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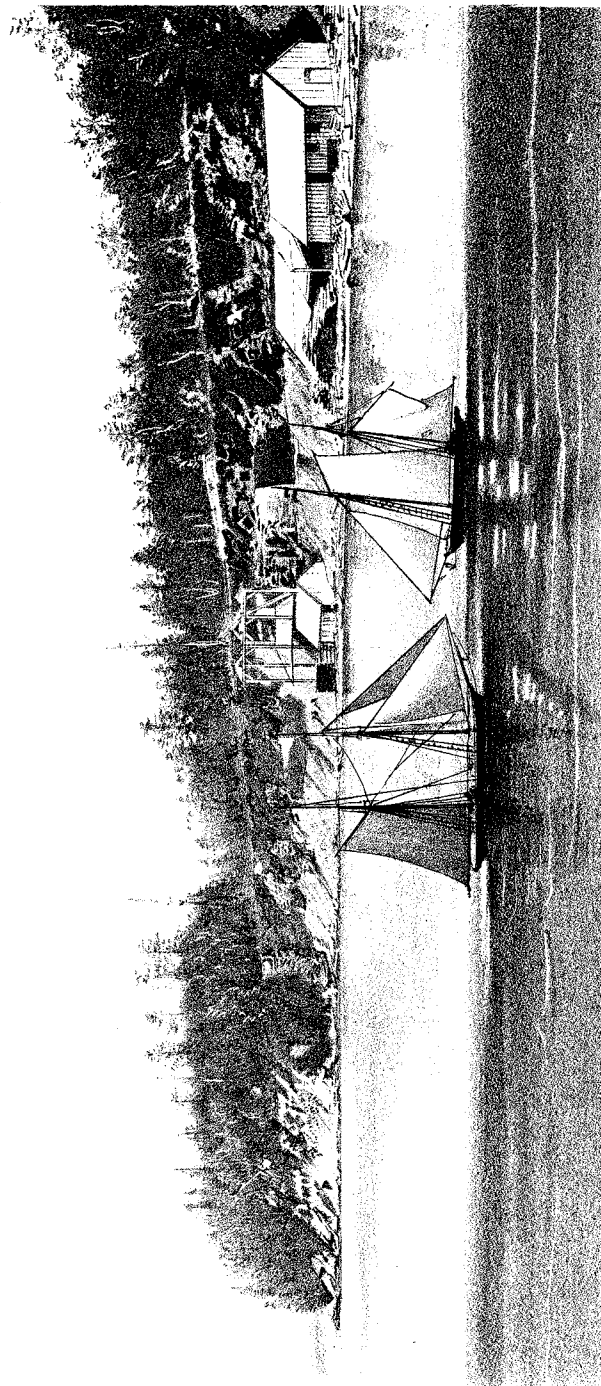
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GEOLOGICAL SURVEY
OF



MICHIGAN

1876.



Ben Hill.

LIMESTONE BLUFFS, LITTLE TRAVERSE BAY.

P. H. Wood

P. 76. 76002

GEOLOGICAL SURVEY OF MICHIGAN.

LOWER PENINSULA

1873-1876

ACCOMPANIED BY A

GEOLOGICAL MAP.

VOL. III.

PART I. GEOLOGY.

PART II. PALÆONTOLOGY—CORALS.

BY

C. ROMINGER

STATE GEOLOGIST.

PUBLISHED BY AUTHORITY OF THE LEGISLATURE
OF MICHIGAN

UNDER THE DIRECTION OF THE

BOARD OF GEOLOGICAL SURVEY.

NEW YORK
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PART I.

GEOLOGY

OF

LOWER PENINSULA.

BY

C. ROMINGER.

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* In pocket, in back of book.

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*To the Honorable the Board of Geological Survey of the
State of Michigan.*

GENTLEMEN:

I have much pleasure in submitting to your honorable body my final Report, giving the results of the Geological Survey of the Lower Peninsula of Michigan, commenced in the spring of 1873, and prosecuted without interruption during the past four years.

For several reasons, but especially as so many of the results of this survey had to be attained through the combination of fragmentary observations, made at different times and in far separated localities, it was found impossible to call any one to my assistance without danger of incurring endless complications, and of arriving, in many instances, at most unsatisfactory conclusions.

Therefore, with exception of the special report on the salt production of the State (Appendix B), I may claim the work as all my own. That report has been elaborated by my friend, Dr. S. S. Garrigues, the State Salt Inspector, a gentleman who, from his long official connection with that industry, must be better qualified than any other to treat of it in a work of this character.

Very respectfully yours,

C. ROMINGER,

State Geologist.

ANN ARBOR, July 1st, 1876.

CHAPTER I.

GEOGRAPHICAL POSITION AND SURFACE CONFIGURATION OF THE LOWER PENINSULA.

THE Lower Peninsula of Michigan comprises an area of about 35,000 square miles. It is situated between $82^{\circ} 25'$ and $86^{\circ} 50'$ of longitude, west from Greenwich, and $41^{\circ} 44'$ and $45^{\circ} 47'$ of northern latitude.

On the west it is bounded by Lake Michigan, on the north by the Straits of Mackinac, on the east by Lake Huron, Lake St. Clair and Lake Erie, besides the intermediate, river-like arms connecting the three lakes.

The southern limits are formed by the State lines of Ohio and Indiana. In a north and south direction, the greatest length of the peninsula is two hundred and seventy-five miles. In an east and west direction, the greatest width, coincident with a line drawn from Port Huron to Grand Haven, is about 200 miles.

