, 1 foot. Rominger sketches this as follows (Fig. 7), and found no outcrops elsewhere on the west side of the island.

*Report, 1860, p. 102.

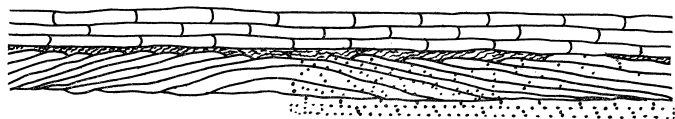


Figure 7. Illustration of section on Big Charity Island, after Rominger, Vol. III, p. 119, showing discordance in the Bayport limestone. Completed so as to show the lower bands as we observed them, in dots.

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

The point to the north is made up of gravel and boulders, but a short distance southeast of the lighthouse, the outcrops of characteristic layers of limestone with abundant *Lithostrotrion*, chert nodules, and *Phillipsia pygidia*, begin. On the first little point from the lighthouse in this direction there are 6 feet of bluish shaly limestone with abundant *Allorisma*, in nodules and geodes, *Lithostrotrion*, etc. (Sp. 19178-19186). About 50 steps farther southeast we find close to the water's edge a three inch bed of hard ringing flaggy gray limestone (Sp. 19187) undulating somewhat, but apparently under the *Lithostrotrion* beds and dipping gently southwest. On top of this bed, *and thus replacing the limestone*, we find an almost pure white sandstone, cross-bedded strongly with a dip to north of west in the cross-bedding (Sp. 19188). About ten steps on in the lower part of the sandstone are large *Allorismas* (Sp. 19139). Flinty and cherty limestone layers, over-and underlain by sandy ones, continue near the coast to the east point. The bay opening southeast is sandy, but on the long point to the south we find flat outcrops in the broad zone left by the recent water retreat. They frequently contain calcite geodes and weather yellowish brown (19192-19202). They are sparsely fossiliferous, the most interesting form

being one that resembles *Athyris subquadrata*, but there are also fragments of *Productus*, *Lithostrotrion*, *Bellerophon*?, etc. On the coast facing Little Charity Island there are low paving-slab outcrops of brown brittle dolomite with cavities, and the surface is strewn with chalcedony and other geodes, which have evidently been left by solution of the limestone that enclosed them, as the irregular surface has not been rounded by erosion (19190-19191).

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

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

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

the north side of the island, we come to a layer rich in Lithostrotion; which seems to overlie the beds just mentioned, as in the Bayport quarries, and dip gently to the northeast.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4. Another similar bed, 1 foot.

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

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

7. Arenaceous limestone laminated, 2 feet.

8. Sand rock, few in.

9. Delicately laminated limestone, 6 in.

10. Shale, seam.

11. Gray limestone with cherty nodules, 1 foot.

12. Greenish white calcareous sandrock, 5+ft.

Total, about 25 feet.

Comparing this with exploratory section No. 3, on Sec. 36, T. 17 N., R. 9 E., we can identify the bottom bed 12, with the sandstone of the same and beds 7 to 11 probably with the 3 2-3 feet of limestone; beds 2-6 may be the 4 1-4 feet "firestone," No. 2 being the bed from which our Sp. 18207 is taken—from outcrops near the picnic grounds west of the railroad. The upper ten feet correspond to the outcrops on the west line of Sec. 36, and the first three feet of the quarry, bed No. 1, Fig. 8. The next beds are the building stone beds of the quarry (No. 2 Rominger=F. of Winchell?) and the black shale seems to be represented in the quarry at 8 feet, 6

