in the paths of the former glaciers and were completely over ridden by them, but give no suggestion in their forms of having been abraded. These conspicuously exceptional features of a glaciated region will be considered more fully on a later page; the immediate subject in hand being the characteristics of ice-abraded rock surfaces.

The influences of variations in the texture of rocks on the characteristics of ice-abraded surfaces, is well shown at several of the localities indicated on the map forming Plate XVI, where striæ are recorded, and particularly on Drummond Island, the locality north of Hessel, near Orville, and at Marblehead. At each of these localities and less conspicuously at other places where striated rock surfaces were seen, the limestone or dolomite, contains silicified fossils, which are harder than the rock about them. In numerous instances where such bodies are embedded in a glaciated surface, there are grooves about their borders on the side from which the ice came; these grooves usually a fraction of an inch in depth and in width, extend along the lateral margins of the obstructions, and becoming less deep die out at a distance of an inch or so on what may be termed their lee border in reference to the direction the ice flowed over and about them. When these grooves are present there is also a tapering ridge on the lee side of the obstruction and at its proximate end having the same height above the adjacent surface, which tapers to a point in the direction the ice moved. In many instances, however, the tapering ridge on the lee of a silicified shell, is present, but a frontal groove with its decreasing laterals is absent.

The grooves and ridges just described, are of special interest as they show the direction in which the ice moved which produced them. The grooves occur on the side of the obstructions from which the ice came and passing about them, die out in the direction in which the ice moved; while the tapering, cone-like elevations, are on the lee side of the obstructions and point in the direction the ice left them as it flowed. While the grooves and striæ that glaciers charged with debris make on rock surface, do not in themselves show in which direction the abrading tool moved which engraved them whether, for example, from north to south or south to north, the grooves and trains just described answer this question with great precision. There are other markings, also, as will be noted below, which furnish similar testimony.

The grooves and ridges just referred to, are also instructive in reference to the evidence they furnish concerning the physical condition of the ice which shaped them. The grooves show that a downward direction or eddy-like movement was given to the ice when it met an obstruction, similar to the eddy on the upstream side of a stone in a stream, which enabled the ice to scoop out a depression in the rock surface; but the tapering train on the lee side of an obstruction is equally positive evidence that the ice did not plunge over the elevation in its path as flowing water would have done, so as to scoop out a depression on its down stream side, but on the contrary, there was a relief of pressure in such situations and less abrasion than on the adjacent surface. In other words, an obstruction met by the ice formed a groove in its bottom which slowly collapsed. An exceedingly delicate adjustment of the ice between a condition of fluidity and a condition of rigidity is thus indicated; the ice being in such state that it could flow about the obstruction and be deflected downward so as to grind out a groove, and at the same time sufficiently rigid to be itself grooved by the obstruction over which it passed, and kept from abrading the

rock under its lee. The knobs with grooves and trains, seem to show that ice under heavy pressure behaves like a viscous but almost fluid body, but variations in the results produced on abraded surfaces,—such as the absence of the frontal grooves about obstacles in many instances, and the presence of striæ and deep grooves which imply a firmly held tool,—are equally eloquent in proclaiming the rigidity of the ice which was concerned in their production. These diverse conclusions seem to show that the ice in the basal portion of glacier is at times viscous and almost fluid-like in its mobility, and at other times behaves as a decidedly rigid solid. Two variations in the controlling condition may reasonably be surmised to account for these contrasts in results; first, differences in pressure, and second, variation in the percentage and character of the foreign material, such as sand, gravel, etc., present in the ice.

Variations in pressure while tending to vary the degree of plasticity of ice,—if the pressure were sufficient it would cause the ice to melt at the temperature normally present, and thus become a fluid—can scarcely be claimed as the controlling condition which produced the differences in results referred to, which in one area record the passage of a highly viscous body, and on a neighboring surface, give evidence of the passage of a decidedly rigid body. Indeed, both of these contrasted conditions are frequently recorded on the same surface only a few square feet in area. At the bottom of a glacier several hundred and possibly a few thousand feet thick, variations in pressure from place to place or variations in short spaces of time at the same locality, cannot reasonably be assumed to be such as to produce the differences in the grooved and ridged rock surfaces to which attention has been directed.

While pressure on ice tends to make it behave as a plastic body—the greater the pressure up to the limit of elasticity, if not to the point of melting, the greater the plasticity—debris added to the ice acts in the other direction and tends to reduce plasticity, and if present in sufficient amount would cause the ice to remain stagnant under conditions of pressure, which otherwise would cause appreciable flowage. Differences in adjustment, therefore, between pressure and per cent. of contained debris may be taken as the immediate control which determines whether the ice at any locality in a glacier will behave as a rigid or a plastic body. This conclusion requires to be qualified, however, as not only the per cent. of rigid (under the pressure present) material such as sand and gravel, but its degree of comminution exerts an influence as does also but to a less extent perhaps, its uniformity or heterogeneity of grain. For example, a given per cent. of fine sand enclosed in a given mass of ice would exert a different influence on its flow under pressure, than if the same per cent. of debris was in the form of gravel or large boulders.

In order to bring to a focus these ideas suggested by observing the grooves and trains of glaciated rock surfaces, I would say that at the base of a glacier several hundred or a few thousand feet in thickness, the weight of the ice would be sufficient to cause its basal portion to flow like a decidedly plastic substance as for example, pitch at a temperature of 100° F. under one atmosphere of pressure. If the ice under this condition was lightly charged with fine dust-like particles, or contained a small per cent. of fine sand, it might still retain its freedom to flow, but be capable of smoothing and polishing the surface over which it moved. It is under such conditions that the grooves at the front and along the sides of hard obstructions in

limestone, and the trains on the lee sides of such elevations seem to have been produced. If the percentage of foreign material present in the ice should be increased, it would make the mixture more and more rigid, the pressure remaining the same, and may reasonably be assumed to impart to the ice such a consistency that it would hold firmly to sand grain, or larger rock fragments, and carry them along so as to striate and groove the rocks over which they were drawn. Under this latter condition the small grooves and trains, considered above would not be produced, but larger features of a similar nature might result. Observations are seemingly in harmony with these deductions, since frontal grooves and lee-trains are absent from deeply striated rock surfaces, but features of a similar character as rock bosses, with or without trains of debris on their lee, are features in the landscape of many glaciated countries. These considerations invite a discussion of the entire field of glacial abrasion, glacial flow, etc., but this would lead too far afield.

In connection with the facts concerning glaciated rock-surface referred to above, I desire to put on record one suggestive observation which may be of interest to the reader.

On a finely polished limestone surface exposed at the bottom of a well, about 25 feet deep, dug in reddish, bouldery till, near Orville, there are many well-formed frontal grooves and leeward-tapering trains, associated with fossil shells embedded in the rocks and partially exposed to view by glacial abrasion. One fragment of a shell, nearly an entire valve of a brachiopod, about the size and thickness of one's thumb nail, was emplanted vertically in the rock at right angles to the direction of the former ice movement. The ice impinged on the side of the delicate shell, but was deflected by it and caused to scoop out a well defined frontal groove which was prolonged on each side of the shell in the usual manner, while in the lee of the obstruction a typical train about an inch in length was left in relief owing to the more intense abrasion of the adjacent surface. In this case, a thin, fragile silicified shell may be said to have turned a continental glacier from its course. As is evident the lateral pressure exerted against the shell was exceedingly small, probably not in excess of a few ounces to the square inch; the abrasive power of the moving ice was also exceedingly small as it failed to wear away a layer of quartz not over a tenth of an inch in thickness.

However powerful erosive engines glaciers may be when properly supplied with tools with which to abrade, the frontal grooves and tapering trains to be seen on many glaciated rocks and especially such instances of delicate work as just cited, furnish equally clear evidence that in the absence of tools they are nearly powerless to scour the surfaces over which they flow.

Chatter marks: Persons visiting localities where glaciated rock-surfaces occur in Northern Michigan, may also find still other examples of glacial inscriptions or markings the nature of which has been admirably described by Chamberlin, in the report referred to above. Among these records are "Chatter marks" in the bottom of strong grooves and assumed to have been produced by a vibration of the stone as it was forced along, which dug out the groove. These markings are curved cracks which cross the bottoms of glacial grooves from side to side, and as a rule present their convex sides to the direction from which the object came which led to their production. That is, if the ice moved from north to south, the chatter marks produced will present their convex sides to the north; but exceptions to this rule, or perhaps imitative markings have been noted, and chatter marks alone cannot be considered as decisive evidence of the direction a former glacier flowed.

Crescentic cracks: Crescent-shaped cracks of larger size than chatter marks, and usually occurring on flat rock-surfaces, seemingly independently of striæ and grooves, are also present at several localities in Northern Michigan. Examples of these crescentic "cross-fractures" as they have been termed by Chamberlin, occur on the south shore of Lake Duncan, and on a bare rock surface crossed by the road leading from Garden to Fayette near Garden Bluff (T. 39 N. R. 19 W.) where they are unusually abundant. The cracks are three to four or five inches long, and occur in series in the direction of ice movement, at intervals of two to perhaps four inches. Some of the series containing six to ten cracks, all curved in the same direction and presenting their convex sides to the northwest, the direction from which the ice came. Just how the cracks of this nature were produced is not known, but they are clearly glacial records, and seemingly furnish good evidence as to the direction of ice movement. The cracks penetrate the rock to the depth by estimate of two or three inches, and frequently endure when striæ and other of the more delicate records left by former glaciers have been obscured or removed by weathering. The presence of a series of parallel crescentic cracks separated by intervals of two to four or five inches, is sometimes all the evidence that remains of the former passage of a glacier over a rock outcrop.

GLACIAL DEPOSITS.

The vast continental glaciers which came from the north and advanced southward over Michigan, left records of their invasion not only in the form of inscriptions on the solid rocks over which they passed, as described in part in the last few pages, but deposited debris both directly and with the assistance of the streams formed by their melting. Two classes of superficial deposits thus originated; one glacial and the other fluvio-glacial.

Till: The material gathered by glaciers as they advance and deposited as they flow, or left when they melt, is known as till. In the region here considered the till consists very largely of a reddish, sandy clay, usually containing many angular or sub-angular stones and rounded rock masses. The larger stones whether angular or rounded, deposited by a glacier are termed boulders. The material which glaciers deposit directly without the assistance of streams, passes under the general name of moraines; but this term is applied more specifically to the irregular ridges and hills of sandy clay and boulders, accumulated about their margins, as lateral moraines, terminal moraines, etc., or concentrated on the surface of the ice as medial moraines. Such heaps and ridges are not present in the portion of Michigan described in this report, which means that the former glacier did not halt in that region and maintain a definite frontal alignment for a sufficient length of time to permit of the deposition of recognizable deposits of the nature just mentioned. If the ice lingered with a front extending cross the part of Northern Michigan referred to, it was so nearly clear of debris that no ridges or hills were formed. Glaciers under certain conditions of load, deposit material as they flow and on melting leave all of the debris previously contained in them, or present on their surfaces; in this manner a general sheet of rock-waste is deposited like a blanket over the country they occupied and mantles the hills and valleys. Such a sheet of glacially deposited debris is termed a till sheet; typical till being an unstratified sandy-clay well charged with sub-angular stones and boulders. It is material

of this nature which now constitutes the surface layer over large portions of Northern Michigan and adjacent regions.

Restricting attention to the land adjacent to lakes Huron and Michigan on the north, it may be said that a sheet of till was left over its entire surface when the former glaciers finally melted. Exceptions to this rule were probably furnished by precipitous slopes, such as the cliffs on the border of Mackinac Island, the face of Burnt Bluff, etc., but localities of this nature are rare, and most likely every ledge even on the faces of such precipices formerly had some glacially deposited material upon it. Since the ice melted which deposited the nearly universal till sheet referred to, many changes have occurred; the till has been washed from steep rock declivities by the rain, and rills and streams have cut channels through it, but the most conspicuous modifications are due to the wash of the waves and the action of currents in the waters occupying the basins of lakes Huron and Michigan, when they stood higher than at present. Below the old beaches, indicated on the map forming Plate XVI, the till has to a large extent been removed, assorted and redeposited through the action of lake water.

In physical composition the till in the region under consideration is nearly always reddish in color, conspicuously sandy, and contains numerous stones and boulders. The reddish color and sandy consistency is due, as seems evident, to the fact that much of it was derived from the red sandstone which is largely developed about Lake Superior, and probably now occupies much of the basin of that lake.

Two general classes of stones and boulders are present in the till; one class consists of limestone and dolomite fragments derived especially from the Trenton and Niagara formations which form the hard-rock surface of much of the region in question; and the other class embraces the stones and frequently rounded boulders of all sizes up to about three feet in diameter, composed of crystalline rock, such as is only found in place in the Lake Superior region, in Canada and in Northern Michigan to the west of the longitude of Marquette. As may be most reasonably inferred the boulders of crystalline rocks occurring in the drift to the north of Lake Huron, were derived principally from the portion of Canada lying to the north and east of Lake Superior; while the similar debris in the region north of Lake Michigan, was mainly derived from areas of crystalline rock to the south and southwest of Lake Superior. In reference to the relative proportions of locally derived, mostly calcareous material, and of the crystalline rocks brought from a greater distance, the former is nearly everywhere conspicuously in excess of the latter.

The nature of the stones contained in the till furnishes a means for determining from what direction the former glacier came, and the direction the ice moved, but as yet this criterion cannot be applied except in a few instances, as the rocks represented usually occur in place at more than one locality, or are not sufficiently characteristic to be readily identified.

There are two conspicuously characteristic rock outcrops, however, the debris from which can with certainty be referred to the parent ledges from which it was derived. These are: A red jasper conglomerate which outcrops in Ontario, to the north of North Channel, and about fifty miles north of Drummond Island; and the copper-bearing rocks of Keweenaw Peninsula.

The red jasper conglomerate is easily recognized by the angular fragment of bright red jasper it contains, embedded in a usually white, somewhat

vitreous quartzite base. Fragments of this rock frequently a foot or two in diameter, were observed on Drummond Island, about Hessel, on Bois Blanc, and other localities as far west as the St. Ignace Peninsula. Evidence is thus furnished that glaciers once covered the region to the north of Lake Huron, and moved southwest at least as far as the north end of Lake Michigan. This may not have been a single direct movement, but a general southwest flow of the glaciers at some time during the Glacial epoch in the region indicated is certainly shown by the distribution of jasper conglomerate just cited. Fragments of this same red jasper conglomerate are present in the glacial deposits of Southern Michigan, Northern Indiana and Ohio, and have been found in the vicinity of Cincinnati. A surprisingly wide distribution from a restricted area is thus shown to have occurred and taken in connection with other evidences indicates that the material laid down during one ice advance was removed and redeposited during one or more subsequent ice advances.

Native copper derived, as seems most probable at least, from the copper-bearing rocks of the Keweenaw Peninsula, has been found in the glacial deposits of Menominee county, on the Garden Peninsula, and as far eastward as the St. Ignace Peninsula, thus demonstrating that during some portion of the Glacial epoch there was an extensive ice movement over Northern Michigan from the northwest toward the east and southeast. Boulders of native copper have also been found in the glacial deposits of Southern Michigan and Ohio, thus showing as wide a dispersion by ice moving from the northwest, as do the boulders of red jasper conglomerate referred to above, in reference to the ice which came from the northeast. On the St. Ignace Peninsula, these two general movements overlapped as they did also over an extensive region to the south. Which was the earlier movement so far as is now known, is not definitely shown in Northern Michigan, although as will be stated later, in Menominee county the last ice invasion of that region came from the northeast and covered a till sheet containing native copper and fragments of iron ore, which had previously been deposited by a glacier moving from the northwest. In Southern Michigan, and the states adjacent on the south, much more definite information is recorded by terminal moraines, etc., than has yet been discovered in Northern Michigan, and a complex history has been deciphered by Frank Leverett and others.

The blanket of till covering the country under consideration is thin, not only in comparison with the glacial deposits of Southern Michigan, etc. but actually as measured in feet. From the east shore of Drummond Island westward to the north end of Lake Michigan, an estimate based on the records of a few wells and on the height of the present surface above observed rock outcrops, places the general depth of the superficial covering of rock-waste at from 20 to 30 feet. Practically all of this region, however, has been covered by lake waters, and the surface material has to a considerable extent been reassorted and concentrated especially just below the abandoned shore lines of the former lakes. Where the till has not been disturbed, as on the hills about six miles north of Hessel, on the summit of Mackinac Island, and about Allenville, etc., its thickness on an average is approximately from 15 to 20 feet. To the west of the St. Ignace Peninsula, numerous measures were obtained of the depth of the till sheet there generally present, and an estimate of from 10 to 20 feet may be taken as a general average of its thickness. To the south of the Minneapolis, St. Paul and Sault Ste. Marie railroad, on the triangular area terminating at the south in Point

Patterson, many surface exposures of the underlying limestone are present, and the greatest thickness of till obtained from the records of well, is 20 to 25 feet; the average for the area indicated is thought to be not over 10 to 15 feet. On Garden Peninsula to the south of the surface sand which occupies much of its northern portion, the covering of till is noticeably thin, many rock outcrops being present, and numerous well records available, and its average depth is certainly not over 10 feet. On the Bay de Noc Peninsula, a large amount of testimony gathered in part from farmers, shows that the thickness of the till which is spread quite uniformly over the level surface of the underlying limestones is on an average not over five feet. Throughout the greater portion of Menominee county, situated to the west of Green Bay, numerous hills composed of drift, termed drumlins, are present, and much more glacial debris was left on the underlying hard-rock surface than elsewhere in the region here considered. The hills referred to are in many instances about 40 feet high, and composed of till throughout, while in the intervening valleys the underlying rock although bare in places is usually from five to ten feet below the surface. The depressions or valleys occupy more space than the hills and for the entire country the average depth of till is probably not over 20 feet. Observation made on the hills about Metropolitan and Iron Mountain, show that in that region the true till sheet is from 10 to perhaps 15 feet in thickness, although in the low lands, considerably thicker deposits of the same material together with water laid sand and gravel are present.

The thinness of the sheet of morainal material left by glaciers over the portion of Northern Michigan described in this report, is in conspicuous contrast to the deep accumulations of similar material over all of the Southern Peninsula, and in fact of nearly the entire glaciated area of the United States from the Atlantic to the Dakotas. To the north of Lake Superior, however, as is known at least in a general way, glacial deposits are wanting over extensive areas, and bare and for the most part glacially abraded rocks are exposed. Northern Michigan thus appears to be situated between a region of glacial abrasion on the north and a region of glacial deposition on the south, but is more nearly related to the northern area. The facts presented above in reference to the small thickness of till in the part of the Northern Peninsula referred to, and the absence in that region of moraines, such as are formed about the margins of glaciers, together with the notable depth of glacial deposits, inclusive of surface-formed moraines, over the whole of the Southern Peninsula of Michigan, show that the change from abrasion to deposition in the case of the former glacier which covered Michigan, occurred in the region bordering Lake Superior on the south. It should be remembered, however, that glaciers may both erode and deposit at the same locality, at different times, and that deep glacial deposits may formerly have been present in North Michigan and later removed through the same agency which laid them down. In fact, as will be shown later, there is evidence of a conspicuous amount of ice erosion of previously deposited till in the region here considered.