Lake Michigan is 320 miles in length and 100 miles broad at the widest part, its total area being 22,000 square miles. Lake Huron is 260 miles long; 160 miles is the maximum of its breadth, and 20,400 square miles its surface extent. Both lakes have about an equal elevation above the ocean level, which is 578 feet. The elevation of Lake Erie above the ocean is 565 feet. These immense sweet-water basins, carved out in some places to a depth of over 900 feet, are evidently the result of eroding forces, acting on the sedimentary strata which once were spread without interruption across this entire lacustrine area, and these forces undoubtedly were identical with those by which the heavy masses of rock débris, known by the name of drift, were accumulated over a large zone of the northern hemisphere in this and in other continents. The longitudinal axes of Lake Michigan and of Lake Huron approximately have a north and south direction. Coincident with them

is the long axis of the Lower Peninsula which they inclose. Its north end is indented by two large bays.

One of them, Little Traverse Bay, extends fourteen miles from west to east, with a width in the centre of about six miles; its geographical position is in latitude $45^{\circ} 25'$, and longitude 85° , at their intersection in the centre of the bay. Only a short distance south of the small bay is the entrance of Big Traverse Bay, which has a north and south direction. Its length from Lighthouse Point to Traverse City, situated at the head of the bay, is thirty-four miles, its width about ten miles. A landspur, parallel with the longitudinal axis of the bay, divides it into two arms; the length of the spur is sixteen miles, with a breadth of one to three miles. On both sides of the bay, and only a short distance from it, are inland lakes of very elongated form, which evidently owe their origin to the same erosive forces which carved out the bay. On the east side of the peninsula, in the same latitude with Big Traverse Bay, Thunder Bay indents the coast in a northwestern direction; its length is about ten miles, equal to the width at the entrance. Fifty miles further south is the entrance of Saginaw Bay. Its direction is southwest, its length forty-five miles, and its width, between Point of Barques and Ottawa Lighthouse Point, twenty-seven miles.

The rise of the peninsula from the level of the lakes is generally gradual, and in a few places only is it abrupt. The surface is of an undulating, hilly character; the hills are rounded and never attain a very great height above the surrounding country. The southern part of the peninsula is lower than the northern. The swell of the land, forming the water-shed of this southern division, coincides with a line drawn in a southwest direction from Port Austin at the entrance of Saginaw Bay, to the southwest corner of Hillsdale County, where it enters the boundaries of the State of Ohio. Within the limits of Tuscola and Sanilac counties, the known surface elevation of this water-shed is about 400 feet above the lake; in Lapeer and Oakland counties it rises to 500 feet; further south, in Washtenaw and Jackson counties, it falls again to about 400 feet; while in Hillsdale, not far from the southern State line, some points with an elevation of 600 feet are recorded, but the water-shed is probably not over 500 feet high. The ascent from the lakes to the height of this water-shed is so gradual that a travel-

ler, in crossing the peninsula from either lake to the other, if he follows the river valleys, can scarcely perceive it. The northern division of the peninsula rises to almost double the height of the southern part; its surface is more broken, and diversified by steeper descents toward the lakes from terrace to terrace. Its highest points in the vicinity of Otsego Lake are, according to the records of the railroad surveys, 1100 feet above the lake level. Otsego Lake has a length of about five miles by a width of not quite one mile; it lies directly west of Thunder Bay, in the median line, and not far from the northern terminus of an extensive high plateau with undulating surface and an average elevation of from 700 to 800 feet.

All the rivers of the northern part of the peninsula have their sources within this plateau, which is dotted with a number of inland lakes, some of which, like Lakes Higgins, Houghton, and St. Helen's, are of large size. The terraces by which the descent from the plateau is made, form a succession of broad belts; their sides are moderately steep and finely timbered; the lowest are wider, gradually slanting toward the shore or overlooking it in bluffs of from 40 to 60 feet. In some places on the west side, the bluffs are from 100 to 200 feet high; and Sleeping Bear Point, a promontory facing Lake Michigan, west of Big Traverse Bay, is said to have an elevation of 500 feet. Opposite this point, twelve miles out in the lake, the Manitou Islands rise abruptly to a height of 200 feet above the water. South of the second correction line, the plateau rapidly declines toward Saginaw Bay. Between the north and south parts of the peninsula, a depressed strip of land extends from Saginaw Bay to the mouth of Grand River on Lake Michigan, having rarely more than 100 feet elevation. Its position is indicated by the river-beds of Bad River, which comes by its watershed in connection with the headwaters of Maple River, the latter emptying into Grand River. An astonishing number of smaller and larger inland lakes are found in every part of the peninsula; all have crystal-clear water, and the principal supply of the head branches of our rivers comes from them. The more important rivers, collecting the waters of the western slope of the peninsula, are the St. Joseph's River, Kalamazoo River, Grand River, Muskegon River, and Manistee River. The three first-named ones have their sources in close proximity to the elevated lands of Hillsdale and Jackson

counties. From the same swell of land the river Raisin emanates, flowing eastward into Lake Erie.

Raisin River enters the lake near Monroe; it drains the southern part of Washtenaw County through Saline Creek, Macon Creek, and through its main north arm, which, bending west, enters the southeast corner of Jackson County, and draws its branches from a number of small lakes. The south branches of the river have the drainage of the larger part of Lenawee County, and an arm extends southward into the State of Ohio. The west part of Lenawee and the south part of Hillsdale counties send a portion of their waters southward to the Maumee River in Ohio. The St. Joseph's River, Kalamazoo River, and Grand River almost touch each other within the small area of a few square miles in the county of Hillsdale.

The St. Joseph's River, originating in a number of small lakes and marshes in Hillsdale, flows through the southeast corner of Calhoun County into Branch County and St. Joseph County. It leaves the State at the southwest corner of St. Joseph, and enters it again in the southeast corner of Berrien County with a northerly direction, to enter finally Lake Michigan at the village of St. Joseph.