inches. (Compare Winchell's C.) Rominger's sandstone bed No. 8 may be parallel with the sandstone from 9 feet, 8 inches in Fig. 8. Rominger's beds 9 and 10—the "delicately laminated limerock and shale"—may represent the cement rock of the quarry section, cement rock being generally an argillaceous limestone, and we have as satisfactory a correlation, as can often be got. The dip of the limestone from hole No. 1 in the quarry to hole Xo. 4 on Sec. 35 is * about 12 feet to the mile, which is not far from that indicated by the contours in the underlying Napoleon sandstone in Fig. 6, for the same direction. The dip between holes No. 3 and No. 4 would be † 26 feet a mile, which would yield for the three points a dip to W. 39° S., of 27 feet per mile, but the position of the limestones on North Island and their dip forbid us from regarding this as a dip at all widespread and indeed it is not justifiable to join three points on a pitching synclinal to obtain a dip which can be expected to hold generally true. However, it shows plainly enough that the dip is really west and not east. The corresponding strike seems moreover to be almost exactly that of the limestone ridge from Sec. 5, Winsor, to Secs. 9 and 15, where the Lithostrotion beds lie at nearly the same altitude as on Sec. 5, and are very close to the surface. The limestone is exposed in a slabby pavement profusely strewn with weathered out Lithostrotion in the ditch on the north side of Sec. 5 and we find *Lithostrotion proliferum*, and also *mammillare* (= *canadense*) profusely strewn upon the fields in Sec. 9. The last place in this direction where the limestone lies near the surface is Sec. 22. All the way along it forms a pronounced ridge in the rock surface with bluffs facing an old river valley to the northeast. The sides of this river valley may be even more precipitous than our contour map indicates them, for such a massive cherty limestone overlying a formation of soft shales and gypsum, would be practically sure to outcrop along a river valley in an escarpment of vertical bluffs in which caves would be likely to form. And in fact we find in developing the quarries, and running the adjacent railroad spurs that the northeast wall of the limestone is nearly vertical so that the drop of the limestone is reported to be from 12 to 18 feet. Reports of cavities struck in this formation in sinking wells are also frequent. I happened to be standing by when one was struck in Bauers well at Sebewaing.

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

†(20.43 - 8)—(11.16 - 10.5) i. e. 12 feet in 0.47.

Turning from the Bayport quarries to the southwest on the other hand, we find the limestone falling gently in this direction, according to the quarry authorities about 3 feet per hundred to the west, more than the dip above given, but that was an average taken very nearly to the center of the synclinal. In the quarry the bottom is now in the thinner bedded, bluer limestones and the bituminous shale parting shown in Fig. 8, at 8 feet 5 inches. The Lithostrotion occurs most abundantly above bed No. 1, and the quarry has developed about 3 feet of limestone above layer No. 1 of Fig. 8, which has been analyzed.

(Chapter VII, § 7.)* The chert concretions which contain some clay are very often pear shaped, with a pit at one end, not infrequently enclose some shell, and are most abundant immediately below in layer No. 2, Fig. 8. In the lowest bituminous layers I observed a large ammonoid that I was not able to extract. The Producti are not altogether abundant, and are more often perhaps in the lower layers. The Allorismas sometimes occur in the chert concretions. The two valves are commonly together, but frequently flaring, showing the original presence of the ligament, and often not at all parallel to the bedding, in noteworthy contrast with the way the shells occur in the beach deposits of the Marshall.

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

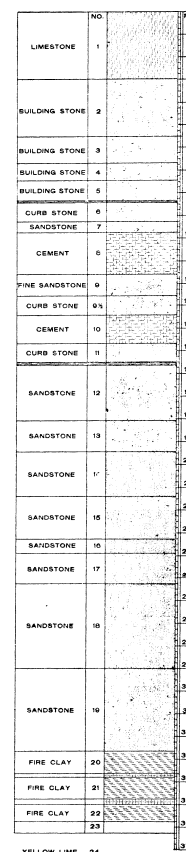


Figure 8. Beds as given at Bayport quarries.