DRUMLINS.

Among the characteristic changes in topography produced by the broad ice sheets of the Glacial epoch, both in Europe and North America, are smooth-surfaced, oval hills and ridges composed of till, the longer axes of which are parallel to the direction of flow of the ice which shaped them. These symmetric "lenticular hills," as they were at first termed in this country, are now designated as *drumlins*, a name first applied to them in Ireland and signifying a back or a ridge. Two types of drumlins have been recognized; one comprising short, broad forms, elliptical in ground plan, the longer axis only two or three times the length of the shorter axis, and measuring from a few hundred to perhaps two or three thousand feet in length; and the other consisting of long narrow ridges, in which the length is perhaps ten or twenty times the width, which attain lengths of from perhaps a mile to two or three or more miles. Between these two most common types, however, intermediate gradations may be found; and in many regions, more or less oval hills and ridges composed of till, approach in shape the true drumlin, but are less regular and less systematically arranged and may be termed *drumloids*. By this term is meant that the hills and ridges to which it is applied, approach or simulate typical drumlins in many ways, and are probably to be considered as incomplete or immature topographic forms of the same mode of origin.

In Northern Michigan two drumlin areas are known; one including Les Cheneaux Islands, and a portion of the adjacent mainland; and the other situated principally in Menominee county to the west of Green Bay. These two regions in each of which the dominant topographic forms are drumlins, are from 125 to 150 miles apart in essentially the same latitude, and are conspicuously different in the trend of the longer axes of the oval hills and smooth crested ridges which give them character. In Les Cheneaux area the direction of the last ice movement was from the northwest toward the southeast; and in the Menominee region from the northeast toward the southwest. The drumlins in each area were fashioned and given their characteristic shapes by the last ice sheet that moved over it, but the direction of ice movement in one of the areas, as just stated, was at right angles to the similar movement in the other area. This contrast in the direction of glacial flow is suggestive when taken in connection with the records of ice movement furnished by striæ, etc. on the solid rocks of the same general region and by the character of the boulders in the till, which can be traced to their parent ledges. That is, the details in the history of the Glacial epoch are far more varied and complex than is perhaps generally appreciated.

LES CHENEAUX DRUMLIN AREA.

An examination of the shore line about the Great Lakes as platted on the charts of the Northern and Northwestern lakes issued by the Corps of Engineers, U. S. army, shows that the outline of the land among Les Cheneaux islands and along the neighboring coast of the mainland, is conspicuously different from that of any other portion of the borders of the Great Lakes. The exceptional feature is the conspicuous parallelism in trend of the islands and of the capes on the adjacent mainland. Six measurements of the trend of the longer axes of the islands and capes made on the charts referred to

(reproduced in part on Plate V), give an average bearing of S. 52° 30′ E., with an extreme variation of less than one degree. Long narrow, stony ridges on the adjacent main land have the same trend as the similar ridges which form the islands and capes. In brief, the leading characteristic in the relief of the land and in the trend of the shore line, is furnished by a series of long, narrow parallel hills, part of which stand on the land and a part in the water. These hills are composed of till and have other characteristics of drumlins. As the reader will infer from these statements, Les Cheneaux Islands, owe their peculiar and conspicuous alignment to the fact that a group of drumlins is there partially submerged by the water of Lake Huron. This conclusion is rendered still more evident when the relief of the islands is also considered, as their surfaces present ridges and troughs, similar to the corresponding features about the neighboring villages of Hessel and Cedarville. The larger islands bear on their surfaces groups of parallel ridges trending northwest and southeast, the troughs between the ridges being above water except at their ends where narrow bays extend into the land. A number of the smaller islands as Richard, Isadore, etc., which consist of a single straight ridge with rounded cross-profile are individual drumlins. In a few instances as shown on the Lake Survey charts, the ends of islands and of capes are hooked or barbed, as for example the northwest end of Boot Island, and the extremity of the cape where Hammel's fishery is located. A visit to these localities showed that the exceptional outlines they present are due to wave action along the shore, such as the building of spits, or connecting bars between islands, etc.

The trend of the longer axes of a group of drumlins as already stated, is as a rule parallel to the direction of flow of the glacier which shaped them. This test can be applied to the long narrow hills in the Les Cheneaux region. On a flat limestone surface about one mile north of Hessel and crossed by the road leading north from that village, glacial striæ and associated markings are well exposed. The general direction of ice movement thus recorded, is from northwest to southeast, and indicated on the map forming Plate XVI. Two series of striæ, etc. are present; the stronger, and as the evidence seems to show, the earlier series, trends N. 70° W. (an average of six measurements with a range of 10 degrees); crossing this series is a series of more delicate striæ, bearing N. 57° W. (three readings being the same). The trend of Les Cheneaux Island as stated above is S. 52° 30′ E. This as nearly as can be determined is also the trend of the longer axes of the ridges, as measured along their summits; the trend of the hills thus corresponds approximately with the direction of the lighter series of striæ on the adjacent rock surface; the difference being four and one-half degrees. In this instance the ice at the time the hills were given their present symmetrical shapes, crossed a previously scored rock surface but left only a delicate inscription upon it.

The drumlins at Les Cheneaux, are of the elongate type, being in several instances from one to two miles in length, with a maximum width of from about five hundred to eight hundred feet in the largest examples and with a height above the intervening troughs of forty to about fifty feet. How many drumlins there are in the group is not definitely known, but there are certainly fifty and perhaps twice that number may be present. They are composed of compact clayey till of a reddish color and contain many large boulders. The boulders are in part composed of limestone and are of local origin, and in part of crystalline rocks such as occur in places in the neighboring portion of Canada. At one excellent section across a drumlin

at Cedarville, where a cut for a road has recently been made, the stiff clay is laminated, the laminæ being distinct in the upper five or six feet of the exposure, but less evident and seemingly wanting at a greater depth. The laminæ are curved and parallel with the convex surface of the ridge as exposed in cross sections.

One of the most conspicuous features of the drumlins forming Les Cheneaux Islands, etc., is that their surfaces are strewn with a multitude of boulders. This feature is well shown by the photograph forming Plate VI, A, taken at Hessel. This roughness of surface and abundance of loose boulders is exceptional to the normal condition of the surfaces of drumlins, which as a rule are conspicuously smooth and even. Its explanation lies in the fact that the waters occupying the Lake Huron basin were formerly higher than at present, and the waves and currents working on the drumlins removed much of the fine material from their surfaces and thus concentrated the stones and boulders. In their present condition they may be termed washed drumlins. At one stage in the history of the basins of the Great Lakes the water was about 200 feet deep at Les Cheneaux Islands the shore line being then about six miles to the north, where islands were present in Lake Algonquin as the former water body has been named. The washing, however, which removed the finer material from the surface of the drumlin, as just mentioned, occurred when the lake waters were at a lower level and principally when they stood about forty feet above their present horizon and what is known as the Nipissing beach was produced. The position of this old lake margin is shown by gravel terraces on the sides of some of the drumlins about Hessel and is particularly well marked at Cedarville.

MENOMINEE DRUMLIN AREA.

Distribution: Well defined and characteristic drumlins occur over the greater portion of Menominee county, with the exception of the sandy region five to six miles wide adjacent to Green Bay, and perhaps extend northward into Marquette county and westward into Dickinson county. The drumlin area is more extensive than the one at Les Cheneaux Islands, and is thought to embrace about 750 square miles. The number of drumlins is certainly many hundred, and possibly several thousand, but no reliable estimate in this connection can as yet be made. The most characteristic portion of the area so far as now known, lies between Wallace on the south, and Northland on the north, and in an east and west direction, between Ford River station and Hermansville. The drumlins are numerous along each of the railroads radiating westward from Escanaba within the region just indicated, and are especially abundant along the line of the Chicago and Northwestern railroad between Bark River and Powers. Perhaps the best localities for observing them is in the vicinity of Wilson, Spalding, Powers, Hermansville and thence southward to Stephenson.

Absence of solid-rock cores: The region just designated is underlain by Trenton limestone which is approximately horizontal, and has a nearly even surface. No suggestion of rocky knobs or other elevations that might have served as nuclei for the accumulation of glacial debris are present.

Shape: The drumlins are largely of the elongate or ridge like type, many of them being from half a mile to two miles long, while some are yet more extended. Their widths are in numerous instances, from 300 to 800 feet in the widest part. A typical example, the first one cut by the Chicago and Northwestern railroad to the west of Indian Town, measured by pacing,

is 9,000 feet in length, and 750 feet wide in the central part; and has a maximum height of 30 to 35 feet above the adjacent marshy troughs. It tapers gradually in both width and height from the center toward each end and terminates in each direction in a well defined obtuse point. Several neighboring examples have similar dimensions. The ratio of width to length in these instances is in general about as one to twelve or fourteen. In some of the smaller examples near Spalding, this ratio is approximately one to two or three.

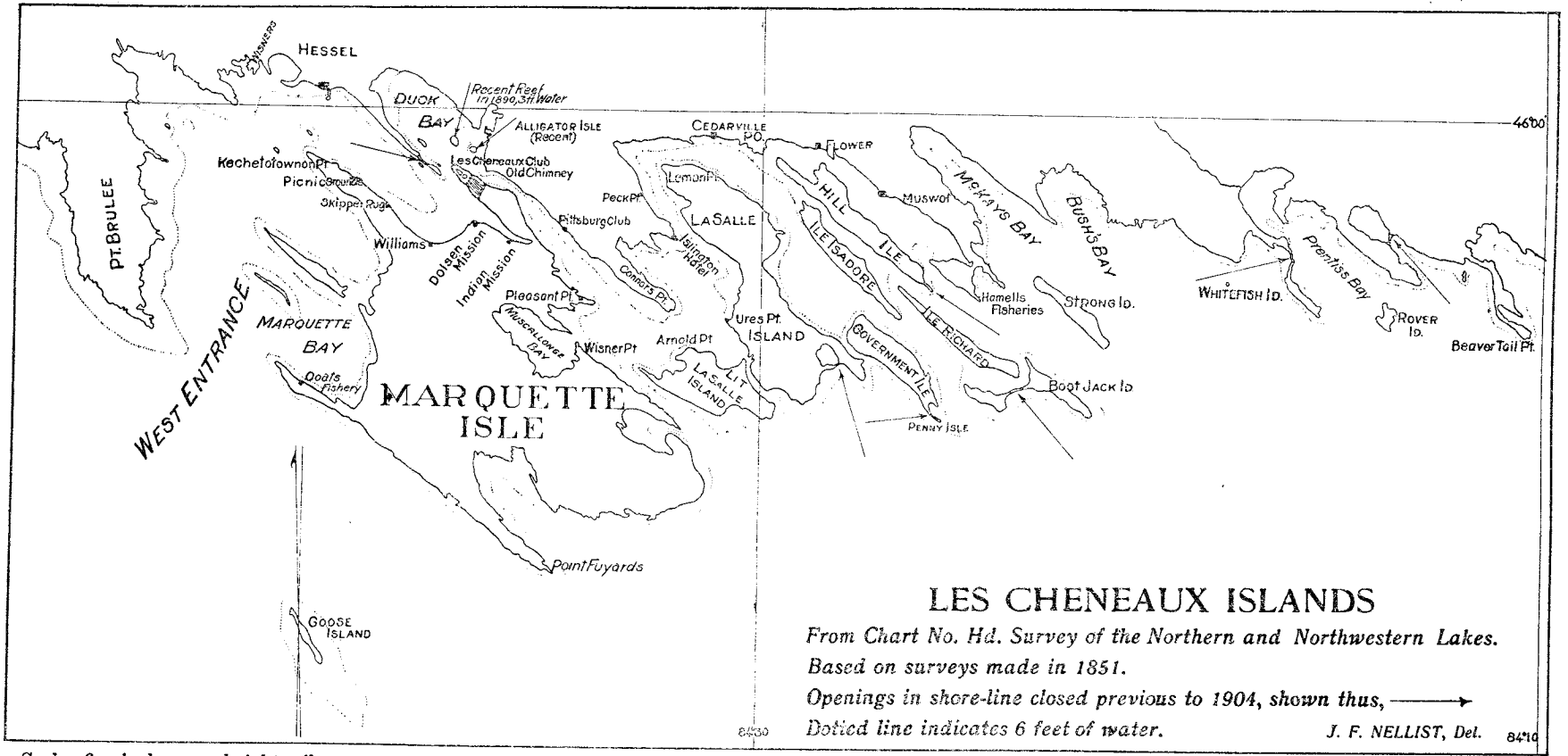
Trend: The general trend of the longer axes of the drumlins is northeast and southwest, but considering the entire area there are conspicuous variations in this particular. While neighboring drumlins as for example throughout a distance of a mile measured at right angles to their general trend, are in some instances strictly parallel, in other instances a divergence of trend of their larger axes amounting to fully fifteen degrees as observed. Throughout the portion of the area which was traversed the extreme variation in trend is between N. 12° E. and N. 55° E. These variations seem to have an orderly sequence and the drumlins over a large area to swing symmetrically, but not enough observations are in hand to make this conclusion definite.

Uniformity in elevation: A more conspicuous feature than the general parallelism of the drumlins is their nearly uniform height. An observer standing on the highest portion of the crest of any one of the larger examples and examining the neighboring drumlins with the aid of a hand level will find that all of the larger ones in view rise to the same level with a variation of less than five feet. Some of the smaller examples fail to reach the summit level of their larger companions, but no drumlins rise above that level. In other words, if the depressions and valleys between the drumlins were filled to the level of the summit of the majority of them, a horizontal or essentially horizontal plain would be produced.

Height: The height of the drumlins above the bottoms of the intervening valleys is in general from thirty-five to forty feet; the variation being due to the depth to which the valley has been excavated, and the amount of stream deposited sand and gravel or peaty material present in them.

Rock striæ: Exposures of rock surfaces between the drumlins are somewhat common, and at one locality about one mile east of Spalding, on the line of the Chicago and Northwestern railroad, a glaciated limestone surface bears glacial striæ and related markings, which record an ice movement from the northeast toward the southwest. The striæ bear N. 38° E. That is the direction of glacial flow as recorded by striæ, etc., is substantially the same as the trend of the longer axes of the drumlins; it is worthy of note, however, that the drumlins nearest to the locality where the striæ were observed, trend N. 55° E.

Composition: The drumlins with the exception of a thin surface layer, are composed of reddish, sandy till charged quite uniformly with stones and boulders. Their appearance in section is well shown on Plate VI B. Many of the stones are angular fragments of Trenton limestone, derived from near at hand, but the larger and more conspicuous boulders are of hard crystalline rock and usually well rounded. In certain of the drumlins near Powers, the limestone fragments amount to fully eighty-five or ninety per cent of the rock-masses present which are a foot or more in diameter. Of the finer material between the stones and boulders quartz sand constitutes a conspicuously large proportion. The limestone fragments are mostly flat masses broken from strata from two to six inches thick and are without orderly



LES CHENEAUX ISLANDS

From Chart No. Hd. Survey of the Northern and Northwestern Lakes.

Based on surveys made in 1851.

Openings in shore-line closed previous to 1904, shown thus, ——→

Dotted line indicates 6 feet of water.

J. F. NELLIST, Del.

Scale: five inches equal eight miles.

arrangement; that is, the flat blocks are packed in the enclosing sandy-till with their longer axes pointing in all directions.

Absence of lamination: In no instance was the lamination observed, which is sometimes stated to be peculiar to drumlins. This feature as cited on a previous page, is present in the clayey till of the drumlins at Cedarville, and its absence in the drumlins under consideration, suggests that it is dependent on the physical condition of the till of which drumlins are composed, and is to be expected in those consisting largely of clay but not in those composed of decidedly sandy till.

Copper and Iron boulders: In certain of the drumlins near Powers, Nadeau and Daggett, several battered and scratched masses of copper have been found, and also large fragments of specular iron ore. These boulders as already stated, were no doubt derived from the copper and iron-bearing formations which come to the surface in Northwestern Michigan and show that the glacier which transported and deposited them moved from the northwest toward the southeast. The trend of the striæ on a rock surface near Spalding, and the general alignment of the drumlins as already stated, point conclusively to an ice movement from the northeast toward the southwest. The bearing of the evidence thus furnished, of two ice movements, —the later being at right angles to the earlier—on the theory of the origin of drumlins will be considered later.

Surface material: The surface portions of the drumlins as stated above, differ from the material beneath. As observed in a large number of instances their surfaces to a depth of about a foot or eighteen inches, are uniformly covered with a layer of fine dustlike loamy sand. This material when examined under a microscope is seen to consist principally of angular grains of quartz, but mingled with the determinable grains are fine, brownish, amorphous particles. It is so fine that 66.35 per cent of it will pass through a sieve having one hundred meshes to the linear inch.[1] This fine surface soil is exceedingly favorable to agriculture and for this reason the drumlins throughout the Menominee area, have to a great extent, been cleared of forests, and are now under cultivation. Mingled with the fine dust-like material of the surface layer are numerous stones of all sizes up to boulders fully three feet in diameter. These surface stones are to a great extent limestone fragments, but a few and including the larger ones, are of crystalline rock. In many of the fields on the drumlins, the surface stones have been removed and piled in large heaps, leaving a surface of conspicuous evenness composed of fine rich loam. Where the stones have not been removed they form a pronounced feature of the surface.

Irregularities: Normal drumlins, as is well known, are smooth oval hills without irregularities; while the majority of the drumlins in the Menominee region fulfill these conditions, there are certain notable and suggestive exceptions. It is difficult to classifiy the irregularities referred to, but they may at least provisionally be termed transverse trenches, side trenches, surface pits, and asymmetry in ground plan and marginal slopes.

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1 An average sample of the soil freed from pebbles, and subjected to mechanical analysis in the presence of water, gave the following results:

Retained on a sieve having 10 meshes to linear inch	6.73 per cent.
Retained on a sieve having 50 meshes to linear inch	11.21
Retained on a sieve having 100 meshes to linear inch	15.71
Passed through sieve having 100 meshes to linear inch	66.35
Total	100.00

Of the portion of the sample which passed through a 10 mesh sieve, 20.05 per cent was soluble in hydrochloric acid, and may be termed a dolomite rock-flour.