The streams which form the headwaters of the Kalamazoo River take their rise in Scipio, Moscow, and Somerset townships, in Hillsdale County. The river runs north to Albion, and flows in a due west direction to Kalamazoo, whence it bends northwest, intersecting Allegan County, and falls into Lake Michigan near Saugatuck.

Grand River springs from a few lakes in Liberty township, in the south part of Jackson County, and from a number of other lakes in the northeast quarter of the county. It runs north through Ingham, Eaton, Clinton, Ionia, Kent, and Ottawa counties, when it opens near Grand Haven into Lake Michigan. On the east side of this water-shed a few more rivers deserve notice.

Huron River collects its waters from innumerable lakes and marshes in Livingston and Oakland counties; first it flows southwest; at Dexter it turns southeast and retains this direction, passing through Washtenaw and Wayne counties, until it enters Detroit River in the northern corner of Monroe County.

Clinton River drains the eastern part of Oakland County and all of Macomb County, entering Lake St. Clair near Mount Clemens.

Black River is remarkable for its southern course for nearly fifty miles, parallel with the shore of Huron Lake, at a distance of only five or six miles from it. It begins in the north part of Sanilac County, and enters St. Clair River near Port Huron.

Saginaw River is the receptacle of a whole system of rivers. By the Tittibawassee River, the waters of the north and west, from Gladwin, St. Clair, Isabella, and Midland counties, are led into it; the Shiawassee River collects from the south, in Livingston and Shiawassee counties; Flint River, from the south and southeast, in Genesee and Lapeer counties; and, finally, Cass River brings its waters from the northeast and east, gathering them in the counties of Tuscola, Huron, and Sanilac.

The river system of the northern part of the peninsula consists of the following rivers: Commencing at the southeast side, we find, first, Rifle River and Aux Grees River, which drain the southeastern shore-belt surrounding the before-mentioned high plateau. Sable River is the next largest river north of them. It draws its branches right from the heart of the high plateau, and drains Lake Otsego in the north end of it.

Thunder Bay River, opening into Thunder Bay, spreads its arms north, south and west, reaching the foot of the high plateau. Sheboygan River, on the north end of the peninsula, forms the outlet of three large lakes: Black Lake, with an area of about 16 square miles, Mullett and Burt Lakes, both together with an area of about 45 square miles. These lakes are fed by rivers of good size. Rainy River and Black River empty into Black Lake; Mullett River and Pigeon River into Mullett Lake. On the west side of the peninsula two large rivers deserve to be mentioned yet. Manistee River originates very near the headwaters of Au Sable River on the east side. Its mouth is at Manistee, a little distance to the north of the second correction line. Muskegon River is a still larger river than Manistee; its branches extend to the top of the central high plateau, and are fed by Higgins and Houghton lakes. The mouth of the Muskegon is a short distance south of the first correction line.

Of all the rivers mentioned, none is navigable. In some cases, however, the mouths for a few miles inland from the lake border are wide and deep enough to afford harbor for vessels of medium size. The water-power afforded by these rivers is ample, and those, the branches of which flow through timbered lands, are of

vital importance to the lumber business as mediums for the transportation of felled timber, from otherwise almost inaccessible parts of the interior, to ports or railroad stations.

The greatest portion of our world-renowned stores of pine timber would be comparatively worthless to the owners, and to the community at large, without these rivers. Their importance can only be fairly appreciated by one who has seen with his own eyes the lumberman at work. In the fall of the year, hundreds of axemen and teamsters, with horses and yokes of oxen, penetrate for seventy and eighty miles up the rivers into forest desolation, scarcely cutting a rough, narrow road, which seems impassable for man or beast, yet by which, during their stay in the winter, the necessary supplies are conveyed to them from time to time. Arrived at the places with valuable timber, huts are erected, temporary stables built for the animals, and the work begins. Tree after tree sinks to the ground with its mighty crown under the pitiless strokes of their axes. The valuable parts of the trunks are cut into logs of proper length, and drawn on sleighs to the nearest creek, where they are piled up, until, in spring-time, by the melting of the snow, the creeks are swollen into impetuous streams, which are kept back and hemmed in by dams. After the water has risen sufficiently, the braces holding the logs on the banks are removed, when with terrible speed, smashing every thing in their way, they dash down into the muddy pond. This being done, the gates of the dam are opened, and swiftly glide the logs along with the rapid current, accompanied by a crew of men, who remove all obstructions, walking with surprising dexterity to and fro over the floating logs. Finally they reach the mouths of the rivers, which usually expand into lake-like basins, but are sometimes artificially transformed into such. It often occurs that a river-bed for many miles up its course is jammed with logs, representing several square miles of forest, an interesting and curious sight. There are the mills, erected only a few years since, surrounded by acres of ground heaped with mountains of sawdust and other refuse material, witnessing the stupendous amount of work performed. On entering, what a humming, buzzing from all sides—a gigantic beehive; hundreds of persons at work in admirable order, making use of the irresistible steam-power, in the most diversified way, without a minute's loss of time, engine and men working in unison.

A log five feet in diameter floats toward the mill; a minute more, and, fastened to a chain, it moves up the slideway, goes straight under the saw, and in another minute is converted into boards, which, without loss of time, are passed singly through the edging machine, coming out ready for the market. Meanwhile, before a car is loaded to remove them to the lumber pile, all the edging slabs have been transformed into fence pickets and plaster laths, all with the regularity of clock-work. These sights make an impression on the mind of a thoughtful spectator which is more than simple admiration; he feels overpowered by the wonders which man is capable of performing by perseverance and energy, coupled with an intelligent use of the forces of nature.