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

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

The calcareous sandstone here exposed is very fossiliferous, and has been noted by previous writers. It should be studied by an able palæontologist on the spot, as it is often very friable, even when charged with fossils. Beside previous forms is one described as *Spirifera Keokuk*, which appears to me to be more likely a *Spiriferina*. For a fuller list see Chapter X, § 4. These beds must be in the lower part of the formation, for the wells after passing from the calcareous sandstone, which is the surface rock, into a more massive limestone, which has been developed by some test pits below, in about 12 feet pass into a "blue rock," which appears to belong to the Michigan series, and to be a pyritiferous shale. South of this exposure the limestone is absent for some distance, being lifted up by the anticlinal indicated in Fig. 6, and the depth to rock is greater, but if we may trust the Lake Survey charts, there is a rock bottom almost all along the coast, and in that case the limestone ridge or bluff probably turns to the south almost at the coast line and following it along returns again, as indicated on the map, somewhere north of Sebewaing, to the land.* In its return, however, it is much thinner, as shown by the record in Bauer's well in Sebewaing, and in some of the well records in this corner of the county cannot be recognized at all.

*Between Haffner's in Fairhaven and Sebewaing, is $2\frac{2}{3}$ miles. Difference of elevation of Napoleon sandstone is $(610 - 132) = 478 - (596 - 252) = 344$, i. e. 134 feet; accordingly the dip is 50 feet per mile. Hence the limestone bottom 127 feet down at Sebewaing $(596 - 127)$, 469 feet above tide, will strike the rock surface 540 feet above tide about 1.42 miles north-northeast of Sebewaing.

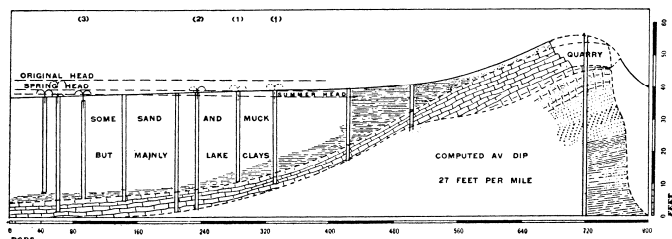


Figure 9. Cross-section from Bayport quarries, southwest showing the relations of present surface, rock surface, flowing wells, and varying water level at point of intake.

§ 5. Coal measures.

The Coal measures occur only in a little basin near Sebewaing. This formation does not anywhere outcrop, and we are therefore dependent entirely on the well records and the shafts for our information. I am obliged to the courtesy of Mr. Chappell for an opportunity to visit the mine of the Sebewaing Coal company. As litigation

was in prospect, our notes are in some ways deficient and wanting in numerical accuracy. The following sketch-map (Fig. 10) and section Fig. 11, show the general relations. The two companies to first mine the coal both began in troughs. The main shaft of the Sebewaing Coal company has about $4\frac{1}{2}$ feet of coal at a depth of 125 feet. At the air shaft, 200 feet west, the coal is but 109 feet deep, and at the first shaft which was opened (still farther east), by John T. Russell, it was but 86 feet down through the coal. In this first mine there was much water. One miner* reports having encountered a water channel into which he could stick his whole head, and I myself saw such a channel in the present mine which would easily admit an arm. Turning from the 125 foot shaft to the west we find the coal rising, for the last fifty feet quite sharply, as much as one foot in six, until we come to a fault, which may be from 350 feet to 650 feet west of the shaft. On the line of the fault was this cavity which had a corroded surface, somewhat as if the water had made it by dissolving pyrite from the rock. This cavity is 8 inches by 5 inches and many feet in depth. Slickensides on the coal are well marked and also in the slate. Though the fault was always reported to me as having an upthrow west, it appeared at this point as having a downthrow of about 2 feet, the overlying slate coming in at the roof. The dip of the fault, judging both by the cavity and slickensides aforesaid, was steeply to the west.† The general relations along an east and west line are illustrated by Fig. 11.

*Geo. N. Fleming.

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

I noticed little crystals of gypsum on the surfaces of the coal at this point and as we approach the fault the mine is very wet, and the mine water is somewhat salty, and very strong of sulphates, depositing in the galleries a heavy flocculent precipitate of iron. The water is said and seems to come in from the bottom. It is true, however, in a general way, that the fault throws the formation up, i. e., that the coal to the west and southwest is higher than at the shaft; and as we often find in going toward the center of a coal basin another seam makes its appearance above the first. The section on Sec. 7 is about as follows:

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

Sandstone, 15 feet or less.