Transverse trenches are trench-like depressions through a drumlin at right angles or nearly so, to its longer axis and in the case of the deeper examples resembling railroad cuts. Their bottoms are frequently on about the same level as the adjacent troughs or valleys but in some cases are less deep. In no instance were deposits observed in the marginal troughs at the ends of the trenches, of the nature of alluvial cones, such as would suggest that the trenches are due to the action of streams since present conditions obtained; although in certain cases a small amount of gravel has thus been washed out of them and deposited at their ends. Good examples of the kind of irregularity here considered and in fact of several of the irregularities mentioned above, may be seen in the first drumlin cut by the Chicago and Northwestern railroad to the west of Indian Town. Another typical instance is present about one mile southwest of Wilson and to the south of Cedar River. The most instructive example thus far seen, however, occurs near the southwest end of a drumlin about half a mile northwest of Spalding (in the N. E. quarter of section 9, T. 38 N. R. 26 W.) In this instance an esker, as will be described more fully later, which follows an irregular east and west course, approaches the transverse cut in the drumlin from the east, and at the west end of the cut continues its course westward, The conditions are such as to show that the esker was deposited by a sub-glacial stream which excavated the trench across the drumlin.

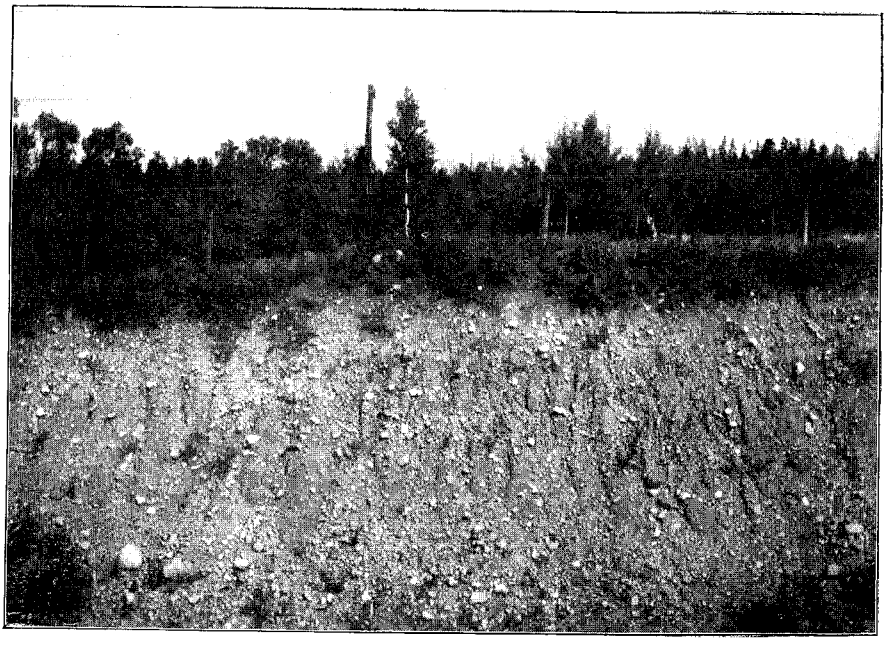
Side trenches are cuts in drumlins which begin near their crests and extend down one side, becoming deeper and broader as the adjacent valley is approached. In a number of instances the depressions referred to head well to one side of the crest of a drumlin, cut through its axis and open out into the trough on the opposite side, thus showing most of the features of the transverse trenches, but having a distinct proximal end. For example, in the first drumlin west of Indian Town and near its northeast end, an excavation begins on the southeast side of the drumlin and only a few feet above the level of the marginal trough on that side, and extends toward the northwest through the drumlin and opens out on a level with the interdrumlin trough on that side. These trenches are usually nearly straight, but in some instances their courses are conspicuously curved.

Each of the types of trenches just noticed, is favorable for the passage of roadways and in several instances they have been utilized for this purpose.

Surface pits are irregular depressions in the surfaces of drumlins, which have no draining channel and in at least one instance, at the south end of the Indian Town drumlin, retain sufficient rain water to form a small swampy pool. The pits are from perhaps ten to thirty or fifty feet across, and in many instances five to seven feet deep. These occur principally on the summits of the drumlins both in their central and terminal portion. Numerous examples of these irregular pits were observed but many drumlins are free from them.

By asymmetry in ground plan, is meant an irregularity such as would be produced if a portion of the side of drumlin should be eroded away, as by a stream for example, leaving a steep bluff. Irregularities of this nature are rendered conspicuous by reason of the exceptional steepness and boldness of the slopes they present, which are in striking contrast to the smooth undulations of the lines characteristic of a drumlin landscape. Two examples of the asymmetry referred to, were observed; one on the northwest side of a large drumlin situated partially in section 3 and partially in section

A.—SURFACE OF WASHED DRUMLIN NEAR HESSEL.
July 10,1904.



B.—SECTION OF A DRUMLIN NEAR POWERS.
September 1, 1904.

10, about one mile northward of Spalding; and the other on the southeast side of a large and otherwise characteristic drumlin, crossed by the road leading south from the same village and three miles distant. The former has a steep bluff on its northwest margin, and the latter a similar bluff on its southeast margin. In each case the regularity of the elliptical ground plan of the drumlin is rendered irregular by a flattening or straightening of its curvature where a steep bluff occurs.

The grooves and valleys between drumlins: The drumlins in certain instances as about Spalding, and Powers, and thence southward to the vicinity of Daggett, may be said to occupy as much ground space as do the intervening depressions. In many portions of the region referred to, the depressions between the drumlins form the exceptional feature in the landscape, and call for an explanation rather than the smooth oval hills they surround and separate one from another. The depressions are normally broad, shallow concave troughs (Plate VIII, B) which widen adjacent to the ends of the drumlins and become narrow where the drumlins broaden in their central portion. The troughs like the hills they separate, have smooth, flowing outlines, and even surfaces, except where gravel and sand in the form of eskers and kames have been heaped up within them. If accurately mapped they would be found to have a current-like arrangement, analogous to the shallow channels between the numerous sand bars and islands of an overloaded or "braided stream," such for example as the Platte River at low water.

A characteristic example of the grooves to which attention is here directed, is associated with a small drumlin, about one mile northwest of Spalding, (it is crossed by the road between sections 4 and 9, T. 38 N. R. 26 W. and lies principally in the N. E. $\frac{1}{4}$ of the N. W. $\frac{1}{4}$ of section 9.) It is one of a cluster of four or five closely united drumlins and is situated on the southern side of the general mass and on a southward descending slope. Its length is about one thousand feet, width in central part approximately two hundred feet, height about twenty-five feet, and trend N. 48–49° E. About the northeast end of the drumlin and extending all the way along its eastern side, and for about half the length of its western side, there is a distinct, round-bottomed groove about twenty-five or thirty feet wide and ten to twelve feet deep. This groove is evidently a result of erosion by flowing ice and has been excavated in till. The absence of the groove as a distinct feature on the southwest side of the drumlin, is owing to the fact that the slope there descends into the valley of Cedar River and other topographic conditions prevail. Some of the features just described are shown on Plate VIII.

The groove just described, recalls to mind the frontal grooves with side extensions, to be observed on many glaciated rock-surfaces where hard bodies are embedded in softer material, but while such grooves are usually less than an inch across and a fraction of an inch deep, the one in question is measurable in feet as just stated. The similarity in form in these two instances is conspicuous, however, and tends to strengthen the conclusion that the groove about the drumlin is due to ice erosion.

The groove about the proximal end and along the sides of the drumlin near Spalding is similar to many other grooves and shallow depressions between neighboring drumlins in the Menominee region and leads to the suggestion that the drumlins throughout that region have been given their prominence principally by the erosion of the grooves and valleys separating them.

Terrace on the side of a drumlin: The drumlin here considered is situated about one and one-quarter miles northwest of Powers, on the branch of

the Chicago and Northwestern railroad which connects Powers with Iron Mountain. The railroad crosses the drumlin by means of a cut about eight hundred feet long and thirty to forty feet deep in the central part; in the sides of the cut, good exposures of the normal reddish, sandy and bouldery till of the region may be seen. The trend of the drumlin is N. 53° E. or about at right angles to the railroad track, and its length by estimate in the neighborhood of one mile.

The drumlin is normal in every way so far as seen, except that on its southeast side there is a terrace-like flattening of the slope about midway between its base and summit. In cross profile the surface of the terrace is about thirty feet wide and slightly concave. It can be traced nearly the entire length of the drumlin and in longitudinal profile is convex upward, being parallel with the crest line of the drumlin on the side of which it occurs.

Hypotheses as to the origin of the drumlins of the Menominee region and explanations of the irregularities they present will be considered later. As the drumlins are intimately associated with another class of topographical forms, namely eskers, it is convenient to insert here a brief record of such observations as were made concerning them.

ESKERS.

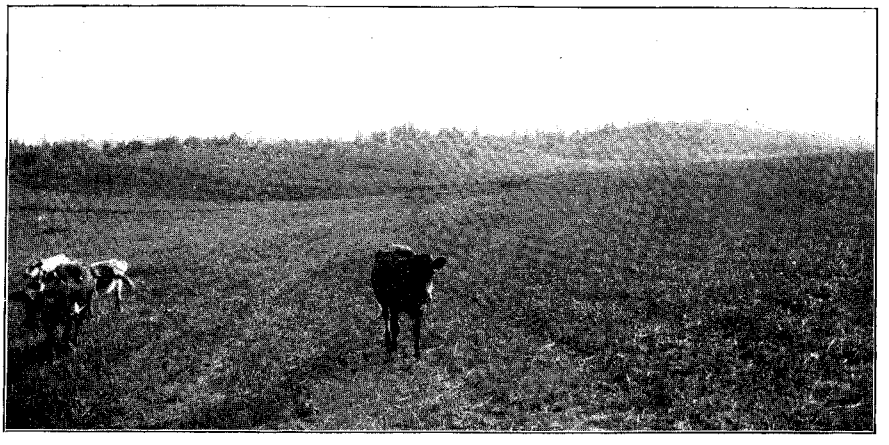
Under this name have been grouped certain irregular, winding ridges composed of crossbedded or current-bedded gravel and sand, which occur in regions formerly occupied by ice sheets. Their lengths are from a few hundred yards to many miles, the shorter ones in numerous instances being clearly disconnected portions of what would otherwise be conspicuously elongated examples. In width they measure from a few score feet to several rods, and their heights are equally variable, being at times only a few feet and in other instances one or two hundred feet. One of the chief peculiarities of these irregular ridges, is that they cross the regions where they occur with but slight if any reference to other features of the relief. The name *esker* has been applied by Irish geologists to the class of ridges here considered; in Scandinavia they are known as *osar*, but the former term seems preferable.

As to mode of origin, the eskers are considered perhaps by most students of glacial phenomena, to have been formed by streams flowing in tunnels at or near the bottoms of glaciers, but hypotheses assigning them to the work of streams flowing in open cuts in ice sheets have been advanced, as well as other explanations.

In the Menominee region eskers are numerous and have a significant distribution in reference to the drumlins with which they are intimately associated. Most commonly they occur in the troughs or valleys between drumlins, and in a general way trend with the longer axes of the drumlins with which they are most nearly associated. In certain instances, however, they cross the trend of the drumlins approximately at right angles and in a few cases are superimposed upon them.

Eskers in the valleys, which follow the general trend of the associated drumlins, occur in the immediate vicinity of the several branches of Cedar River, particularly to the northward of Spalding, but are also frequently present in valleys that have only insignificant draining streams, or none at all. In this connection it is suggestive to note in reference to the mode of origin of eskers, that the streams of the region under consideration, flow between or about the numerous drumlins, and, do not cut through them.

A.—DRUMLIN HALF A MILE NORTHEAST OF SPALDING; LOOKING EAST.
September 5, 1904.



B.—DRUMLIN TOPOGRAPHY NEAR NADEAU, LOOKING SOUTH, SHOWING GROOVE BETWEEN DRUMLINS.
September 7, 1904.

That is, the streams are consequent to the relief of the surface as produced by glacial agencies, and have modified that surface to only a slight degree. The streams wind about the bases of the drumlins, but so far as observed have not cut into them so as to break their normally even and flowing outlines. The greater number of the eskers follow similar courses and occur in the immediate vicinity of streams which they parallel in a general way. In many instances the streams have cut trenches through the eskers.

But one conspicuous example of an esker extending in a direction approximately at right angles to the longer axes of the associated drumlins has been observed. The one referred to, was mentioned on page 74 in connection with a description of a transverse cut in a drumlin about half a mile northwest of Spalding, and is crossed by the road leading north from that village. It has an irregular east and west course across open fields and from the road is in sight for a distance of about half a mile. At the west it approaches the east end of a trench in a conspicuous drumlin situated in the N. E. $\frac{1}{4}$ of Sec. 9, T. 38, R. 26. The same esker is again crossed by a road leading northwest from Spalding near the center of section 9, and to the south of a cemetery. To the east of the cemetery the esker follows an irregular course across a field to the west end of the trench which cuts the drumlin. This association of the eskers with a trench across a drumlin is good evidence that both the esker and the trench owe their origin to the same cause; namely a subglacial stream which deposited the gravel and sand of the esker and excavated the trench across the drumlin with which it is intimately associated.

An example of an esker perched upon the summit of a drumlin, is furnished by a prominent ridge immediately south of Wilson, which is about a mile long, seventy to eighty feet high in the central portion, and trends N. 32° E. The extreme northeast end of the ridge is crossed by the Chicago and Northwestern railroad by means of a shallow cut in the sides of which coarse gravel is exposed. The main portion of the surface of the ridge is also composed of gravel and sand but its southwest end consists of till and has the smooth flowing contours characteristic of drumlins. The compound ridge in its summit portion is conspicuously higher than any of the numerous drumlins in sight from its summit. This exceptional height, together with the facts just noted, indicates that an unusually large esker for the region where it occurs, was deposited on the summit of a drumlin, the longer axes of the two coinciding, but at the southwest the till of the drumlin extends farther than its covering of water-laid material.

The conditions pertaining to the prominent ridge near Wilson are repeated on a smaller scale at a locality about one mile east of Nadeau, or more precisely at the corner common to sections 8, 9, 16 and 17, T. 37 N. R. 26 W. At this locality there is an irregular hill trending about N. 43° E. which by estimate is fifty to sixty feet above the adjacent swampy valleys, and as is evident to a person standing on its summit, is higher than any other of the numerous hills in sight. The summit portion of the hill is composed of sand and well rounded gravel but to the southeast this material terminates in a steep slope about fifteen feet high and the continuation of the ridge is composed of till and has the contours and other features normal to drumlin. In this instance, however, the deposit of gravel and sand on the summit of the drumlin, lacks the characteristic ridge form, conspicuous at the esker near Wilson, and the deposit may perhaps be of the nature of the gravel and sand hills described below.

KAMES.

This name has been given to irregular heaps of gravel and sand, made by streams in association with glaciers, but without the extended ridge-like form peculiar to eskers. Kames, as a rule, occur as more or less isolated groups of irregular knolls and hills, with underdrained depressions among them; their general arrangement being parallel with the margin of the ice sheets about, or perhaps in part beneath, which the material composing them was deposited.

Kames are present in the Menominee region but they are less common and less conspicuous features of the relief than are the eskers, and as it seems, one form grades into the other. A characteristic group of kames occurs about a mile and a half south of Wilson, south of Cedar River, in section 18, T. 38 N. R. 26 W.

Comparisons: The drumlins, eskers and kames, of the Menominee region, present certain characteristic differences, which make them easy to distinguish one from another and are also of economic significance.

The drumlins are conspicuously smooth, and at the surface are composed of exceedingly fine sandy loam which makes them highly valuable for agricultual purposes. The soil is porous and absorbs all the water that comes to it as rain, or from melting snow, and even on steep slopes in plowed fields, is not scored by rill channels. Owing to the excellence of the soil on the drumlins they are to a great extent, cleared of native vegetation and under cultivation. For farming purposes they furnish the best conditions found in any considerable portion of northern Michigan.

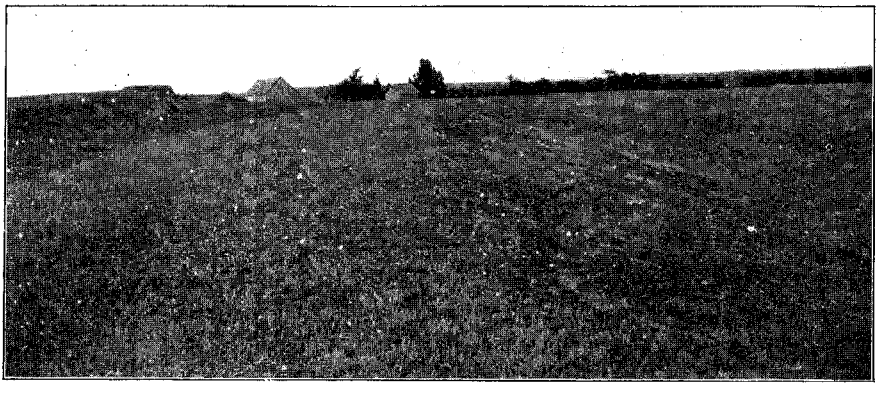
The eskers are composed of coarse material, are unfavorable in most instances for agriculture, have conspicuously uneven surfaces and although partially cleared in many instances, are usually left bristling with stumps and the dead trunks of trees and serve best for pasture lands. The absence of fine soil over the eskers is apparently due to its having been washed down into the open spaces in the coarse, loose material beneath, for as will be stated later, it seems that the eskers like the drumlins must at one time have had a thin surface sheet of fine silt-like material on their surfaces.

The kames, judging principally from the nature of the group of hills a mile and a half south of Wilson, are composed of finer material than the eskers, and in reference to agriculture are nearly as favorable as are the drumlins. Both eskers and kames, like the drumlins are unscored by rill channels. Throughout the entire Menominee region, in fact, with the exception of the bottom of certain of the larger valleys, the topography is still in almost precisely the same condition that it was when the region was abandoned by the ice sheet and associated streams, which gave it shape and character. That is, post-glacial changes are trifling and over large areas are practically absent.

The entire Menominee region was until recently entirely forest covered, and probably more than half its area is still occupied by trees and shrubs. A conspicuous difference between the drumlins and eskers, in reference to their relation to the trees which once grew upon them, is that the fine soil and till sub-soil of the drumlins, gave a good anchorage for large trees, while the trees growing on the loose-textured gravel-ridges were less securely rooted. On the drumlins there is but little evidence that trees have been uprooted by storms, but on the eskers the characteristic mounds with accompanying depressions which overturned trees produce, are a common and characteristic feature.

A.—DRUMLIN WITH FRONTAL AND SIDE GROOVE, ONE MILE NORTHWEST OF SPALDING; LOOKING SOUTHWEST.

September 5, 1904.



B.—DRUMLIN WITH FRONTAL AND SIDE GROOVE, ONE MILE NORTHWEST OF SPALDING; LOOKING NORTHEAST FROM TOP OF THE DRUMLIN.

September 5, 1904.

ORIGIN OF DRUMLINS AND ESKERS.