The rivers have all eroded their valleys into the loose drift masses which almost universally cover the surface of the peninsula in great thickness. Only in rare instances have they carved deep enough to touch the solid rock ledges below the drift; or if such deep cuts did ever exist, they have filled them up again with débris, and the beds of the present streams lie high above those of former times. The peninsula was in its original condition heavily timbered, with the exception of a few marshy flats. Climate and quality of the soil determined the character of the vegetation. In the southern part of the peninsula, deciduous trees, particularly hard-wood timber, prevail. Pine is only sporadically intermingled—the mildness of the climate favoring the growth of oak, hickory, walnut, poplar, etc., which abound here, but become rare further north, where beech, maple, and birch take their place. The sandy soil of the central high plateau is most congenial for the growth of pine forests, which have taken exclusive possession of nearly the entire district. The marshy condition of some other places adapt them for the tamarack, asp, elm, and willow-tree, or for the growth of cedar, while a few parts of the high plateau, proving even too sterile for the pine, afford sustenance to nothing more than a stunted, scrubby growth of *Pinus Banksianus*, and a few creeping herbs which attempt to hide the barrenness of the scene. Such barrenness has, in some instances, been caused by accidental fires, which annihilated forests of large area, totally denuding the surface, which, when of porous sand exposed to the burning rays of the sun and to the exsiccating winds, can not for a long time, if ever, recover its former well-timbered condition. On more fertile soil, with sufficient moist-

ure, the case is different. A few years after a forest is burned down it sprouts again with fresh vigor, but the new growth is generally of a different kind from that which preceded it.

To the first settlers of the country, the heavily timbered forests were a great impediment; with great labor the trees had to be cut down and burned, for no other purpose than to get them out of the way. This system of destruction, first suggested by necessity, has been continued up to recent times, and while it is true that the development of agriculture has been considerably hastened by it, yet it is equally true that, in the lower part of the peninsula, our forests are reduced to such a degree, unnecessarily in some cases, as to render it highly advisable that measures be adopted for the preservation of what we have left, otherwise, I fear, our descendants will sorely feel the consequences of the unwise husbandry of their fathers.

CHAPTER II.

GEOLOGICAL STRUCTURE OF THE LOWER PENINSULA.

(Surface Material.)

THE entire surface of the peninsula is covered by heavy drift deposits, with the exception of a few limited localities, in which the drift, subsequent to its deposit, has been washed off by floods, or by rivers carving their courses deep enough to touch the rock beds of older formations. These drift masses are nearly the same in character as those described from the Upper Peninsula in the first volume of the geological reports. The material has been changed somewhat by an admixture of rock débris from the formations encountered by the moving glaciers in their southward course. The glacier drift spread itself in a compact body over the entire surface of the Lower Peninsula, in evidence of which fact the rock beds, wherever they are found denuded, and the nature of the rock has been capable of preserving the marks, bear the traces of its motion on their scratched surface. Not all the drift material found on the lower peninsula has been transported there by glaciers; a large proportion of it must have been carried southward by water, partly in suspension, as mud and sand, partly frozen into floating ice, as the coarser material, the gravel and boulders.

The glaciers deposited moraines, heaps of rubbish composed of all kinds of rock débris in every degree of comminution from the large boulder down to the impalpably fine clay. Much of the drift is not found in this orderless form of moraines, but is disposed in well-stratified layers, assorted according to the weight of its particles by water-currents. It is suggested that floods, acting subsequently on the masses of the moraines, sifted and washed the lighter transportable particles out of them, to deposit them elsewhere as layers of clay, sand, or gravel, but this can not explain all the phenomena we observe in the arrangement of the drift material. We find large boulders, some of them many tons in weight, in

the midst or on top of well-stratified drift layers; this could not be if the strata were formed by rearrangement of the moraines; but, by the suggestion that a transportation of the material has occurred through floods with swimming icebergs, no difficulty exists in explaining the position of the hugest blocks within or on top of well-stratified layers; while the mud or sand carried along by the currents settled down into layers, the large blocks carried by the ice over these forming deposits were occasionally dropped and became buried or remained lying on the surface. The glacier period was only the commencement of the drift transportation. A long time of submergence of the land by inundation must have followed the glaciers. The surface of the highest points of the peninsula, 1100 feet above the level of the lakes, is formed of stratified drift sand mixed with pebbles, from which fact we must draw the inference that at one time the water had reached to this height. By looking at the topographical features of the country at present, it is hard to conceive how this could happen, and I make no attempt to suggest the mechanical conditions by which the water level of the lakes could rise so high; but the fact of this occurrence is indisputably proved by the sediments left behind by the water; also the terraces found in the circumference of the peninsula at different heights testify the high elevation of the lake levels in former times. The waters must have receded at different periods for a certain distance, and then kept stationary for a while before a further lowering of their level occurred; and each of these temporary shore lines is marked by a distinct terrace. In many places, such terraces are quite conspicuous, especially so those in proximity to the present shore; the higher terraces, more remote, are sometimes obscured by dense forests covering their slopes, and by the action of atmospheric influences through scores of centuries which has rounded and levelled off their former marked contours; yet any traveller ascending to the central high plateau can not avoid observing that he makes his ascent from terrace to terrace.