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

Fireclay and lighter shales, 19-6 feet.

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

"Fireclay," 0-5 feet.

Sandstone, 12 feet and more.

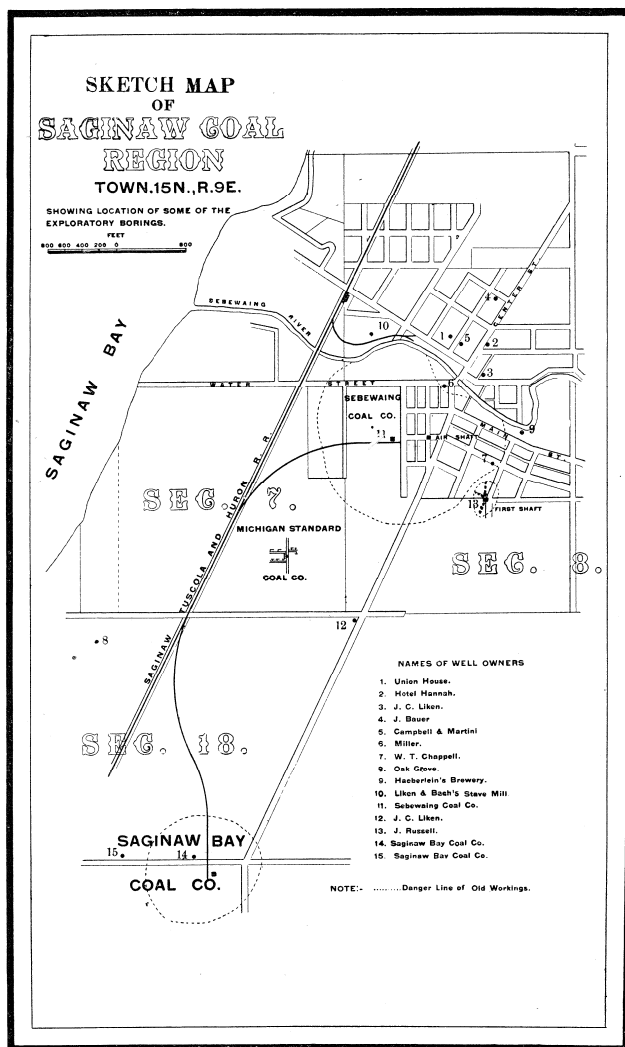


Figure 10. Sketch map of Saginaw coal region, showing location of some of the exploratory borings. The mines have not been mapped, but the dotted line indicates the danger line or area within which the workings are probably confined.

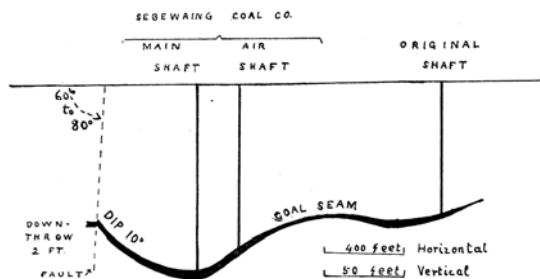


Figure 11. Illustrating the relations of the coal and the fault at Sebewaing. This is a cross-section in a generally westerly direction, but the shafts and borings shown are not in line.

At the time the coal was formed the land was just about the level of the water, and in the marshes and flats thus formed the coal was deposited. It has been estimated that in the shrinkage from vegetable matter to coal, a loss of volume to about one-fifteenth takes place, so that a four foot bed of coal would mean an original swamp deposit some 60 feet thick. Thicker deposits would generally be formed in the hollows of the surface, and as they subsequently shrank and settled, there would be a

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

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

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

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

1 inch to 1½ inches of pyrite then

4 feet of fair coal somewhat pyritiferous.

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

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

(Adapted so far as possible to a well 2270 feet deep at Caseville and one 1920 feet deep at Harbor Beach.)