On the preceding pages considerable evidence has been presented concerning the nature of drumlins, eskers and kames. It now remains to sum up this evidence and learn to what conclusion in reference to the mode of origin of the topographic forms referred to, it lends support.

The drumlins of the Menominee region share certain characteristics in common, while a few of them present individual peculiarities. Any hypothesis to account for their origin should, therefore, explain each of these two classes of conditions in order to be worthy of acceptance:—

Their like features are: the till of which they are composed is of the same general nature in all instances, there is an absence of lamination, the flat stones present have no orderly arrangement or orientation, a thin surface layer of fine silt-like material associated with many stones and boulders is seemingly always present, they have the same general shape and the same general alignment.

Their unlike features are: transverse trenches, lateral trenches, surface pits, frontal and side grooves, asymmetric ground plan, et cetera, as described above, which are present in certain and relatively few examples but usually wanting.

The till of the drumlins, as has already been stated, contains boulders of native copper and of iron ore, showing that it was deposited by an ice sheet which flowed from the northwest toward the southeast: while the trend of the longer axes of the drumlins and the striæ observed in one instance on a rock surface exposed in their midst, record an ice movement from the northeast toward the southwest.

The best translation of the records just summarized with the aid of current knowledge in reference to the nature of glaciers and the various discussions as to the origin of drumlins that have been publishd, is as it appears, the following:

A till sheet about fifty feet thick was spread with a conspicuous degree of uniformity over the Menominee region by an ice sheet which came from the northwest; afterward, this ice sheet melted, or a change occurred in the direction of its flow and a movement from the northeast became general. During the later stage of glaciation the ice eroded the till over which it flowed, and excavated grooves and valleys and pressed and moulded the intervening ridges into the smooth oval hills and ridges which are now present. As the nearly clear ice melted, which eroded the previously deposited till, it left a thin sheet of fine material (as is presumed composed largely of dust which accumulated on the ice) together with loose stones and boulders, over the surface of the land it vacated. On the drumlins this surface sheet or dustlike material still remains, but on the coarser textured eskers it has been carried down into the interstices in the gravel beneath by percolating rain water. In the shallower grooves between the drumlins the fine material is also still present but in the broader and deeper valleys it has not been observed and presumably is concealed beneath subsequently formed peaty soils.[1]

The last glacier which covered the region, as has been stated, excavated the till over which it passed, but did not remove it uniformly in all places. The ice, as seems to be well shown by the grooves and channels it left, flowed in currents which were somewhat flexible and curved about and among

1 The surface covering of fine silt-like material, may in part have been deposited as dust during the post-Glacial time, but as the region was formerly forested, the contributions from this source were probably not great.

the masses of till which remained. Over certain areas ice erosion was more intense than at other localities, and all the till was removed and the hard rocks beneath striated. The hypothesis of ice erosion thus seems to account for all the normal characteristics the drumlins present.

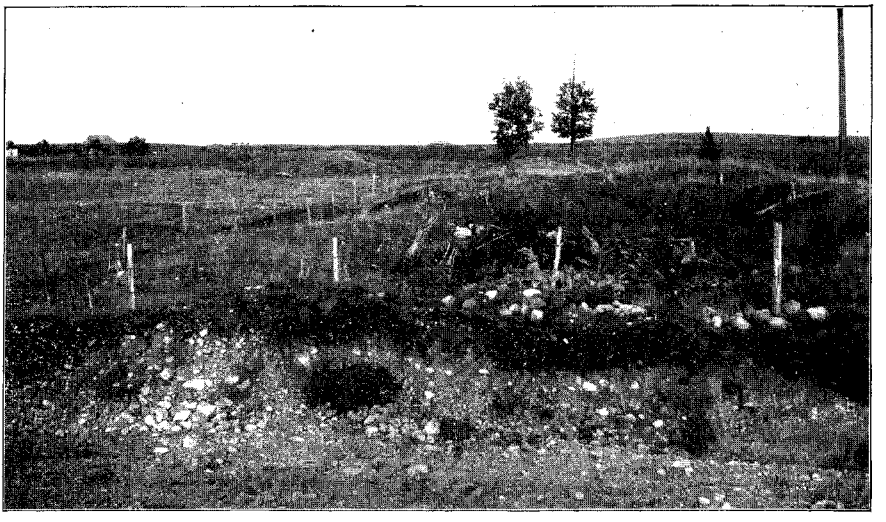
As shown especially by the frontal groove in connection with a drumlin near Spalding, the current in the basal portion of the eroding ice-sheet was deflected, as it seems by some apparently moderate irregularity in the resistance of the till it rested upon. Similar deflections when they caused an ice current to impinge on the side of a previously well shaped drumlin, eroded it and if the process was checked by the melting of the ice, before the drumlin was completely removed, an unsymmetrical drumlin with a portion of one side removed and a steep bluff produced, would result. Examples of such irregularities as already described, are furnished by a drumlin one mile northeast of Spalding which has been eroded on its northwest border, and by a drumlin three miles south of Spalding, which has been eroded on its southeast border.

The pits in the surfaces of the drumlins can be accounted for on the assumption that depressions were present in the surface of the till sheet before it became eroded, the depressions being occupied by stagnant ice over which the moving ice passed by shearing; or else the material of the drumlin has settled unequally since it was formed. I am strongly inclined to accept the first of these two alternatives, but other explanations may be forthcoming.

The transverse and side trenches present in certain of the drumlins, all though in part perhaps, like the surface pits, to be ascribed to depressions in the till before ice erosion began, are evidently in most instances due to corrasion by running water. The material removed however, is not present in the condition of alluvial fans etc. in the adjacent, and in certain instances streamless valleys,—the exceptional case when an esker is in line with a transverse trench will be referred to below—and from this it is safe to conclude that the water corrasion did not occur since the melting of the last ice sheet which occupied the region. The uniformly smooth surfaces of the drumlins and the entire absence of rill channels upon them, is strong collateral evidence in favor of this same conclusion. If the transverse and lateral trenches were not excavated since the melting of the ice sheet which gave shape to the drumlins, they must have been formed while the ice was still present. This conclusion is in harmony with the accepted explanation of the origin of eskers, and is a warrant for the farther conclusion that streams of water flowing in ice tunnels or in ice channels were present.

The intimate association of an esker with a transverse trench in a drumlin, referred to between dashes above, is highly instructive, as it shows in what portion of the glacier the streams were situated which cut the trench and deposited the associated esker. That is, the stream was sub-glacial, or nearly so, since the crest of the drumlin across which it excavated a channel is only about twenty feet above the bottoms of the adjacent troughs.

The only remaining irregularity of the drumlins under consideration to be re-considered at this time, is the terrace-like shelf on the side of a drumlin, one and a quarter mile northwest of Powers, described on pages 75–76 This terrace it will be remembered, is on the side of the drumlin, has a convex curvature in the direction of its length, and is parallel or nearly so with the curvature of the longitudinal crest-line of the drumlin with which it is associated. Now, at several localities in the same general region, drum-



A.—ESKER NEAR CEMETERY, HALF MILE WEST OF SPALDING, LOOKING NORTHEAST. September 5, 1904.

B.—ESKER HALF A MILE NORTH OF SPALDING, LOOKING NORTHEAST. September 5, 1904.

lins are present in close juxtaposition, but separated by a round bottomed groove. They have a relation one to another, to use a familiar comparison, similar to that of loaves of bread baked in the same pan; that is, the groove between two adjacent drumlins is all that serves to differentiate them. If two loaves of bread which have become united along their sides while in the oven are broken apart, a scar remains on each one; so in the case of two drumlins which are united along their sides, if one is eroded away an irregularity or scar showing where it was formerly united with its neighbor may remain. The terrace on the side of the drumlin referred to above, is of the nature of such a scar; the companion drumlin having been removed by ice erosion, but leaving a portion of the bottom of the groove which formerly separated the two. It thus appears that both the normal and the abnormal features of the drumlins of the Menominee region can be consistently accounted for on the hypothesis of ice erosion of a previously formed till sheet, and that this as it seems must be the true explanation of the origin of the drumlin of that region. This explanation is not new, but is essentially in harmony with an hypothesis of the origin of drumlins proposed by N. S. Shaler[1] several years since, but as it seems, not generally accepted by geologists.

Other explanations of the origin of drumlins as is well known, have been advanced[2] but a general discussion of them cannot be undertaken in this report. I need scarcely warn the reader that the conclusion reached above, in reference to drumlins having resulted from the ice erosion of a previously deposited till sheet, relates to the Menominee region simply, and is not at present advanced as a general explanation applicable to all drumlins.

FLUVIO-GLACIAL DEPOSITS.

Under this title students of glacial phenomena group a considerable number of deposits with various topographic forms, which are due to the work of streams in intimate association with ice sheets. Examples of two classes of such deposits in the Menominee region, namely eskers and kames, are described above. A third class, termed valley trains and outwash plains, have a wide development in Northern Michigan and the adjacent portion of Wisconsin, but to only a minor extent enter the strip of country adjacent to lakes Huron and Michigan which is especially considered in this report.

Valley trains and outwash plains consist of cross-bedded sand and gravel, which has been washed out of a glacier and deposited about its margin and in depressions in the land leading away from it. Such deposits as a rule have even, gently sloping surfaces, but are sometimes conspicuously pitted or contain large irregular depressions, owing to the melting of ice which was contained in or surrounded by the sand and gravel at the time of its deposition. When these features are prominent in an outwash plain it becomes a "pitted plain," and the depressions frequently contain lakes.

Sand and gravel plains of the nature just noted, are a common feature in North Michigan, particularly to the north of Little Bay de Noc, and as is judged from the reports of persons familiar with the region mid-way be-

[1]Boston Society of Natural History Proceedings, vol. 13, 1870, pp. 196–204; see also, U. S. Geological Survey, 7th Annual Report, p. 321.

[2]The nature and origin of drumlins has been well discussed by Warren Upham, and many references to the literature of the subject given, in Boston Society of Natural History Proceedings, Vol. XXIV, 1889, pp. 228–242, and Vol. XXVI, 1892, pp. 2–25.

tween Lake Michigan and Lake Superior are there extensively developed. The plains referred to are commonly designated as "jack-pine plains" but other sandy areas have similar characteristics of forest growth. Pitted plains occupy an extensive area to the west of Iron Mountain, and extend into Wisconsin, but this area, like the greater part of the jack-pine plains referred to lies outside the region here especially considered.

The only localities where sand plains of fluvio-glacial origin form a conspicuous feature of the region described in this report, are on the west border of Little Bay de Noc, as at Gladstone, and thence northward along the west side of the valley occupied by Rapid and White Fish rivers, and on the east border of the same valley from near Ensign northward. This valley now in part submerged, is a little over two miles wide near Rapid River village and has a nearly flat floor. Two streams flow down it, but without a noticeable height of land between, and each river has a solid rock bottom, (limestone) throughout much of its course. Resting on the rock of the valley floor is an irregular sheet of the ordinary reddish sandy till of the region, usually as it seems from the records of wells, from five to fifteen feet deep, the solid rock beneath being glaciated. There is also a minor quantity of stream deposit of sand and gravel in the valley, but its amount is seemingly insignificant. These features show that the valley is either preglacial or was excavated by the ice which occupied it. Without discussing this question I may state that the first of these hypotheses is probably true. That the valley is not due to post-glacial stream erosion, even to the extent of removing the incoherent deposits left by the ice which last occupied it, is shown by the parallel but independent courses which Rapid and White Fish rivers follow for a distance of about twelve miles, each of them being in a channel from a few inches to three or four feet deep cut in solid rock. This conclusion is apparent from the consideration that if the valley had been cleared of debris by stream erosion, only one main stream would have resulted from the process of stream development that must have obtained.

The most striking features of the valley occupied by Rapid and White Fish rivers, however, is the boldness and the composition of its borders. The escarpment overlooking it both on the east and west is made by slopes of sand which border extensive plateaus. A southward continuation of the bluff on the west forms the conspicuous escarpment of sand which extends from near Rapid River station past Gladstone, to the mouth of Escanaba River, and is present in a modified form, in the western part of Escanaba. The bluff at Gladstone is about 160 feet high, but so far as can be judged from the facts in hand decreases in height when traced northward. The corresponding bluff, on the east side of White Fish River is about 75 feet high. In other words there are two conspicuous escarpments of sand facing each other, with a rock-floored valley between, each sand bluff being the margining escarpment of an extensive sand plain. The sand plains referred to are in each case at least five miles wide in the row of townships (T. 41 N.) crossing the head of Little Bay de Noc, and widen in a conspicuous manner when followed northward. These plains are occupied by open growth of pine and juniper, and are typical "jack-pine plains."

The conditions just described call for an explanation, but as the plains referred to have their chief development to the north of the region examined by me, and pertain more particularly to that section of the state, only a tentative suggestion as to the manner in which they were formed will here be indulged in.

The hypothesis that presents itself in the above connection, is that during the final melting of the former ice sheet which rested on Northern Michigan, a tongue of ice or a narrow ice lobe, lingered in the valley now occupied by Rapid and White Fish rivers and that outwashed sand from the general ice field at the north, accumulated as sand plains along its sides. When the ice tongue finally melted, the sand on its borders was left with steep escarpments facing the depression it left. Stated more briefly, the extensive sand plains bordering the valley of Rapid and White Fish rivers are of the nature of Kame-terraces, as described by R. D. Salisbury[1] and others.

BEACHES OF FORMER LAKES.

Predecessors of the present Great Lakes: One of the most interesting and instructive episodes in the later geological history of North America, for the reason in part that it has an immediate and tangible influence on the commercial and other industries of to-day, relates to the development of the present Great Lakes. As has been shown by the long continued and painstaking investigations of a considerable body of geologists, the Great Lakes have had a varied history and important changes are still in progress.[2]

Previous to the Glacial Epoch, as is judged but not as yet specifically demonstrated, the region occupied by the Great Lakes was well drained and had a maturely developed topography. With each advance of an ice sheet from the north pre-existing conditions were greatly altered, but during each of the several intervals between the ice advances, as has been in part determined, large lakes were probably present. With the final melting back of the ice of the last or Wisconsin stage of glacial occupation, there came a time when the southern margin of the retreating glacier withdrew to the north of the divide separating the streams flowing to the Ohio and Mississippi from the watershed now tributary to the St. Lawrence. The water-parting referred to, is an irregular line, and the southern margin of the retreating ice was also irregular. For these reasons, as the ice melted back, certain portions of the northward sloping land adjacent to the ice became flooded and several small lakes were formed, as for example, at the west end of the Lake Erie basin, the south end of the Lake Michigan basin and the west end of the Lake Superior basin. As the ice withdrew still more to the northward and northeastward, these first formed lakes expanded, and in time united one with another. As successively lower and lower outlets became available, the water of the lakes fell and many changes in their outlines occurred. These changes were controlled mainly by variations in the dam of ice which retained the waters, but movements in the land, of the nature of upheaval and subsidences, also exerted an influence. These earth movements as a whole, tended to tilt the surface of the region in which the basins of the Great Lakes are located; the net result being an elevation of the northeastern portion with reference to the southwest portion.

When the ice had withdrawn sufficiently toward the northeast to leave the entire region now occupied by the Great Lakes to the west of the Ontario basin, free of glaciers, but still lingered in the valley of the St. Lawrence, the Ontario basin discharged its surplus waters by way of the Mohawk

[1] Geological Survey of New Jersey, Vol. V of the final report of the State Geologist, 1902, p. 121.

[2] A popular account of this chapter of geology with the title; "A short history of the Great Lakes," by F. B. Taylor, may be found in Charles R. Dryer's "Studies in Indiana Geography," 1897. Published at Terre Haute, Indiana. The chief first-hand contribution to the literature of the subject may be found in indices to American geology, under the names of E. Desor, Charles Whittlesey, J. W. Spencer, G. K. Gilbert, F. B. Taylor, Frank Leverett, and H. L. Fairchild.

valley into the Hudson. At this time a vast lake named Lake Algonquin, larger than the combined areas of all of the present Great Lakes, flooded the basins of lakes Huron, Michigan and Superior, and overflowed into the Ontario basin by way of the valley of Trent River. Lake Algonquin existed sufficiently long to permit its waves and currents to form well defined gravel terraces and accompanying lake-cliffs about many portions of its border.

A farther withdrawal of the ice which lay on the surface of the present province of Ontario, coupled with movements in the earth's crust, made the Nipissing-Ottawa valley available for the drainage of Lake Algonquin. Its surface was then lowered and it gave place to another lake at a lower level, known as Lake Nipissing. This lake also formed gravel terraces and cliffs about its shores which are stronger and better defined than the similar records left by Lake Algonquin. Lake Nipissing was somewhat smaller than its predecessor, but occupied nearly the entire area now included in lakes Superior, Huron and Michigan, and was larger than the present area of these lakes combined, since its waters were maintained at an horizon about 40 feet above the present elevation of the water in the straits of Mackinac.

The existence of Lake Nipissing was brought to a close by a tilting of the land, which raised its outlet above the level of the channel occupied by St. Clair river, and the present distribution of the Great Lakes was initiated.

Such contributions to the history of the basins of the Great Lakes, as I was able to secure along the northern borders of lakes Huron and Michigan, relate principally to the Algonquin and Nipissing shore-lines and their accompanying gravel and sand deposits.

Topographic Features of Lake Shores: At many localities on lake and ocean shores there is a well defined terrace due to the action of waves and currents in eroding the land. A characteristic cross profile of such a topographic feature is here presented:

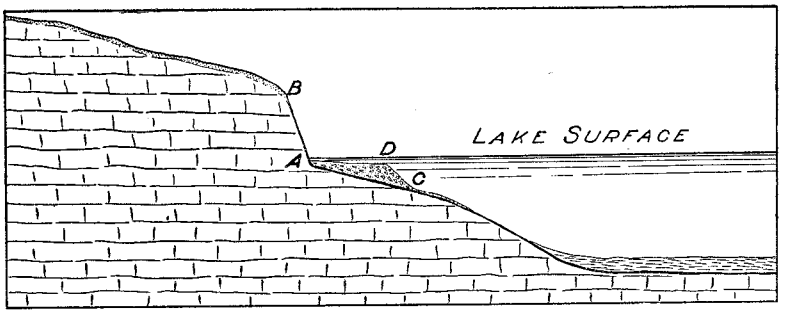


Fig. 5: Cross profile of a lake-cliff and accompanying terrace.

The notch at *a* is due principally to the beating of waves charged with sand and gravel against the land; by this process the cliff *a b* and the cut terrace *a c*, are produced. The deposition of sand and gravel on the cut terrace and extending lakeward, forms a built terrace with a surface inclined downward toward the eroding water-body. When the land bordering a lake slopes gently upward from its margin, and the water deepens gradually lakeward, the destructive action of the waves is less than

under the conditions referred to above, and a lake cliff and its accompanying cut terrace may be obscure or wanting. Under these conditions the pricipal topographic change produced by waves and currents is usually a sand and gravel ridge built in shallow water, parallel with the shore line.