The older glacier drift and the later deposits of floods and icebergs are materially of the same composition; both are made up of clay, sand, gravel, and boulders, of the detritus from crystalline and metamorphic rocks, mixed with *débris* of younger sedimentary strata. The orderless, rubbishy condition of the glacier drift

became partially transformed into well-stratified layers by the same floods which deposited the superimposed drift beds, whereby they became blended to such a degree that a distinction of the older and younger drift layers by lithological characters is impossible, and can only locally be made by observation of their direct superposition. The non-stratified condition of the drift is not confined to the lowest beds, but repeats itself in higher positions. The atmospheric influences acting on the loose, non-indurated drift material, instead of sifting and assorting the masses, as sometimes they do, often have the contrary effect; the stratified condition of the superficial masses is obscured by them, and by sliding and other similar causes, they become intermingled. But, leaving this alteration of the surface crust out of consideration, we find extensive accumulations of unstratified boulder drift high above other non-stratified deposits, and separated from them by well-stratified layers of sand and gravel. The coarse boulder drift, covering large surfaces of Washtenaw County and of other counties in the southern part of the State, occupies this higher position, and deeply below it, separated by intervening, well-stratified layers, we find other non-stratified masses again. In the high bluffs on Huron River, a half mile south of Ann Arbor, an instance of this superposition can be directly observed. At the foot of the bluff we can see about 60 feet of a dark blue, indurated, sandy clay, mixed with many smaller pebbles and with a few large boulders, which all bear very distinct marks of glacier striation; the clay has not the least sign of gradual deposit lines; it gives the impression of a solidified mud-stream. Above it we find well-stratified sand layers with discordant bedding and wedge-like intercalations of seams of gravel, amounting in all to about 30 or 40 feet. The top of the hill rises at least 60 or 80 feet higher, and all of it is formed by non-stratified boulder drift, mixed with clay and sand in such proportion as to compose a productive soil on these stony hillsides. The boulders of this horizon are partly large granitic blocks, or green stones, quartz conglomerates, partly blocks of the Trenton, Niagara, Helderberg, or Hamilton group, with characteristic fossils inclosed; also, sand-rock slabs of the Waverly group and from the coal measures are mingled with the others, all bearing distinct glacial striæ on their surface, but otherwise of sub-angular outlines, indicating little wearing by trituration under

water. The coarse boulder drift all through the southern part of the peninsula appears not to occupy the lowest position, in which most frequently a hard, dark blue, sandy clay, with pebbles and some boulders intermingled, is found in layers of considerable thickness. It is known among laborers by the popular name of *hard-pan*. The beds of clay, sand, and gravel in the stratified drift are not deposited in a certain order of sequence which would hold good even for limited precincts; every locality has to be studied for itself, and if denudations of larger horizontal extent are observed—which opportunity sometimes happens in the bluffs of the lake shores—we see constant local changes in the details of structure, although in some principal features a uniformity of the strata may be perceptible. This irregularity in the structure of the stratified drift explains itself, if we consider the conditions under which the deposits were formed and that the already formed deposits were by subsequent causes repeatedly displaced. During the slow emergence of the peninsula from the waters, much of the surface material was shifted about by waves and fluctuations of the retiring lake, and when the river channels began to form, and deep valleys were carved in all directions through the drift masses, immense quantities of material became displaced and deposited anew in a different order, governed entirely by local circumstances; and this process of destruction and building up is to this day in constant operation.

In the report on the Upper Peninsula, I have described, among the drift materials, an impalpably fine red-colored clay deposit of considerable thickness, which rests there frequently in immediate superposition on the older rock beds, and is in some localities—as, for instance, at Au Sable Point, on Lake Superior—overlaid by 300 feet of sand and gravel beds of the drift. In the drift deposits of the Lower Peninsula a similar well-stratified red clay is observed, but there it is not found at the base of the drift. It has a higher position, and is underlaid by stratified sand and gravel beds, while below them follows the non-stratified tough blue clay with pebbles, which, in the southern part of the State, is always the lowest of the drift. The relative position of this red clay to the other drift beds is best seen in the high bluffs lining the shore in the northwest part of the peninsula. The lowest blue gravelly clays, in non-stratified condition, are sometimes visible at the base of the

bluffs; above them follow well-stratified sand beds on which the red clay beds rest in almost shale-like, laminated form, amounting to a thickness of from 30 to 50 feet; usually this clay belt is divided by interstratified sand layers into several bands. Certain seams of the clay are soap-like, absolutely free from coarse particles; others contain numerous pebbles, or are mixed with various proportions of sand. The impermeability of this thick clay mass to water causes the issue of copious springs along the bluffs above the horizon of the clay. The upper part of the bluffs, which locally attain a height of 200 feet, is formed of alternating layers of sand and gravel in irregular, discordant stratification. The gravel beds between the sand strata are often five or six feet thick in the centre, and wedge out on both sides into linear seams, which, perhaps, further on, may be seen expanding again, or entirely vanish. Large boulders are mixed into the strata at all heights, but in certain levels of the upper part of the bluffs, boulders are more abundant, and stratification becomes obscure. On top of the bluffs heavy masses of fine sand are deposited, which partly have the character of dunes, partly are stratified, aqueous deposits, but of much more recent origin than the lower portion of the bluffs. Exactly the same exposures of the drift as on the shore of the mainland of the peninsula, are seen on the west side of the Manitou Islands, in connected sections of about 150 feet in height. Sleeping Bear Point, a promontory opposite the Manitou Islands, on the main shore, said to be of 500 feet elevation, is remarkable for its barren, naked surface of a fine, loose sand, without any vegetation. Its base is composed of the same drift layers as the bluffs further south, of which it is a direct continuation. In many other localities of the interior, the same well-stratified red-clay beds are uncovered, always holding a position below the principal coarse boulder drift. The banks of Cass River, near Vassar, in Tuscola County, or the bed of Muskegon River near Big Rapids, give occasion to see the clay beds in their relative position to the other drift strata. In a cut of the railroad between the Big Rapids and Muskegon, close to the first-named village, an interesting section through the drift is laid open. Deepest, at the bottom of the cut, boulder drift mixed with stiff bluish clay is exposed. The large boulders, as well as the smaller pebbles, are plainly marked with drift scratches. Above them are about 30

feet of sand layers with discordant stratification; the layers are bent into tortuous, serpentine flexures. Incumbent on these sand beds is a thick coating of apparently non-stratified boulder drift, differing from the lower boulder drift by less clayey, more sandy constituents, and by having its boulders much less distinctly drift-marked. In the surface of the sand deposits, underlying these upper boulder drift masses, narrow, acute ravines are observed, which are filled with boulder drift. Sections through them are laid open by the railroad cut. It seems as if the surface of the sand deposits had been exposed for a while to the atmosphere, and deep, narrow ravines cut into them by rain-streams, which subsequently were filled out with the boulder drift, without disturbing the sharpness of their angular contours. How this was effected I am not prepared to explain. The flexions of the sand strata, I suppose, are caused by lateral pressure exerted by sliding of the masses. I have frequently observed similarly bent sand deposits in other localities—as, for instance, in the bluffs of Manitou Island.

The incoherent masses of gravel and of sand become in certain localities firmly cemented into conglomerates and sandstones by carbonate of lime, deposited by springs percolating the gravel and sand banks. Such conglomerates, forming large, bulky masses, of concretionary form, are abundantly seen in the above-described bluffs on the shore of Lake Michigan, and more southward, at the mouth of Muskegon and of Kalamazoo rivers; also in the gravel pits along the railroad from South Haven to Kalamazoo, and in a great number of other places. Near the mouth of Kalamazoo River, at Richmond, I have seen such sand rock of the drift in very compact, hard ledges, which would make a durable building stone. Sometimes we find, instead of lime, the sand or pebbles cemented by hydrated sesquioxide of iron, but not in so large masses, and always close under the surface, while the calcareous conglomerates are often found interstratified with other drift beds quite remote from the surface. These ferruginous conglomerates have the same origin as bog-iron ores, from springs holding iron in solution by means of carbonic acid, and depositing it, in some cases, as incrustation over pebbles and sand, and in others, over vegetable stems, which subsequently decay and leave the ore in the porous condition in which usually it is found.

Bog iron occurs very frequently in small patches of marsh land

in all parts of the State. Several localities are also known where ore deposits of larger extent have been discovered, but up to the present time no practical use has been made of them, and it is questionable whether any of these deposits is of sufficient magnitude to be an inducement for the erection of furnaces, or for their mining and transportation to other melting works.

Calcareous tufa, a deposit of springs, analogous to bog iron, is sometimes found in large masses spread over springy hillsides. Locally, this tufa is used for lime-burning; sometimes, however, the porous rock mass is sufficiently compact and hard to be used as a building stone, but I have not often seen it so employed in Michigan.

The bottoms of a number of inland lakes are covered with a peculiar modification of calcareous tufa, a white, marly substance, in part composed of the shells of sweet-water molluscs, mixed with white pulverulent carbonate of lime deposited from solution by the lake water. Pine Lake, near Charlevoix, one of the largest lakes in the north part of the peninsula, has its entire bottom covered by this marl, and to a greater or less extent the same is the case with a great many others. I am not aware that any practical use has been made of these shell marls. They would certainly be good fertilizers.

As another surface deposit, peat has been mentioned. Innumerable larger and smaller patches cover the swampy surface depressions throughout the whole State. It is formed by a continued growth of a certain class of plants in wet places, where, submerged, the basal parts of the plants die off, and become decomposed and changed into a coaly substance, which accumulates sometimes to very great thickness. Peat is at present little used in Michigan. Several experiments to prepare it for commerce by compressing it with hydraulic machines have given very good results, as far as its usefulness and heating qualities are concerned, but in the light of a pecuniary transaction the results were less favorable. Fuel is too cheap yet, but the time will come when peat will be appreciated at its true value.

CHAPTER III.

SOILS OF THE LOWER PENINSULA.

By the nature and distribution of the drift material, which has almost exclusive occupancy of the surface of the peninsula, the quality of its soil is determined; the localities where its character is modified by the lower rock formations are of very limited extent, and deserve no particular consideration in this place. The soil possesses two important requisites for vegetation. It gives to the plant a secure hold in its position, and furnishes to the roots the material necessary for life and growth. Soil is composed of pulverulent particles of mineral substances, generally mixed with a proportion of organic matter. The mineral components must contain all the chemical elements which enter into the composition of plants, in a condition available for absorption by the roots. In moist conditions, it has a certain degree of coherence and plasticity; it is porous, readily absorbs water, and retains it with a certain tenacity. These are the general requisites for a soil, to make it adapted for the growth and nutrition of plants.

The chemical elements necessary for the organism of vegetation are oxygen, carbon, hydrogen, nitrogen, sulphur, phosphorus, chlorine, iodine, potassium, sodium, calcium, magnesium, aluminium, silicium, iron, manganese—all of which are to be found distributed in varying proportions almost everywhere on the surface of the earth.

Soil constantly forms by the action of atmospheric influences on the superficial rock beds, slowly effecting their chemical decomposition, or causing mechanical disintegration by frost or mutual trituration. A soil forming on the spot by decay of the underlying rock beds participates in their chemical composition, and may be destitute of certain ingredients necessary for a good soil. Soil formed of drift material, being composed of the greatest

variety of mineral species, generally has all the chemical requirements of a good soil.