It is by means of these and other similar topographic changes made by the waves and currents of lakes that their former outline can be traced when their waters subside.[1]

The Algonquin Beach: As is indicated on the map forming Plate XVI shore lines made by the waters of Lake Algonquin occur at several localities in the area represented. These are: on the hills about six miles north of Cedarville and Hessel; about the summit portion of Mackinac Island; in the vicinity of Cook's Mills, and again near Ensign, each of these localities being a few miles northward of Big Bay de Noc; about the higher portions of Garden Bluff and Burnt Bluff, on the west side of Garden Peninsula; and a few miles inland from the west shore of Little Bay de Noc and of Green Bay, from the vicinity of Gladstone and Escanaba, southwest to Birch Creek station, about six miles north of Menominee.

At the locality to the north of Cedarville and Hessel there is a group of hills formed principally of Niagara limestone which rise about 300 feet above the present level of Lake Huron. These hills formed two and perhaps three Islands in Lake Algonquin, which have been named by F. B. Taylor, the Munuscong Islands.[2] The waves of the old lake beat on the border of these islands until a well defined beach of coarse gravel was formed about them. A good example of this deposit now excavated for gravel with which to make roads, occurs six miles north of Hessel, where two roads cross at the northwest corner of section 36 T. 43 N., R. 1 W. A fine example of the same ancient lake margin is present about six miles northwest of Hessel near the northwest corner of the township in which that village is located. At the last named locality an extensive view may be obtained of the region to the south and west, which includes the neighboring land and broadly expanded waters of Lake Huron as far as Mackinac Island. With this far reaching landscape in sight, it is easy to fancy the waters of Lake Algonquin restored, and to picture the scene the region formerly presented. At the time referred to, the only land in sight from the Munuscong Islands, in all the vast expanse of water to the south, west and north, was a tiny island formed by the summit portion of the present Mackinac Island. To the northeast, the nearest land was in what is now Ontario to the north of the site of Mud Lake and St. Mary's River. In all other directions the ancient lake extended somewhat farther than do the waters of lakes Superior, Huron and Michigan at the present time.

The elevation of the Algonquin beach about the borders of the former Munuscong Islands is 860 feet above tide and 280 feet above Lake Huron, (The level of Lake Huron being taken as 580 feet.)

The waves as stated above, beat on the margins of the islands for a sufficient length of time to make a well defined gravel beach and the sand washed out from the shore was deposited on the bottom of Lake Algonquin near at hand, and where the water deepened rapidly and especially to the south and west, made extensive accumulations. This apron-like

[1] The changes which lakes make in the topography of the land margining them, has been clearly described by G. K. Gilbert, in an essay entitled "Topographic Features of Lake Shores," in U. S. Geological Survey, 5th Annual Report, 1885, pp. 69–123, see also, "Lakes of North America," by Israel C. Russell published by Ginn & Co., 1895.

[2] American Geologist, Vol. XV. 1895, pp. 24–33.

extension of sand below the old shore still remains and is a conspicuous feature of the low land adjacent to the former islands. Near the northwest corner of the township in which Hessel is located, a well has been dug in this sand to a depth of about ninety feet. The sand about the Munuscong hills becomes gradually thinner, when traced southward but meets the similar deposit made at a lower level by the water of Lake Nipissing, and for these reasons, nearly all the soil of the lowlands to the north of Les Cheneaux Island are sandy.

While the waves were breaking on the borders of the Munuscong Islands and also after the waters of Lake Algonquin subsided, sand was blown over their surfaces from the encircling beach and in places, quite conspicuous sand dunes were produced.

Mackinac Island was much smaller during the existence of Lake Algonquin than at present; the water then stood about 205 feet higher than now on its sides, or 785 feet above tide, according to measurements made by F. B. Taylor and Frank Leverett, and cut a well defined shelf which in places is margined on the landward side by a lake-cliff. At most localities the terrace is covered with water-worn gravel; but in places characteristic gravel beaches are present, without the usual accompaniment of a cut terrace and lake-cliff.

"With the exception of the rocky faces of the great limestone cliffs," as has been well described by Taylor,[1] "which rise on its eastern and western sides, all the lower levels of Mackinac Island show plain evidence of post-glacial submergence. The modern beach is composed almost entirely of limestone pebbles which are generally well rounded. The proportion of crystalline drift material from the north is not great and is confined mainly to bowlders of considerable size. The narrow strip of land upon which the village is built, and which rises to an altitude of 40 to 50 feet at the base of the cliff, is composed entirely of the same characteristic beach material; as may be seen in any of the little gardens of the villagers and in the deep cut back of the Astor house and the old court house. But on ascending to the higher levels of the island the evidence of post-glacial submergence are even more marked. At an altitude of about 170 feet there is a heavy, well developed beach ridge. This ridge is the lowest of a series of four or five like ridges which rise by successive steps to an altitude of about 205 feet above the strait or about 787 feet above sea level. These old beaches may be seen to best advantage on the short target range back of Fort Mackinac. The ground is there cleared of trees and is covered with a short, thick turf, so that the whole series of beach ridges, with their intervening troughs and minor ridges, is admirably exposed to view. At this place the ridges are parallel and comparatively narrow, though strongly developed, and they are also more compactly arranged and more convenient of access than in any other part of the island.

"The short target range crosses the beaches nearly at right angles and the width of the series here is a little less than a quarter of a mile. But on the southwestern side of the island it is three times this width. In some places two or more ridges run together and form one, as is often observed elsewhere. On the short range four heavy ridges are clearly seen with possibly a fifth less distinctly formed. In two of the wider troughs, which

[1] B. F. Taylor, "The highest old shore line on Mackinac Island," in American Journal of Science, Vol. XLIII, 1892, pp. 210–218. In this article the statement is made that the water body termed above Lake Algonquin was an arm of the sea. This view is now held by few if any students of the history of the Great Lakes, and was long since proven to be untenable by Taylor's own investigations.

are five to six feet deep between the main ridges, there are apparently several other little ridges, one or two feet in height. A road which runs parallel to the range and close to its west side cuts the top of each ridge and shows its composition to be a characteristic beach formation. The 205 foot beach is not only the highest one of the series here described, but also the highest on the island. If this ridge be followed through its full extent around the higher ground, it will be found to surround a small tract on three sides. On the remaining side, which is a long, straight line of limestone cliffs facing towards the northeast, all the beach ridges, except the lowest or 170 foot ridge, are wanting. This beach is situated at a considerable distance from the cliff, and the ground between is a broad, level plain with an altitude of 170 to 175 feet. On this plain a heavy talus of fragments and angular limestone bowlders lies against the base of the cliff. While the waves were forming the 205 foot beach around the other sides of the circumscribed tract, they were beating against this northeast cliff and the water on the plain at its base was 30 to 35 feet deep.

"The little island of ancient times, thus defined, was about three-fourths of a mile long and less than half as wide, with its longer axis running about northwest and southeast. Its north end was a sharp promontory formed by the long cliff facing northeast, as just described, and another shorter one facing almost directly west. At the base of the latter the 205 foot beach is well developed, but it is very narrow and the ground drops off rapidly westward to the 170 foot plain. The highest point of the ancient island is at its southern end which forms a rounded promontory and rises to a little less than 100 feet above the 205 foot beach. This point is now crowned by the earthworks of old Fort Holmes, built in 1812, and the descent to the 170 foot plain on the east, and to the 205 foot beach on the south is a steep slope of drift. On its west side, and about a quarter of a mile south of its north point, the surface of the island descends gradually to the 205 foot level. The upper beach is here wide and flat and encloses a considerable tract of low ground behind it."

On the lower portion of the slopes of Mackinac Island, there are other beaches, the Nipissing beach being especially conspicuous, as will be described later.

The hills on the St. Ignace Peninsula rise to a height of about 160 feet above the level of the lakes Huron and Michigan and were completely submerged during the existence of Lake Algonquin, but as the water was drawn off, several islands appeared and at two stages, above the Nipissing horizon, strong well defined beaches were produced.

To the west of St. Ignace in the belt of land adjacent to the north shore of Lake Michigan, the next elevation sufficiently high to stand above the water of Lake Algonquin, is at Cook's Mills on the line of the Minneapolis, St. Paul and Sault Ste. Marie railroad, and near the landward end of the Garden Peninsula. At this locality as determined by Taylor,[1] the Algonquin beach has an elevation of 750 feet above tide, or 168 feet above Lake Michigan. An island or group of small islands existed at this locality during the highest stage of the water in the basins of the Great Lakes and was the first land to the west of Mackinac Island.

The Algonquin beach appears again near Ensign, about 15 miles west of Cook's Mills at an elevation of approximately 700 feet, but this, however, is an indefinite measurement.

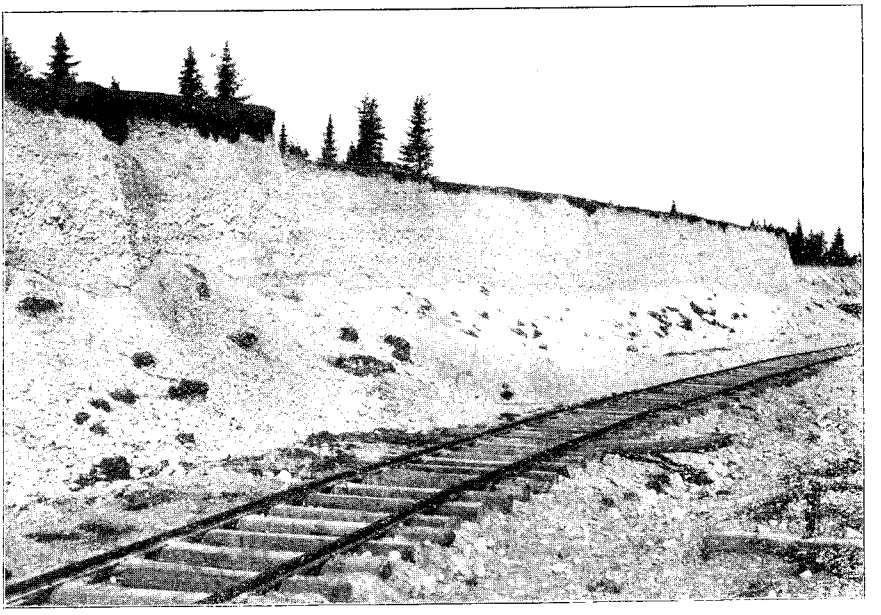
[1]F. B. Taylor, "A reconnaissance of the abandoned shore lines of Green Bay," in The American Geologist, Vol. XIII, 1894, pp. 316-327.

On the west side of Garden Peninsula, the coast bordering Big Bay de Noc is bold and rendered picturesque by prominent headlands. From Garden Bay toward the southwest there are several bluffs, the most conspicuous being known in their order from north to south as Garden Bluff, Middle Bluff, and Burnt Bluff, each of which has beach lines about its higher portion. The summit portion of each of these elevations stood as an island in the water of Lake Algonquin. The highest beach on Burnt Bluff, which from its position is identified as a portion of the shore of Lake Algonquin, is 705 feet above tide, or 125 feet above Lake Michigan. The measurements of this elevation by Taylor and myself, by means of aneroid barometers, are identical. Burnt Bluff (Plate XI) is not only the highest elevation in the region about Big Bay de Noc, but is one of the most picturesque localities on the border of the Great Lakes. It resembles Mackinac Island, but presents a steep slope to the northwest instead of southward, and faced the direction from which came the chief ice movement that left striæ on neighboring rock-surfaces. Its summit is covered with glacial drift, proving that like Mackinac Island, it was completely buried beneath ice during at least one and probably during each ice advance of the Glacial epoch. On the bold face of the bluff overlooking Big Bay de Noc, as may be seen from Fayette and other neighboring localities, there are two horizontal lines, due to the presence of cliffs with more or less definite terraces at their bases, which mark the position of the Algonquin and Nipissing shore lines.

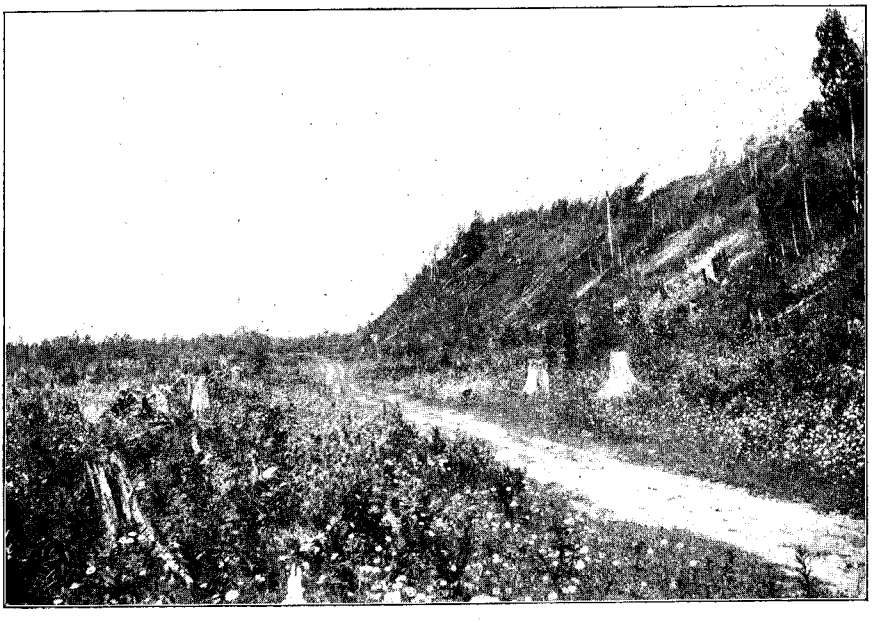
As has been recorded by Taylor in the essay referred to above, the Algonquin beach is present on Washington Island, to the south of the southern point of Garden Peninsula and forming a part of the territory of Wisconsin. Other similar islands existed in Lake Algonquin to the southward of Washington Island and were formed by the highest hills on the peninsula and islands of Wisconsin bordering Green Bay on the southeast, thus showing that the present embayment on the northwest shore of Lake Michigan was outlined in part by a belt of small islands in Lake Algonquin.

The shore line of Lake Algonquin has also been identified by Taylor and myself near Gladstone and Escanaba, and thence southwest near the west border of Green Bay, to Birch Creek, about six miles north of Menominee. Its elevation near Escanaba is about 720 feet above tide, or 140 feet above Lake Michigan, but declines when traced southwest to 630 feet above tide or 50 feet above Lake Michigan as determined by Taylor, at Birch Creek. Throughout the portion of the old beach just indicated its position is recorded in part by a gravel ridge, associated in places with a cut terrace and accompanying lake cliff, but principally by the occurrence on its landward side of drumlins and other topographic features due to the action of glaciers, and on the lakeward side by the prevalence of sand which was deposited in the waters of former lakes.

As shown by the measurements of the elevation of the Algonquin beach given above, it is not now horizontal. As the beaches were at least essentially level at the time they were formed, since they record the surface level of a lake, the present departure of their plane from horizontality is evidence of a movement in the portion of the earth's crust beneath. Tabulating the measurements in hand pertaining to the present position of the Algonquin beach, at localities north of and adjacent to the shores of lakes Huron and Michigan, we have:



AN EXCAVATION IN THE NIPISSING BEACH AT ST. IGNACE.
July 6, 1904.



B.—THE NIPISSING BEACH, A CUT TERRACE AND LAKE CLIFF NEAR ST. IGNACE.
July 20, 1904.

Locality.	Elevation above tide determined by aneroid barometer.	Measured by.
Munuscong Islands, to the north of Hessel and Cedarville.	860 feet....	Taylor.
Munuscong Islands, to the north of Hessel and Cedarville.	859 feet.....	Russell.
Mackinac Island	785 feet.....	Taylor and Leverett.
Mackinac Island	780 feet.....	Russell.
Cook's Mills	750 feet.....	Taylor.
Ensign	700 feet.....	Russell.
Garden Bluff	700 feet.....	Russell.
Fayette	710 feet.....	Russell.
Burnt Bluff	705 feet.....	Taylor.
Burnt Bluff	705 feet.....	Russell.
Escanaba River, two miles west of West Gladstone	720 feet.....	Russell.
Gladstone	700 feet.....	Russell.
Ford River	680 feet.....	Russell.
Pine Ridge	690 feet.....	Taylor.
Birch Creek	630 feet.....	Taylor.

These measurements show an upward inclination of the plane marked out by the waves of Lake Algonquin, from the southwest toward the northeast, at an average rate of approximately two feet to a mile; to the northeast of Mackinac Island, however, the rate increases to about five feet to a mile. Additional observations in this connection made by Taylor, Leverett and others, show that the movement that has occurred since the time of Lake Algonquin, was not of the nature of a regular tilting of the land, but that an irregular upward movement occurred to the northeast of the central part of the former lake. As will be described more fully later, the plane of the Algonquin beach and the plane of a lower, and equally well defined beach in the same region, namely the Nipissing beach, are not parallel and neither of them is now horizontal. That is, earth movements were in progress between the time of Lake Algonquin and of Lake Nipissing and also after the existence of Lake Nipissing.

OLD SHORE-LINES BETWEEN THE ALGONQUIN AND NIPISSING BEACHES.

The outlet of Lake Algonquin as has already been stated, was across the Province of Ontario, by way of the Trent River, and into Lake Iroquois which occupied the basin of the present Lake Ontario. The vast Laurentide ice sheet during the existence of Lake Algonquin, still covered the northeastern part of Ontario, including the valleys of Nipissing and Ottawa rivers. When the margin of the ice melted back so as to leave those valleys uncovered, a lower channel of discharge for Lake Algonquin was rendered available, and its waters were drawn down about 230 feet below their former level. This great change is warrant for giving the lake with a new outlet, an independent name, and it has been christened Lake Nipissing in reference to the river now occupying in part its channel of discharge.

The subsidence of the water from the Algonquin beach to the Nipissing beach was not a continuous process, as beaches strongly defined in certain localities, occur on the sides of the basin these two lakes occupied but intermediate between the beaches they left. On the north side of Mackinac Island, as has been recorded by Taylor, there is a strong well defined gravel beach at the old battlefield now the site of the Wauashkamo Golf Club, known as the Battlefield beach. Its elevation by aneroid is 75 feet above Lake Huron.

A few rods north of the cemetery near the extremity of St. Ignace Penin

sula, there is a well defined beach at an elevation of 84 feet, measured by hand level, above the present level of the water in the Straits of Mackinac. On the hill to the west of St. Ignace near the public school building as recorded by Taylor, there is a strong gravel beach with an elevation of about 75 feet above Lake Huron, or at the same horizon as the Battle Field beach on Mackinac Island.

At Escanaba there is a broad lake terrace between the Algonquin and Nipissing beaches, its elevation being about 50 feet above Lake Michigan.

These and other, but less well defined terraces show that the water lingered at perhaps several horizons during the interval between the formation of the Algonquin beach and the Nipissing beach.

THE NIPISSING BEACH.

The waters of Lake Nipissing lingered longer at one horizon than did the waters of Lake Algonquin and formed much more strongly pronounced shore features. The beaches it left are not only conspicuous in the topography about the north shores of lakes Michigan and Huron, but have an important influence on the drainage of the land and hence on its agricultural and other economic uses.

The Nipissing shore line is in most instances marked by a gravel ridge, but in places where the shores of the lake were steep, cut-terraces and lake-cliffs are present. An important accompaniment of this shore line, as is the case of the Algonquin beach, is the presence on its lakeward side of extensive tracts of lake deposited sand. Nearly everywhere between the beach in question and the margins of the present lakes, the land is sandy, and sand dunes are sometimes present. Above the beach and retained by it are several lakes, and numerous swamps, particularly on Bois Blanc Island and about the borders of St. Ignace Peninsula.

Beginning at the east end of the tract of country considered in this report, (see map forming Plate XVI.), and proceeding westward, the chief localities at which the Nipissing beach is well developed are as follows:

The beach is recognizable at many localities about the borders of Drummond Island and also on the mainland at Detour, at which place its elevation as measured with a hand level, is 51 feet above Lake Huron.

On the south side of a drumlin at Cedarville, (the hill conspicuously marked by the presence on its summit of an old church) there is a strongly defined terrace of coarse well worn gravel, about 40 feet above Lake Huron, which judging from its strength and elevation, is no doubt a part of the Nipissing shore line.

About the heads of several of the deep bays adjacent to Les Cheneaux Islands there are stony gravel ridges at about the height at which the beach under consideration should occur. Owing to the density of the vegetation and in part the swampy character of the land, however, these ridges are somewhat difficult to follow. Les Cheneaux Islands have a general elevation of less than 40 feet and seem to have been shoals during the existence of Lake Nipissing. Their surfaces as already stated, have been washed by waves and currents, and the finer portion of the till of which they are composed, removed, and the stones and boulders it contained concentrated at the surface.

Goose Island and the St. Martin Islands are low, and the Nipissing beach is not present on them, unless, perhaps, about the highest portion of the larger St. Martin Island.

About Mackinac Island the Nipissing beach is strongly drawn, except when precipitous cliffs occur. As has been recorded by Taylor,[1] its elevation is 45 feet above Lake Huron. It forms the terrace on which the higher portion of Mackinac village is built, and on which the Grand Hotel stands. The lake-cliff above this portion of the beach is occupied by the block houses of Fort Mackinac. It is present also near British Landing and is continued as a well defined cut-terrace from there eastward across the north end of the island.

On Round Island this same beach again occurs and a part of the lake-cliff rising above it is noticeable in the forest clothing its eastern side.

All about Bois Blanc Island, the Nipissing beach is well developed. Usually it is a broad gravel ridge, with a surface elevation of about 45 feet above the present lake, but in places, as near Bois Blanc village on the north side of the island and again on the east shore, a stony lake-cliff excavated in limestone is present. The small lake near the east end of the island was not visited by the writer, but judging from the reports of persons familiar with it, seems to be on the landward side of Nipissing beach and to owe its existence to this cause. Duncan or Twin Lakes and its neighboring lake to the east, have a surface elevation of about 35 feet above Lake Huron and are on the lakeward side of the Nipissing beach which is well developed in their vicinity. Between these lakes and the present water margin of Lake Huron, there are sand dunes and beach ridges, pertaining to the time since Lake Nipissing existed. The lakes just mentioned are shallow, the general depth being only five or six feet, their bottoms are dark with peaty accumulations and their waters of an amber color on account of vegetable matter in solution.

All about the borders of the St. Ignace Peninsula, the Nipissing beach forms a conspicuous feature. At the entrances of several embayments on the border of the old lake, stony gravel bars were formed which closed their outlets and transformed them into lagoons. Now that the water in the Huron-Michigan basins has fallen below the level of Lake Nipissing, several of the former lagoons have been transformed into lakes. A fine section of a gravel beach at the Nipissing horizon has been exposed in the excavations recently made for railroad ballast, in the northern part of St. Ignace, an illustration of which is presented in Plate X, A. The appearance of the beach near St. Ignace where it is accompanied by a cut terrace, is shown in Plate X, B.

Lake cliffs due to the undercutting of the borders of Lake Nipissing where the land rose precipitously, occur at St. Louis rock, about three miles north of St. Ignace, and again at Gros Point on the west side of the peninsula where for a distance of several miles a broad cut-terrace with bold bluffs on its landward side, overlooks Lake Michigan. Isolated rocks rising from this terrace show where skerries existed at the time the waters of Lake Nipissing beat upon the shore. Much of the beauty of the scenery in the region about Gros Cap, is due to the shore topography of the old lake. At the cemetery near the south end of Point St. Ignace, the Nipissing beach is represented by a well defined gravel terrace at the foot of a steep slope or lake-cliff, and has an elevation above the level of Lake Michigan, of 45 feet, as determined by means of a hand level.

Brevoort Lake is 20 to 25 feet below the level of the Nipissing beach

[1] F. B. Taylor, "The Second Lake Algonquin," in the American Geologist, Vol. XV, 1895, pp. 100–120, 162–179. (By "Second Lake Algonquin" is meant Lake Nipissing.)

which skirts its southeast border. The lake is separated from Lake Michigan by a broad tract of sand dunes, and probably owes its existence to the cutting off of an embayment of the waters in the Michigan basin at a time subsequent to the existence of Lake Nipissing. Its waters adjacent to its south and west shores are shallow, but in its northern portion are reported to have a depth of 180 feet.

From Brevoort Lake westward for a distance of twenty or more miles, the shores of Lake Michigan are bold and the Nipissing beach was not recognized by me while traversing that region, until reaching the vicinity of Point Patterson where it appears at a distance of from three to five miles inland. From near Point Patterson westward nearly to Manistique the beach is represented by a gravel ridge connected at certain localities with a terrace and low lake-cliffs. At White Dale (Sec. 35, T. 41 N., R. 14 W.) the beach is about 40 feet above Lake Michigan. To the south of the beach the country is usually sandy and in part occupied by dunes, while the lower portions are swampy. Several small lakes below the level of the Nipissing beach owe their existence to beach ridges formed at a later date, or to the accumulation of sand dunes. About the borders of Garden Peninsula the beach is present, and at Burnt Bluff and other localities on the bold shore overlooking Big Bay de Noc, is usually a cut-terrace; but in the valleys leading inland from the heads of the present coves and bays and generally (as is reported) on the low eastern border of the peninsula, it is a sand and gravel ridge. Its elevation at Garden Bay and Burnt Bluff as determined by means of a hand level, is 30 feet above Lake Michigan. As has been recorded by Taylor,[1] "the Nipissing beach has been identified around the northern shore of Green Bay, but was not found to the south of Escanaba. It is the wide flat upon which the higher parts of the towns of Gladstone and Escanaba are built. Back of the former place its upper mark is strong and plain against the foot of a high bluff."

At the mouth of Escanaba River there is a well defined gravel terrace with an elevation of 24 feet above the level of Lake Michigan, and at Farmer's Dock on the east side of Little Bay de Noc, opposite Escanaba, there is a cut-terrace in limestone which records a water level 23 to 24 feet above the same datum[2]

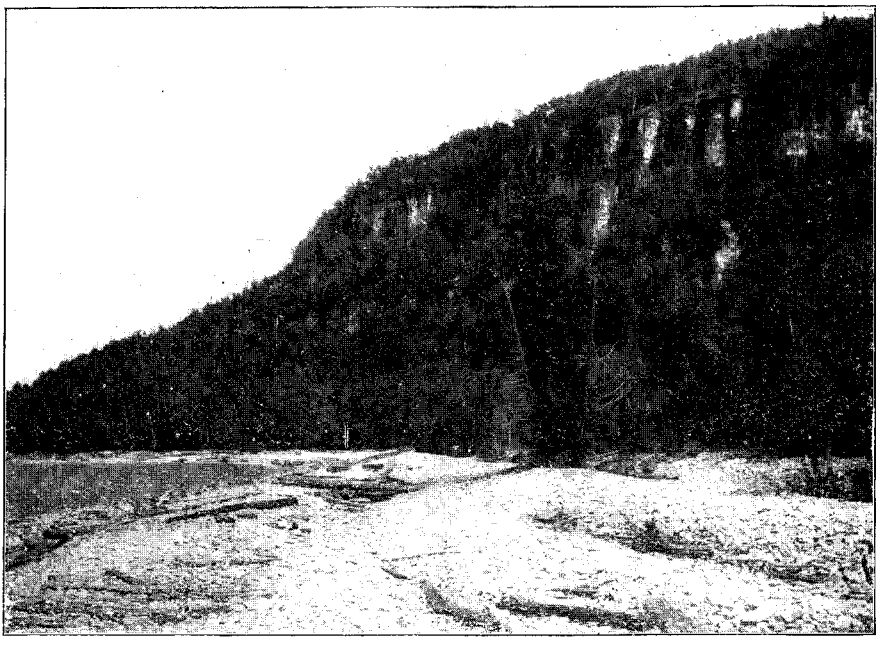
These old shore features are associated with similar records at both higher and lower horizon and their assignment to the Nipissing stage in the history of the Great Lakes basin is based on their relative strength in comparison with the beaches most nearly related to them, and on the conclusion derived from additional evidence by Taylor and others, as to the position the Nipissing beach should occupy in the Escanaba region.

The measurement of the present height of the Nipissing beach given on the past few pages, shows that it declines from 51 feet above the level of lakes Huron and Michigan at Detour, to 45 feet at Mackinac Island and St. Ignace, 30 feet at Garden and Burnt Bluff and 24 feet at Escanaba. The rate of this inclination as determined by Taylor, from a wider range of observation than is indicated above, is 6½ inches per mile.

The planes of both the Algonquin and the Nipissing beaches, in the region about the north shore of Lake Michigan, as stated above, are inclined downward from the northeast toward the southwest, the former at the rate

[1] F. B. Taylor, "The Second Lake Algonquin," in The American Geologist Vol. XV, 1895, pp. 106–107.

[2] The height of the Nipissing beach at Gladstone and Fayette is given by Taylor as 20 feet. American Geologist, Vol. XV, 1895, p. 118.



BURNT BLUFF–GARDEN PENINSULA, LOOKING SOUTHEAST.

August 13, 1904.

of about two feet per mile and the latter 6½ inches per mile. At these rates of inclination the two beaches should coincide in the region about Menominee. The country on the west side of Green Bay between Escanaba and Menominee, for a distance of five or six miles inland, is low, sandy and swamps and covered with dense vegetation. It has not been examined in detail and only the position of the highest beach present and that at only a few localities, has been well determined. Precisely at what locality the two beaches referred to came together is not known.

To the south of Menominee, the Nipissing beach as represented on a map published by Taylor, passes below the level of Lake Michigan, but observations made by Frank Leverett, as yet only in part recorded, seem to indicate that more tilting has occurred to the northward of a northwest and southeast line drawn through Lake St. Clair and the vicinity of Menominee, than to the south of such a line, and that the Algonquin and Nipissing beaches coincide in the southern half of the Lake Michigan basin, their combined records being a well defined beach about 15 feet above the present water level.

The portion of the glacial and post-glacial history of the basins of the Great Lakes outlined in these pages, although serving to explain many phases of the relief of the region here described, pertains to the changes a very much larger region has experienced, the complete records and full significance of which cannot be discussed at this time. A good summary of the changes referred to may be found in a chapter by Taylor, in Dryer's "Studies in Indiana Geography," to which the reader is referred for additional information.[1]

LAKE CLAYS.

At two localities in the portion of Michigan embraced in this report, one near Hessel, and the other in the region about Isabella, to the north of Big Bay de Noc, there are deposits of fine, pink, thinly laminated, highly plastic clay which as shown by its fineness and evenness of bedding was laid down in a large water body. Similar clay is perhaps present at other localities in the same general region, concealed beneath later deposits of sand and possibly of till, but evidence in this connection is at present wanting.

The clay deposit referred to near Hessel, is located about one mile north of the village in a depression between two drumlins. Its known area is only a few acres, and its depth not ascertained. At Isabella and in the region to the north of that village for a distance as reported by residents, of five or six miles, pink clay is well exposed in the sides of stream and rill channels, and evidently has a thickness as indicated by wells, of at least 50 to 75 feet, but probably exceeds these measures. All about the border of this clay area there is sand in part in the form of dunes, as about Moss Lake, but the clay extends under the sand at least to the westward, as may be seen at many localities in the banks of Sturgeon River.

The clay deposit at Isabella is favorably situated for commercial purposes and as indicated by its fineness, plasticity, general freedom from coarse sand, concretions, etc. is well worth experimenting with for the purpose of ascertaining if it will serve for brick making. An analysis of the clay is as follows:

[1] C. R. Dryer, "Studies in Indiana Geography," Inland Publishing Co., Terre Haute, Indiana, 1897, pp. 90–100.

ANALYSIS OF CLAY FROM ISABELLA.

Analyzed by F. K. Ovitz.

	Per cent.
Silica, S_2O_2	52.61
Aluminum oxide, Al_2O_3	15.66
Ferric oxide, Fe_2O_3	4.91
Calcium oxide, CaO	8.54
Magnesium oxide, MgO	3.16
Phosphoric anhydride, P_2O_5	.12
Sulphuric anhydride, SO_3	.11
Manganous oxide, MnO	.28
Sodium oxide, Ma_2O	1.34
Potassium oxide, K_2O	3.72
Loss on ignition	10.18
	100.63

The deposits of clay briefly described above, are of the same character as much larger deposits exposed near Sault Ste. Marie and occurring widely on the Lake Superior shore of Michigan. Judging from the pronounced physical characteristics of the clay at these several localities and its known relation to other and associated deposits, it seems evident that it was laid down in a single widely extended water body. No fossils have been found in it to show whether it is of marine or lacustrine origin, but the presumption is that it was deposited in a lake. As to the date at which this lake existed no good evidence has as yet been obtained in Northern Michigan, but during the past summer similar clay previously known to exist in the northern portion of southern Michigan, has been shown by Frank Leverett to be several hundred feet thick and of older date than the surface morainal deposits of the region and to rest upon older glacial deposits. It is thus shown to have been deposited previous to the southward advance of the Wisconsin ice sheet. This is a highly instructive discovery, and if as now seems probable, the pink clays of Northern Michigan were deposited in the same lake as the similar clays in Southern Michigan, the existence of an inter-glacial lake in the Great Lakes basin of comparable size with Lake Algonquin is made manifest.

SAND DUNES.

General characteristics: Sand blown by the wind is frequently deposited in piles, forming conspicuous hills, in much the same manner that snow is blown into drifts. Sand, however, is sometimes piled up at the same locality during a succession of years and the hills formed are in many instances far larger and more conspicuous than the snow drifts that are formed on the lowlands of temperate regions.

One source of supply of sand available for wind transportation, is along lake shores where it is left on the land by waves generated during storms. When sand thus left becomes dry it is blown about by the wind, and on-shore winds frequently drift it inland and pile it in conspicuous heaps. The localities of annual accumulation are usually determined by the presence of vegetation, and to induce conspicuous deposition the plants which assist in the progress of accumulation must be capable of growing from year to year, with comparatively little moisture. Drifts started in this manner are usually elongated in the direction the prevailing winds travel, but when a considerable elevation is produced it causes an eddy in the winds passing over it, and thus leads to additional sand accumulation, which take the form of a snow drift, and an elongated ridge or drift is produced at right

angles to the direction of the carrying winds. Such drifts of sand or *dunes*, have a gentle slope facing the wind which brings the sand and a steep slope in the opposite direction. Sand swept up the gentle slope to the crest of the drift is precipitated over it and the dunes progress as one side is eroded and the other side added to. In this stage the sand drifts are known as *traveling dunes.*

The sand can only be moved by the wind however, when it is dry, and when but little vegetation is growing upon it. In a humid climate like that of Michigan, the prevailing moisture of the sand and the favorable conditions thus produced for the germination of seeds and the growth of vegetation, are factors tending to arrest the advance of sand drifts. When these conditions become dominant the drifts are soon clothed with vegetation, and their progress is arrested. In this condition they are termed *established dunes.*

The drifting of sand inland from a lake shore, is favored to a higher degree on shores facing the prevailing winds of the region where a lake is located, than when these conditions are reversed. The supply of sand is also regulated by currents in lake waters, which tend to carry sand from one part of a lake shore and to deposit it on another part; such localities being determined respectively by the direction of the wind and the nature of the outline of a lake's margin and the topography of its bottom adjacent to the land. Of these and other less conspicuous conditions, which control the movement of sand by lake water, prevailing direction of wind is usually the most important. For example, the winds blowing over Lake Michigan, are prevailingly from the westward and sand dunes are a common and conspicuous feature of its eastern shore, but are practically absent from its western shore. A more complete analysis of the condition favoring the formation of sand dunes about the margins of lakes would include the breadth of the water bodies, and hence the strength of their waves and currents, a broad water body being more favorable in this connection than a narrow one, but perhaps enough has already been said to enable the general reader to appreciate the significance of the facts concerning the sand dunes of Northern Michigan to which attention is invited below:

Dunes on the north shore of Lake Michigan: Nearly the entire area adjacent to lakes Huron and Michigan on the north, is conspicuously sandy. The sand is composed essentially of fragments of quartz, but the solid rocks of the regions are limestone and dolomite, in which sand grains seldom occur, and none of which would yield a conspicuous amount of sand on weathering. The immediate source of the vast quantities of sand mantling the surface and forming the greater part of the soils, as long since pointed out by Desor, is the glacial drift. All of the larger streams of the region especially during their flood stage, bring quantities of sand to the localities where they enter lakes Huron and Michigan, but many of the smaller streams, and even the larger ones during the low-water stages, are clear but of a brownish-yellow color owing to vegetable matter in solution. The clearness of the streams when not in flood, is due to the fact that they are fed at such times by water which filters through sandy deposits, or percolates through the vegetation of swamps.