But we must recollect that the drift material is frequently found assorted according to the fineness of its particles, and that this assorting is sometimes carried to such a degree as to be detrimental to the quality of the material as a soil. A bed of pure clay, or of sand, or of clean gravel will not make a soil of itself, but a mixture of all constitutes the most fertile that we have. The fertility of a soil is, however, not alone conditioned upon its chemical constituents; it depends in a great measure upon its porosity, adhesiveness, and the state of comminution of its molecules. To learn the chemical composition of soils and their molecular structure, analyses of the most complicated kind have been made, which, taking a purely scientific view of the question, are highly interesting, but are, practically, of a value not in proportion to the labor and expenditure of time in making them. The soil of one and the same farm, or of a single acre of ground, often differs so much that a few analyses would not give a correct idea of its quality, at least none more correct than could be reached by a superficial examination, so that, in buying a farm, I would advise one rather to rely on the judgment of an experienced farmer than on the results of a chemist's laboratory.

The good quality of a soil covered by a thrifty vegetation of certain herbs and trees is immediately recognized. The barrenness of a spot, likewise, needs not to be first ascertained by finding out its chemical deficiencies; and, provided we are acquainted somewhat with the elements of vegetable physiology, we will also soon be able to guess at a proper course for its improvement.

A plant draws a great proportion of its nourishment through its roots from the soil. The roots can only take up nutritive parts when in solution. Easily soluble salts must be highly diluted, or they would injure the plants; usually soils contain little of these, and the mineral substances composing them are of themselves so insoluble in water that the roots could draw no benefit from them, if by the admixture of humic acid, which almost every good soil contains, the solubility of these substances were not induced. This acid is a brown substance, originating from the decomposition of vegetable matter in the soil. It has the peculiarity of forming with all earths combinations which are soluble in water; it displaces carbonic

acid from the carbonates, and decomposes insoluble silicates, and its salts taken up in solution by the plants can be perfectly assimilated, because humic acid is composed of carbon and water.

Vegetation requires more than liquid nourishment supplied through the roots; plants absorb and exhale large quantities of gases through the roots as well as through the parts above ground. A soil must, therefore, be in a degree porous, or a plant will not live in it. A regular process of respiration exists in plants. The green leaves and other green-colored parts constantly absorb carbonic acid from the atmosphere, and exhale in its place oxygen, provided they are exposed to the light. In the darkness the process is inverted; the plants then take up oxygen and exhale carbonic acid. All the parts of plants which are not green, such as roots, bark, petals, and red or yellow leaves in the fall, constantly absorb oxygen and exhale carbonic acid.

The soil of the Lower Peninsula, being a drift soil, is generally very deep, and contains all the chemical constituents of a good soil. The assortment of the drift material into clay, sand, and gravel beds determines its character as these layers happen to occupy the surface positions, while by intermixtures a great variety of intermediate shadings in the quality of soils is locally produced under atmospheric influences. The distribution of soils over the surface of the State is sometimes very unequal and changeable, so that within limited areas, and often within single farms, a number of variations in the character of the soil are represented. But with the differences seen in the surface configuration of certain districts is also usually found a corresponding contrast in the quality of their soil. The high plateau in the northern part of the peninsula has its peculiar soil, a thick, uniform mass of fine sand, containing few pebbles and a small proportion of argillaceous constituents. In accordance with it is the vegetation; the pine-tree finds a congenial home in these sandy hill lands, and their surface is overgrown with splendid forests of this tree, to the exclusion of almost every other kind. This soil, as long as some humus is mixed with it, may give a fair potato crop, or, by careful attendance, garden vegetables can be raised, but its productiveness is so soon exhausted and its moisture so soon lost, that it can never be used for agriculture on a large scale with any prospect of success.

Other districts, represented by lowlands adjoining the lakes, and to all appearance within comparatively recent times parts of the lake bottoms, are covered by a stiff clay soil overgrown with elm, ash, and kindred trees—as, for instance, the lower part of Saginaw valley and a strip of land bordering Detroit River, from Monroe up to Lake St. Clair. Properly drained, this is the richest soil in the State, giving larger crops and bearing the practiced system of exhaustion better than any other. But the most characteristic soil of Michigan, that which makes it a wheat-producing country in the first rank, is a gravelly clay soil which covers the largest part of the surface in the southern half of the peninsula. It unites all the qualities of a good soil, all the chemical essentials for the plants which it bears in such profusion; its molecules are a mixture of all degrees of comminution, from the finest clay mud up to the boulder, producing a proper degree of porosity, and securing the retention of the necessary moisture by a constant drainage of any accidental surplus of it. A certain variety of this gravelly soil is full of large pebbles and boulders to a degree which makes the inexperienced believe its cultivation hopeless, yet such lands give generally very good returns in wheat and corn crops.

Distributed over the country are patches of light, sandy soil, which contain a sufficient proportion of argillaceous and other mineral ingredients to make them fertile. The easy tillage of these lands and their generally fair returns bring them into high favor with the farmers. The climate of the peninsula, which is the other principal factor in its productiveness, is over the whole extent temperate, extremes of cold or heat being prevented by the surrounding large lakes. From the north to the southern end all the cereals can be planted with little risk of failure. The northern part is somewhat colder, its vegetation coming out two weeks later than in the south, and the winter setting in about that much earlier, which affects somewhat the raising of the more tender fruit crops, as grapes, peaches, etc.

The grape and the peach do well in the southern part of the State, and particularly near the shores of the lakes, where the foggy, humid air prevents late frost, the greatest enemy of these fruits. The west shore up as far as Muskegon has become famous for its peaches and other small fruits. The Traverse Bay region, which has been so strongly recommended as a fruit-growing country,

is not fulfilling the expectations entertained of it. They may raise peaches there in seasons when all other places in the south have theirs killed by frosts, but this does not prove the greater mildness of the climate, but simply that the peaches are in bloom there late enough to escape frost. The fruit raised under such conditions may be large and perfect, but in sweetness and flavor it can not compete with fruit grown in a warmer climate.