The waves of the Great Lakes on reaching their shores, as a rule meet deposits of glacial drift, which is eroded, the finer particles being carried lakeward by currents, and the stones and sand dropped near shore in shallow water. This process of washing and assorting the drift has been in operation

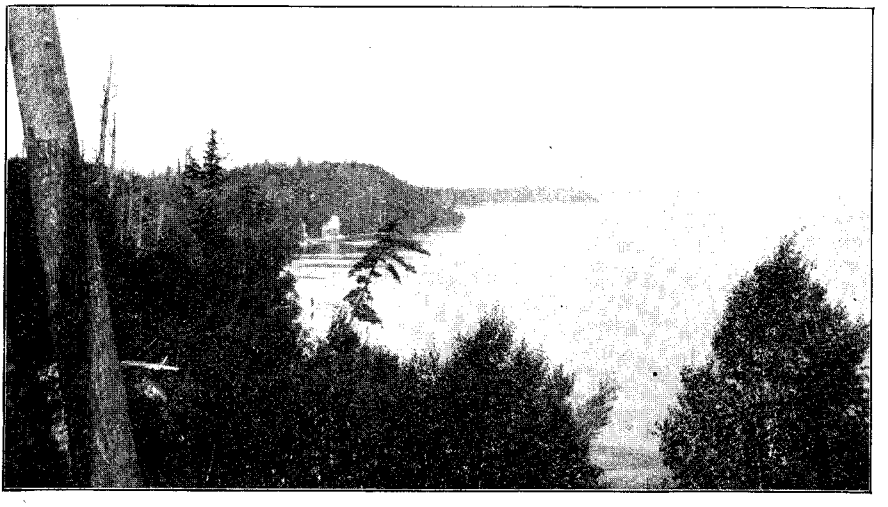
from the highest level reached by former water bodies in the basins of lakes Huron and Michigan down to the beaches of the present lakes and throughout this interval sand is abundant. At the various localities where the Algonquin beach is present, sand dunes are more or less prevalent, but as a rule are not conspicuous. Along the Nipissing beach drifted sand is more plentiful than at higher stations, and below that beach and down to the present margins of lakes Huron and Michigan the influence of the wind in forming dunes is frequently well illustrated. The principal dune and the broadest area of wind deposited sand, however, are adjacent to the borders of the present lakes.

Dunes are not a conspicuous feature of the region examined to the east of St. Ignace, although some drifting of the sand which is so abundant in the vicinity of the Nipissing beach, between Hessel and Detour, seems to have occurred. Adjacent to the north shore of Lake Michigan sand is more abundant than about the north shore of Lake Huron, and at several localities has been shaped into characteristic dunes. From near Gros Cap to Brevoort, on the west side of the St. Ignace Peninsula, there is a belt of country adjacent to Lake Michigan and from one to four or five miles wide, which is conspicuous on account of its dune topography. Over much of this region the sand is still drifting, but in large part the hills that have been formed are completely clothed with vegetation, or in other words are established dunes. Many of the dunes are so old that dense forests grow upon them, and before the region was devastated by lumbermen they supported a fine growth of pines.

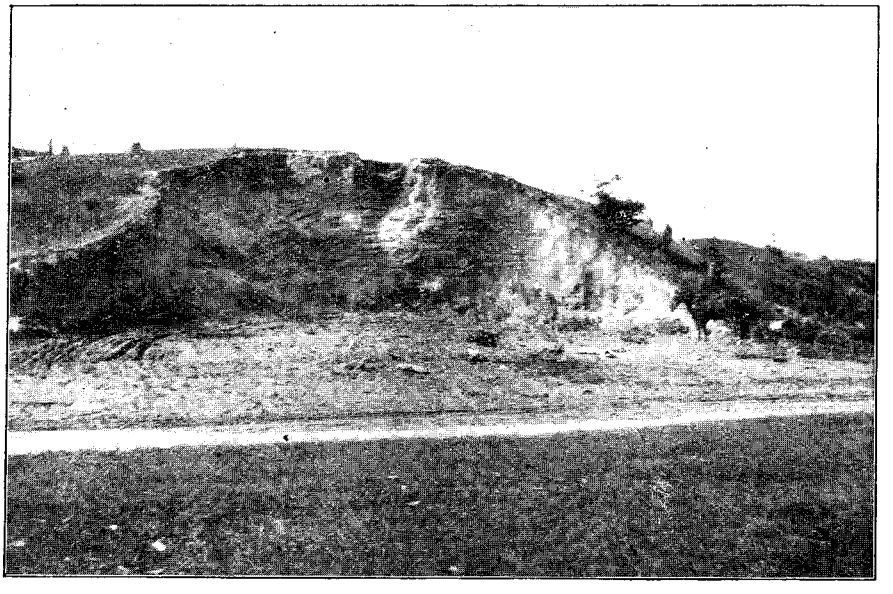
A characteristic portion of the sand-buried area in question, occurs between Lake Brevoort and Lake Michigan, where there is an extensive tract of undulating and hilly country with marshes and ponds, scantily clothed with vegetation. In this region extensive areas are rendered blue by huckleberries in late summer. Conspicuous dunes rising to a height of 60 to 80 feet, border Brevoort Lake on the west and form the highest land in the vicinity. These hills with deep depressions between, something of the picturesqueness of which is revealed by the photograph forming Plate XII, A, were formerly clothed with pines, and owing to the difficulties of lumbering in such a rough region, some of the aged trees still remain. The dunes are in part washed along their eastern bases by the waters of Lake Brevoort and precipitous slopes imparted to them. The sand removed has in large part been spread out in the lake, shoaling its waters, and along its shore when dry, is again being blown into drifts. Certain portions of the clean washed sand, when dry, gives forth a musical or barking sound when trodden upon, not unlike the sounds emitted by snow beneath one's feet during unusually cold weather.[1]

Sand dunes are also abundant on the blunt peninsula which terminates in Point Patterson, and from there westward to Manistique forming a belt, in general from two to three or four miles wide adjacent to the shore of Lake Michigan. In this region as in the case of the dunes near Brevoort Lake referred to above, the dunes are on the lakeward side of the Nipissing beach. The topography has the usual irregularities of regions of drifted sand and in the hollows swamps are frequent. Owing to the piling up of the sand certain low areas have been isolated and basins produced

[1] Such "barking sand," "singing sands," "musical sand," or "sonorous sand," as it has been termed, occur abundantly in various parts of the world, but the reason for its sound-emitting quality when disturbed has not been explained. At Brevoort Lake the sonorous sand is rather coarse, uniform in grain, and free from fine particles. It is dune sand which has been washed and assorted by the waters of the lake and thrown on the shore, where some drifting has taken place. An abstract of an interesting paper on musical sand, by H. C. Boulton and A. A. Julien may be found in Proceedings, American Association for the Advancement of Science, Vol. XXXIII, 1885, pp. 408–413.



A.—ESTABLISHED DUNES ON WEST SHORE OF BREVOORT LAKE.
August 3, 1904.



B.—EXCAVATION IN A DUNE NEAR MANISTIQUE.
August 10, 1904.

which hold lakes. The region was formerly almost completely forest covered, but the pines have now been cut and fires following the destruction wrought by lumbermen have greatly altered the character of the primitive vegetation. A narrow belt of dunes from 30 to 50 feet high, extends along the shore of Lake Michigan for about two miles, eastward of Manistique. Deforesting has there been complete and the smooth curved surfaces of the sand hills have been converted into pasture land. Near the tops of some of the hills the thin sod has been broken, owing to the trampling of stock, the wind has gained access to the sand beneath the shelter of the grass roots, and has begun to scoop it out. Conspicuous changes from this cause are likely to result. Near Manistique the sand of a dune has been excavated for industrial purposes, and a good section exposed in which the irregular cross bedding, characteristic of wind-deposited material, is well shown. A photograph of this section is presented on Plate XII, B.

A conspicuous feature observed in sections of the dunes near Manistique, and common in many of the sand and till deposits of various kinds throughout the part of Michigan under consideration, is the whiteness of the deposits to a depth of from a few inches to a foot or two below the surface, in comparison with the yellowish or reddish color of the same material at a greater depth. This bleaching of the surface portions of previous deeply colored deposits is due to the removal from them of the iron they previously contained, owing to the solvent power of the downward percolation water charged with acids derived from the decay of vegetation.

Drifted sand covers the surface of the northern portion of the Garden Peninsula, as far south as Portage Bay, and is reported to occur all along its eastern shore. In this region and adjacent to the railroad from Manistique to near the crossing of White Fish River sand dune topography is the prevailing feature of the landscape. Conspicuous dunes occur in the neighborhood of Ensign and also to the north of that village over the jack-pine plains bordering White Fish River on the east.

As previously mentioned, the country from Gladstone to Menominee throughout a belt in general about five miles wide, adjacent to the shore of Green Bay, is deeply sand covered, but conspicuous sand dunes are not known to occur except in the immediate vicinity of Manistique where small examples are conspicuous on account of their barrenness, and also because of the flatness of the country about them. The general lack of dunes in the sandy belt just mentioned, is as it appears, due principally to the fact that the prevailing winds are from the westward and tend to blow the sand that is thrown ashore by waves, lakeward instead of landward.

The dunes to which attention has been directed are instructive chiefly as examples of "established dunes." The regions where sand is now being drifted are restricted in area and confined for the most part to the west side of the St. Ignace Peninsula. At this locality the prevailing westerly winds have the broadest sweep across a lake surface, of any part of the country here considered, but the natural conditions have been greatly modified, owing especially to forest fires. Throughout the whole extent of the north shore of Lake Michigan, the conditions were formerly more favorable than at present for the drifting of sand, and indicates that the dunes preceded the forests. This consideration coupled with what is known of the history of the Great Lakes after the subsidence of the waters of Lake Nipissing, seems to show that when the waters fell from the Nipissing beach

to their present horizon, a sandy region was left exposed and before vegetation became abundant upon it the sand was drifted into dunes. It thus appears as if the now "established dunes" were formed soon after Lake Nipissing subsided, and that the accumulation of drifting sand has gone on at a less rate since that event to the present time.

LAKE AND SWAMP DEPOSITS.

Wet basins: Of later date than the glacial drift and also, in part, subsequent to the formation of the beaches of Lakes Algonquin and Nipissing, and subsequent, also, in many instances to the formation of the established dunes about the northern border of Lake Michigan, are certain deposits made in the many lakes and innumerable marshes and swamps of the region under consideration.

In localities covered with glacial drift at higher elevation than the Algonquin beach, depressions are frequently occupied by lakelets, or swamps. In a similar way, below the Algonquin beach where sand is not abundant, the topography of the drift controls the relief of the surface, and wet depressions are not uncommon; areas of this character are frequent at localities at a distance from the beach, which were deeply submerged during the existence of Lake Algonquin. Illustrations in point are furnished by the numerous lakes and undrained basins on Drummond Island. By far the greater number of the lakes and swamps on the land adjacent to lakes Huron and Michigan on the north, however, occur in association with the Nipissing beach or in the usually sandy tract of country below that beach and extending to the margins of the present Great Lakes.

Deposits: In the wet basins to which attention has just been directed, two classes of deposits have accumulated; one class consists of material brought in suspension by inflowing streams, i. e. mechanically formed; and the other class has been produced by vegetable growths, i. e. organically formed.

Of the mechanical deposits referred to, no more need be said at this time, than that they consist principally of sand.

The organic deposits in the wet basins consist principally of (a) peaty accumulations, due to the growth and decay of many generations of water-loving plants together with leaves etc., blown from the adjacent land, and (b) so-called marl, formed principally by the concentration of lime (calcium carbonate) from lake waters by certain species of algæ.

Peat: The peat deposits are widely distributed throughout the portion of Northern Michigan examined, and occur not only in definite basins but quite generally over the surface of nearly flat and poorly drained land. They seldom reach a great thickness, although in some swampy areas, as about four miles north of Hessel and at certain localities on Drummond Island, they are reported to be 20 to 30 feet deep. In general, however, their depth is measurable in inches rather than feet. In a few instances the peat may perhaps be sufficiently deep and of the requisite physical character to be of economic importance as fuel in the distant future when wood shall have become scarce, but in general it has rather the character of muck or a mucky soil, and is of chief value on account of the fertility it imparts to the sand with which it is usually intimately associated. It is an economically important fact that much of the present swampy condition of Northern Michigan is due to the mat of partially decayed vegetation that rests on the surface and clogs the drainage

channel. The removal of this material from the channels of rills and brooks, and the excavations of shallow ditches would result in rendering sufficiently dry for agricultural purposes, pasturage etc., many extensive tracts which are now dense tamarack and cedar swamps.

Marl: White pulverulent, calcium carbonate resulting from the decay of *Chara* and other fresh water algæ, is present in some of the lakes on Drummond Island and on St. Ignace Peninsula, but so far as has been learned, the amount of such material of sufficient purity to be of value in the manufacture of Portland cement, is not great. More careful exploration in this connection is desirable[1] however, before the absence of commercial quantities of marl can be asserted with entire confidence.

SOILS.

The leading characteristic of the soil of the portion of Northern Michigan considered in this report, is its sandiness, the only conspicuous exceptions being the region occupied by pink clay about Isabella, the surfaces of the washed drumlins in or near Les Cheneaux Island, and the presence over many extensive areas and irrespective of the character of the sub-soil, of muck and other forms of decaying vegetable matter.

The soils of the region indicated on the map forming Plate XVI. with the exception of those composed largely of partially decayed vegetable matter, may be classified so as to indicate this economic importance, in the same manner as the superficial deposits to which they owe their principal characteristics are subdivided. The map just referred to thus becomes a soil map from which in a general way the agricultural possibilities of various areas can be judged. In this connection, it is understood of course, that in addition to the general nature of the soil of a region, other conditions such as its topography, drainage, etc. must be considered as affecting and frequently as exerting the leading control in reference to its agricultural possibilities.

The soil in the portions of the region here considered where till forms the surface are in general reddish, sandy loams.[2] From St. Ignace Peninsula eastward to and including Drummond Island, the till soils which are prevailingly sandy, contain in general a higher percentage of clay-like material than do the similar soils to the north and northwest of Lake Michigan. Examples of till soils without the modifications due to submergence beneath lake waters, in the region lying east of the St. Ignace Peninsula, occur only on the summit portion of Mackinac Island and on the hills to the north of Hessel and Cedarville above the horizon of the Algonquin beach. The former of these localities is only a few score acres in area and is not under cultivation; the latter embraces several square miles, and is favorable for agriculture as is shown by the many fine meadows and grain fields it contains. The soil is a rather stiff loam, except where sand has been blown over it from the Algonquin beach, or muck is in excess as is the case in the poorly drained portions. In general the entire area above the Algonquin beach excepting the wet basins, is favorable for agriculture.

[1] See Reports of the Geological Survey of Michigan, Vol. VIII, Part III, p. 340.

[2] A loam is a mixture of sand and clay in various proportions, together with more or less but in general a small per cent, of organic matter; should any one of these three ingredients be present in excess, and form the leading characteristic of a soil, it may conveniently be termed respectively, a clayey loam which may grade into a clay soil, a sandy loam which may grade into a sandy soil, or mucky or black loam, which may grade into a muck soil. These terms are in common use among farmers and others and are here employed instead of certain more technical classifications of soils that have been proposed.

Below the Algonquin beach on the St. Ignace Peninsula and thence eastward to and including Drummond Island, the till soil, when not concealed beneath subsequently deposited sand, is a reddish loam, but in general contains a notable percentage of sand and grades into decidedly sandy tracts where lake waters have deposited material. Drummond Island, owing to the fact that its site was many miles distant from the nearest land during the existence of Lake Algonquin, is mostly free from lake deposited sand and is covered with a reddish sandy loam of glacial origin. The topography of the central part of the island above the Nipissing beach has an uneven surface and owes its hills and hollows to the irregularities of the till sheet which covers it. The soil is in general fertile and is judged to be suitable for the growing of hay and use for pasture, but only comparatively small portions have been cleared.

Till soils are present in the region about Detour, but a mile or two west of the village sand predominates and extends throughout much of the region adjacent to the north shore of Lake Huron, as far as the low tract of densely forested country about the shores of St. Martin's Bay.

On Les Cheneaux Islands and the hills of the mainland adjacent the soil is till, but as previously explained, much of it has been washed by the waters of lakes and the finer surface material removed leaving the stones and large boulders. The surface is excessively stony (Plate VI, A.) and unsuitable for agriculture, although room for fruit trees might be found among the countless boulders that occupy the surface.

Bois Blanc Island is excessively sandy throughout although the presence of boulders indicates that the surface layer is in part at least a glacial deposit. The sand is usually dark at the surface owing to decaying vegetable matter and when newly cleared and cultivated is said to yield favorable returns, but the vegetable matter soon disappears from cultivated areas, being in part blown away when dry, leaving nearly white sand.

On the St. Ignace Peninsula above the Nipissing beach (45 feet above the surface level of lakes Huron and Michigan) the soil is principally a sandy till. Where the land is sufficiently well drained it is favorable for agriculture as is demonstrated by the prosperous appearance of the farms near Allenville etc. In this region the fertility of the soil is probably enhanced by the presence of gypsum derived from the underlying formations. In the main, however, the soil consists of till brought from the northward by glaciers and not subsequently buried beneath lake deposited sand.

Reddish sandy till soil predominates in the various areas above the Algonquin beach to the west of the St. Ignace Peninsula and especially in Menominee county. The comparatively small area at Cook's Mills and Ensign, which are about the horizon just mentioned, are to a large extent covered with wind deposited sand and are not favorable for agriculture. At Ensign, however, a thin layer of reddish sandy till is present, barely enough to conceal the solid rock beneath, and agriculture has been attempted and more favorable results obtained than the thinness of the soil seems to warrant.

The most favorable agricultural region of considerable extent, throughout the portion of Northern Michigan represented on the map forming Plate XVI., is situated in the drumlin area to the west of Green Bay. This region is higher than the Algonquin beach and the soils on the hills and in some of the valley is a reddish, exceedingly fine sand-loam of glacial origin. As has already been explained the hills throughout Menominee County and

extending into adjacent counties on the north and west, were given their characteristic slopes by ice-erosion during the last advance of glaciers over the region, when the ice melted the fine silt and dust it contained together with a notable but not excessive quantity of stones and boulders was left as a surface sheet over the hills and valleys. To this glacial deposit some æolian dust has probably been added since the melting of the last of the former ice sheets.

The fine surface layer thus superimposed on the land furnishes an excellent soil. In the valleys between the smooth, oval hills, gravel and sand was deposited in many localities by sub-glacial streams, and since the Glacial epoch, peaty soils have been formed in the wet depressions. The drumlins on account of the fine rich soil covering them and also because of the rapid absorption and retention of rain water, and favorable exposures to the sun, offered conditions highly favorable for agriculture. The valleys are more difficult to clear of forest growth and to drain, than are the hills, but yet are by no means beyond redemption.

From an agricultural point of view as well as in reference to mode of origin, the hills and ridges of the Menominee region present two very different types of land forms. The smooth surfaced drumlins with silt-like soils and reddish stony sub-soils, are well suited for agricultural purposes and will no doubt all be cleared and cultivated at an early date; while the eskers or winding ridges of gravel and sand, on account of the extreme porosity of the sub-soil and in general the frequently complete absence of a true soil, other than decaying vegetable matter, are unfavorable for cultivation. While economic interests demand that the drumlins should all be cleared and cultivated, the best use that can be made of the eskers, is, seemingly, to reserve them for wood land, or utilize them for growing fruit. The eskers also furnish an abundant supply of gravel for road-making and other uses.

Below the Algonquin beach and above the Nipissing beach, in the portion of the field lying between the St. Ignace Peninsula and Manistique River, reddish till soils consisting mostly of sandy loam, are present over areas which were sufficiently remote from the shores of the lake which formerly covered them to escape receiving a deposit of lake sand. The areas referred to occur principally between Bovee and Manistique, adjacent to the Minneapolis, St. Paul and Sault Ste. Marie railroad, and on the southern portions of Garden and Bay de Noc Peninsulas. In the region adjacent to the railroad, the till soil over large areas is concealed beneath swamp accumulations, but considerable portions of the region in the neighborhood of Point Patterson, have a favorable slope for drainage, and in fact are drained in part by underground streams flowing through limestone caves and have been cleared for farming purposes. On the Garden Peninsula to the south of the deep sand which covers its northern half, the soil is a reddish sandy loam, with many stones and boulders and in numerous localities when drainage conditions are favorable, is susceptible of a high degree of cultivation. This is a favorable fruit region, and in many ways gives evidence of agricultural prosperity.

On Bay de Noc Peninsula the last ice advance seems to have completely removed all previous surface accumulations, that may have been present, and spread out as it melted, a thin sheet of fine sandy loam, containing loose stones and boulders, in composition much like the surface covering of the drumlins in the Menominee region. The soil layer thus formed is seldom

over three feet thick, and its average depth is in the neighborhood of two feet. It rests on a remarkably even surface of limestone and in spite of its flatness is mostly well drained owing to the presence of fissures in the rock beneath. The soil although thin is of good quality, and a fair advance in agriculture has been made. Below the Nipissing beach as roughly indicated on the map forming Plate XVI., sand is almost invariably found, and these areas together with their associated sand dunes and the jack-pine sand plains to the north of Bay de Noc Peninsula, cannot be claimed as favorable for cultivation. Their chief value, as it now seems is for the growing of trees.

The most exceptional soils of the region under consideration are those formed from lake clays, as in the region about Isabella (See analysis p. 94.) These are stiff clay soils which in most situations require ditching or other methods of draining, but are productive and give promise of favorable returns when methods of agriculture adapted to their peculiarities are employed. This soil is closely similar to the soil of the large clayey area to the south of Sault Ste. Marie, which is a prosperous agricultural region, and should be equally productive.

In the above brief review of the characteristics of the lands bordering lakes Huron and Michigan on the north, several references have been made to the muck and peat deposits of swamps. On the whole, the soils which owe their leading characteristics to the presence in them of a predominating percentage of decaying vegetable matter are the most common and widely distributed of any of the soil types of the region. The peaty or mucky soils occur not only in wet depressions but in many instances on surfaces which would have a free drainage if the mat of vegetable litter and roots of living plants which occupies the surface were removed. The dense and all but impassable tamarack and cedar swamps for example, which cover extensive areas in Northern Michigan, frequently have a subsoil of sand, and could be drained at comparatively small expense if the land thus rendered available was of sufficient value for farming, but in general these sandy lands, although perhaps productive in hay and grain for a few years after being reclaimed, deteriorate rapidly as the vegetable matter contained in them decays, on account of exposure to the air, and their ultimate value is probably small.

In brief, the two leading types of soil in the region here considered, are sand which grades into sandy loam, and muck which also grades into sand and when drained and exposed to the air is apt to be removed leaving sand or sandy loam. Considering all conditions the region cannot be justly claimed as being even moderately favorable for agriculture, although there are certain conspicuous exceptions as for example, in the drumlin area to the west of Green Bay, on portions of the St. Ignace Peninsula, etc.

RECENT CHANGES OF LAKE SHORES.

In traversing the borders of lakes Huron and Michigan with the charts of the Lake Survey in hand, it becomes apparent that at certain localities conspicuous changes have taken place in the shore lines of the lakes since the surveys on which the charts are based were made. Evidence in this connection has also been obtained from fishermen and others, which shows still more definitely at what time the changes referred to were produced.

The principal changes that have been observed pertain to the formation

of gravel bars between islands, or uniting a former island with the mainland, the building of gravel spits, and the origin of new shoals and islands.

Included in the Lake Survey chart of the Straits of Mackinac, (No. Hd.), based on surveys made—so far as the shore-lines here considered are concerned—in 1851, there are several localities where the present conditions differ from those represented on the chart. The principal instances noted are among Les Cheneaux Islands, (See Plate V.).

White Fish Island as designated on the chart, is now connected with the mainland by a gravel bar, a view of which looking north from the north end of the former island, is presented on Plate XIII, A. The bar has been produced by the junction of two spits; one starting from the island and the other from the end of a cape on the mainland. Fishermen and others familiar with the locality, state that boats with a draught of four feet, passed through the former opening as late as 1889. The pass was closed between 1890 and 1900[1].

Since the surveys referred to above were made, a gravel spit some five hundred feet long, has been formed at the north end of Rover Island. Owing to the unusual height of the water of Lake Huron during the summer of 1904, the spit was submerged at that time with the exception of a few square yards near its lakeward end.

On the chart referred to above, Boot Island is represented as being separated from another and smaller island to the southwest by a narrow strait. This strait is now closed by a gravel bar the surface of which is four or five feet above the present level of Lake Huron.

At the southeast end of La Salle Island a bay is shown on the chart, with a narrow point of land, i. e. a gravel spit, projecting from its southwest shore and nearly dividing it. The spit has been prolonged during recent years, through the action of waves and currents coming principally from the south, and now completely closes the entrance to the inner portion of the former bay, thus transforming it into a lake, from which a small stream outflows to Lake Huron.

The most conspicuous change in the lake shore among Les Cheneaux Islands, is the tying of a small islet known as Penny Isle, to Isle William. The strait between the two formerly independent islands is now crossed by a gravel bar, a portion of which is shown in the photograph forming Plate XIII, B. The bar is in general from ten to twenty feet wide, and rose about two feet above the adjacent water-surface in the summer of 1904. At one locality, however, near its middle, the waves broke across it during storms from the south. The bar consists of two spits which have been extended until they united. One of the spits was built out from Penny Isle towards the northwest and nearly reached Isle William; the other spit was formed by waves and currents coming from the south, which moved gravel and sand along the shore of Isle William, and at present meets the spit projecting from Penny Isle, near its growing end. The sand and gravel swept northwest from Penny Isle, was, as it seems, supplied by material pushed up by ice floes from the surface of the shoal on which the isle is located. The islet itself although indicated on Lake Survey chart No. Hd., and therefore in existence in 1851, is certainly of recent origin, and probably owes its beginning to the concentration of stones and boulders on the surface of a shoal through the action of ice.

[1] For much of the information here presented concerning recent changes of the shore topography among Les Cheneaux Islands, I am indebted to Prof. John R. Allen, of the University of Michigan, who has made several visits to that region.

The process just mentioned, of moving loose stones which rest on the bottom in shallow water and shoving them into piles, is accountable for the appearance from time to time of boulder reefs at various localities about the shores of the Great Lakes. The stones and particularly large boulders, become frozen into the ice which when it breaks and forms floes is moved by the wind and waves; the tendency seems to be to force the greater part of the material thus held, landward, for the reason that in general the on-shore are stronger than the off-shore winds, and also because when open water is present the waves assist in the on-shore movement but not in the reverse movement. The best example of land formed as seems most probable, by this process, is Goose Island, situated about two miles southwest from Marquette Island the largest of "The Snows."

Goose Island is about a mile long, a few rods wide and from 15 to 20 feet high. So far as can be judged it is composed entirely of well worn limestone gravel together with large boulders derived from the glacial drift, and occupies the central part of a shoal. The action of waves and currents in moving the loose material is conspicuous all about its margin, and especially at its north end where the gravel spit shown on Plate XIV, A, has been produced by the meeting of streams of shore drift which travel northward along its sides.

A similar spit with a recurved end, on the south shore of Round Island, is shown in Plate XIV, B.

The most pronounced of the recent changes in shore topography to be recorded at the present time, is at the northwest end of Round Island, a mile south of Mackinac Island, where a gravel spit about a thousand feet long has been formed during the past decade. Two photographs of this locality from nearly the same point of view, one taken in 1885 and the other in 1904, are presented on Plate XV., which indicate quite satisfactorily the nature of the changes that have occurred.

The recent changes in elevation of the surfaces of the Great Lakes have been critically studied by G. K. Gilbert,[1] and the conclusion reached that a movement is taking in the portion of the earth's crust on which the lakes are situated, of the nature of a rise to the northeast or a depression to the southwest. The rate of tilting is about 0.42 foot per hundred miles per century. That is, in the case of a line one hundred miles long, extending in a northeast and southwest direction, and situated in the region of the Great Lakes, the differential movements of its extremities would be 0.42 foot in one hundred years. This change tends to cause a rise of the water on the southwest shores of lakes which have no outlet in that direction, and a shoaling of the water on their northeast shores. From the nature of this change, it is to be expected that the water on the northeast shore of Lake Huron has been falling during the past century, but certain observed conditions appear to furnish an exception to this conclusion.

At Fort Drummond, situated on the southwest shore of Drummond Island, docks supported by cribs filled with stones, were constructed before 1822, and two groups of cribs are still in place. At the more westerly of these two groups, on July 22, 1904, the water was thirty inches above the tops of the upright posts at the corners of the cribs. At the eastern group of cribs on the same date, the water was forty inches deep over the tops of the corner posts. The posts are square at the top, and not abraded as if cut off by moving ice, but have the appearance of having been sawed to a uniform level. The relation of the summits of the posts to water level

[1] U. S. Geological Survey, 18th Annual Report, Part II, pp. 601–647. See also p. 36 of the Report on Huron County, Vol. VIII, Mich. Geol. Survey.

at the time they were put in place, is not known, but a reasonable supposition is that they were above water at that time. Adjacent to the cribs referred to and south of them, i. e. at the lakeward end of the former dock, the water is now seven feet deep. The bases of the chimneys of a former building now designated by the residents of the locality as the Barracks, are now three feet above the water as measured by a hand level.

The facts just recorded indicate that there has been a rise of water of about three feet since the docks at Fort Drummond were built, but the qualifications mentioned, render this conclusion of doubtful value. Possibly a search of the records pertaining to Fort Drummond, would reveal data for determining more accurately than is now practicable to what extent the level of the water has changed since the old fort was built.

The limited time available for the reconnaissance on which the present report is based, did not permit of my making a detailed study of the changes in shore-line topography to which attention has been directed, but it is hoped that the meager data presented, will lead persons who visit Les Cheneaux Islands, Mackinac Island etc., to photograph the localities where the changes are progressing most rapidly and thus secure a record of the alterations in progress.

DESCRIPTION OF PLATE XIII.

This plate is referred to in the text on page 103 and shows some of the changes which have taken place in a very few years.

A. This photograph was taken looking north from the north end of White Fish Island, July 29, 1904.

B. Is a recent gravel bar connecting Penny Island with Isle William and the photograph was taken July 31, 1904.

The characteristic shape of such bars and the advance of vegetation out upon them is also shown.

A.—RECENT GRAVEL BAR CONNECTING WHITE FISH ISLAND WITH THE MAINLAND.

B.—RECENT GRAVEL BAR CONNECTING PENNY ISLAND WITH ISLE WILLIAM.

DESCRIPTION OF PLATE XIV.

This plate is referred to on page 104 of the text and also illustrates recent changes of shore line. Similar spits have been quite elaborately studied by Gulliver and others.

A. Is a photograph, taken July 16, 1904, of a recent gravel spit at the north end of Goose Island.

B. Is a photograph, taken August 2, 1904, of a recent gravel spit on the southeast shore of Round Island.

A.—RECENT GRAVEL SPIT AT NORTH END OF GOOSE ISLAND.

B.—RECENT GRAVEL SPIT ON SOUTHEAST SHORE OF ROUND ISLAND.
August 2, 1904.

DESCRIPTION OF PLATE XV.

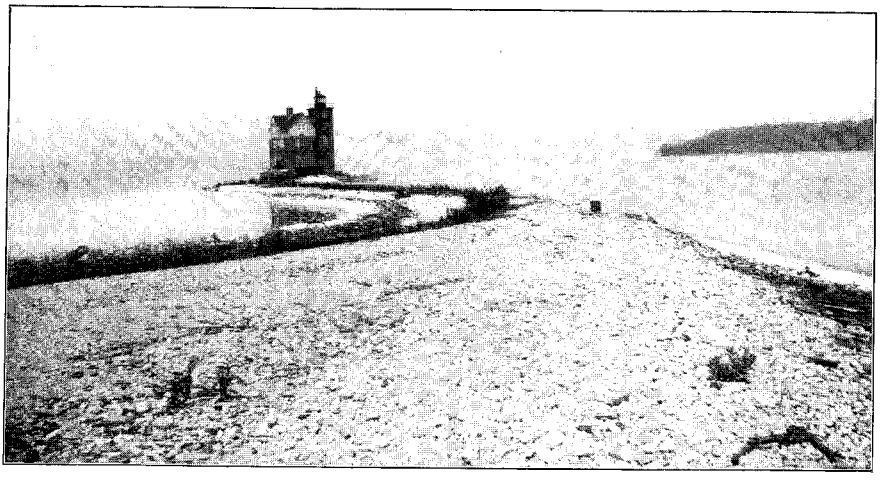
This plate is referred to on page 104. The two photographs were taken from almost the same point and in almost the same direction, at the northwest end of Round Island looking toward Mackinac Island, the bluffs of which appear in the background. The growth of a thousand feet of spit upon which a lighthouse is now located is shown.

There are also some indications of the beach levels on Mackinac Island.

Photograph A was taken July, 1885.

Photograph B was taken July 17, 1904.

A.—NORTHWEST END OF ROUND ISLAND.
July, 1885.



B.—RECENT GRAVEL SPIT ON NORTHWEST END OF ROUND ISLAND.
July 17, 1904.

DESCRIPTION OF PLATE XVI.

This plate is referred to in the text on pages 52, 62, 66, 85, 90, 99, 100, 102, and the features of it more fully explained.

While it shows primarily the glacial deposits, the glacial scratches, and the two most important shore lines left by former extensions of the Great Lakes system, yet on these in a broad way the character of the soil depends, as is more fully explained in the text from page 99 on, so that it may also be taken as a soil map, except that no attempt is made to indicate the smaller areas and peaty deposits. The originally swampy areas are shown on old maps issued by the Silas Farmer Company of Detroit.

SIXTH ANNUAL REPORT

OF THE

STATE GEOLOGIST,

ALFRED C. LANE

TO THE

BOARD OF GEOLOGICAL SURVEY

FOR THE YEAR 1904.

ACCOMPANYING THE PRECEDING PAPERS.

CONTENTS.

ILLUSTRATION.

ERRATUM.

Page 159, line 18, for "westward" read "eastward."

Office of the State Geologist,
Lansing, Mich., Nov. 14, 1904.

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

Hon. A. T. Bliss, President.
Hon. L. L. Wright.
Hon. Delos Fall, Secretary.

Gentlemen:—

The following is my report for the fiscal year July 1, 1903 to June 30, 1904, and the working season of 1904. I will make it as brief as possible, though there are one or two sub-reports to be included, of some length, since this is the legislative winter, and the State printer is extra busy.

The following is the usual statement of expenses from the annual appropriation:

FINANCES.

	Salary.	Field.	Office.	Total.
July	$352 36	$291 78	$155 53	$799 67
August	425 66	1,320 57	26 60	1,772 43
September	395 66	842 21	47 90	1,285 77
October	243 50	448 58	32 14	724 22
November	300 00	68 33	11 48	379 81
December	306 85	80 16	24 27	411 28
January	299 50	36 00	23 98	359 48
February	234 40	48 00	18 98	301 38
March	444 94	60	24 61	470 15
April	313 80	33 27	11 33	358 40
May	367 98	54 33	153 32	575 63
June	353 14	124 66	83 58	561 38
Total	$4,037 79	$3,348 49	$613 72	$8,000 00

In addition to this we have expended $476.87 for the purchase of the lot upon which your building stands in Houghton, sewerage connections, etc. This expense was due to the fact that the College of Mines upon whose lands our building was placed over ten years ago as tenant at will had grown so that they needed the land, and we had to find a permanent site for this building.

We also had $1,000.00 for continuation of the joint topographic survey with the U. S. G. S. With this and with the help of assistants employed from our annual appropriation, the area adjacent to the Ann Arbor folio on the east down to Detroit river has been covered, and I can lay before you photographs of two thirds of the same. I trust that the whole may be published this winter. Up to Nov. 14, of this there had been expended $861.00.

We have also expended for printing as follows:

Appropriation Sec. 1, Act 231, Session 1901.

		Allotment.
Expended mainly for Volume VIII, Part 3, and annual reports for 1901 and 1902	$1,947.21	$2,800.00
Balance is being used to reprint the Douglas Houghton reports.		

Appropriation Sec. 1, Act 178, Session 1903 per annum.

Allotment for 1903–1904		$1,250.00
Expended for Volume IX and for Annual for 1903 up to Oct. 27	$655.90	
Balance is being used to finish these volumes.		
Available for this report and other printing, 1904–5		$1,250.00

PUBLICATIONS.

In regard to the past year the record has not been as satisfactory as I could have wished. The printing has dragged in an unaccountable way, and Mr. Grimsley's report on Gypsum, which ought to have been out months ago and thus anticipated the present lively interest in the State's extensive resources of this material, is still in the hands of the Robert Smith Printing Co., though I hope it will be out this winter. The same thing is true of the Annual report for 1903-4, which is much larger than I expect this report to be, and contains a number of maps, which are thus tied up from the public.

A certain amount of the material of this report has, however, appeared in the Michigan Miner.

The only item, therefore, for the year 1904, is the issue of the map of the Ann Arbor quadrangle by the U. S. Geological Survey toward the preparation of which we contributed. This may be obtained by writing to the Director of the U. S. Geological Survey, and enclosing five cents for a single copy, or $3.00 per hundred.

WORK IN HAND.

A contour map of Tuscola county is in the engraver's hands, proofs have been revised, and will be inserted in one of the annual reports—that for 1903 if it is not later than this.

A contour map of Bay county has also been prepared, is in the engraver's hands, and is waiting to be inserted in the annual for 1903. The Mss. of W. F. Cooper's report on Bay county is practically ready to start off Volume X of the main series.

In response to many requests we are preparing a large map of the State in nine sheets upon which we can place, not only the bed rock geology, or that of the pre-Pleistocene, but also the surface geology of the glacial and unconsolidated sands, gravels, clays and till, and the soil. To this end arrangements have been made for co-operation with Mr. Frank Leverett, as is stated below:

Both C. A. Davis, who is working for us on peat and Tuscola county, and W. F. Cooper, and W. M. Gregory who is working on Arenac county have been delayed in their work for us by taking up hydrographic investigations for Messrs. Leverett and Fuller of the U. S. Geological Survey.

They received for this work better pay, and were still developing our scientific and economic knowledge of the State without expense to the State.