For the apple, our climate and the deep gravelly soil answer exceedingly well, immense quantities of the most delicious kinds being yearly sent to the markets of all the Eastern and Western States.

CHAPTER IV.

PALÆOZOIC ROCK SERIES.

BENEATH the drift the peninsula is underlaid by regularly stratified rock beds, in undisturbed horizontal position, which represent the upper part of the palæozoic strata.

Of deposits younger than the coal measures, no evidence can be discovered on its surface. It forms the centre-point of an oceanic bay, which seems to have existed, without any important alteration in its limits, from the beginning of the Silurian period to the end of the Carboniferous time. We find within the space supposed to have been the bay an uninterrupted series of marine deposits, following each other in the greatest regularity of superposition, which represent all the known formations deposited on this continent from the Potsdam period on to the Coal formation. The northern shore of this ancient silurian bay coincided in part with the present north and west shore of Lake Superior. Some cliffs of the present lake, formed by upheaved Huronian rock beds, were formerly the cliffs washed by the breakers of the silurian ocean.

We find the rounded, water-washed cliffs, with all their fissures and eroded pot-holes, intimately embraced by the sandstones and conglomerates of the Potsdam period, horizontally abutting against them, with their layers discordantly laminated, as we see the sand masses of a beach formed under our eyes. It needs no great degree of illusion to imagine that you see these sand masses dashed upon the shore by the breakers of the present lake, and quickly hardened into rock. One feels strangely impressed at beholding a landscape with its general features as they must have existed myriads of years before, a space of time during which continents formed and disappeared, during which the place itself has undergone the greatest changes, become covered with sediments, the ocean having receded long ages ago from the spot, and then to

imagine glaciers to come, ploughing up the sediments covering the old surface, dredging out a part of the old ocean bed, and finally leaving it filled with the water which now washes the cliffs of the restored shore line, as if it never had left them.

As we recede southward from this ancient shore line, and have passed over a belt of the Potsdam sandstone, we find the Trenton limestones overlapping the sand rock, and still further, belt by belt, successively occur younger rock beds, which follow each other in imbricated superposition. On Mackinac Island we have reached a fragment of the sediments of the Helderberg belt, which resisted destruction when the lakes were carved out. A description of all these rock belts I have given in the geological report of 1873.

On the northern end of the Lower Peninsula, which forms the main subject of consideration in this report, we find the Helderberg group again as the lowest of the exposed rock beds, and only occupying a narrow strip of the northern shore line. The imbricated superposition of younger formations continues southward to the centre of the peninsula, where we find the Helderberg group overlapped by the Hamilton series; following it are the black shales of Ohio, the Waverly group, and a central disk formed by the coal measures.

These concentric arched belts of formations continue across the area now occupied by the lakes, and are met again on the opposite shores of Canada, Wisconsin, and Illinois. The belt of the Helderberg series strikes the Canada shore south of Goderich; the Hamilton group and the black shales are found in Bosanquet township and on Kettle Point, C. W.

On the Wisconsin side, the Helderberg and Hamilton strata barely reach the shore at a place six miles north of Milwaukee. The remainder of the shore of Wisconsin and Illinois, south from there, is composed of the next older rock beds of the Niagara group.

Entering on the special description of the mentioned formations, and of their surface distribution on the Lower Peninsula, I commence with the lowest beds, with the Helderberg group exposed at the northern and southeast ends of it.

CHAPTER V.

HELDERBERG GROUP.

AT the foot of McGulpin's Point, a little distance from the former site of old Fort Mackinac, the bed of the lake is formed of ledges of limestone, a series of which continues at the height of 10 or 15 feet above the water level around the base of the promontory. Its higher levels are formed of drift rising in several well-marked terraces, on one of which the lighthouse is erected. The limestone is light-colored, of conchoidal fracture, rather thin and unevenly bedded, abounding in hornstone concretions. It contains a good many fossils characteristic of the upper Helderberg group, but few of them are well preserved. The strata which form the top of Mackinac Island represent the same geological horizon, and if we were to admit a continuity of the strata across the straits, and take those of McGulpin's Point as identical with the highest beds of Mackinac, the calculated dip of the strata toward the south would amount to 30 feet per mile, Mackinac Island being 300 feet above, and its distance from McGulpin's Point 10 miles.

The limestone ledges can be traced in the shoal water westward to the Waugoshance Islands; the projecting part of them is formed by loose limestone pebbles and regular boulder drift, with no outcrops of the underlying limestone ledges. Further west, the formation extends to the Beaver Island group. The larger of the islands, Hog Island, Garden Island, and Beaver Island, are all composed of drift. Loose, angular limestone slabs, inclosing fossils of the Helderberg group, are found abundantly strewn over their beaches, indicating a proximity of the ledges to the surface; the ledges themselves are visible in the bottom of the lake in the circumference of Whiskey and Trout Islands, which likewise belong to the Beaver Island group.

On the east side of McGulpin's Point the limestone ledges

soon disappear under the drift, and from there to Hammond's Bay no more rock exposures are seen along the shore line. On Round Island and on Bois Blanc Island, limestones of a lower position than those of McGulpin's Point come to the surface. The largest portion of the islands is covered by drift and by gravel and sand accumulations, thrown up at a more recent time by the lake. On Round Island the rock escarpments are, on the north side, formed by thick-bedded, light-colored, somewhat porous dolomitic limestones, projecting in a steep bluff of about 50 feet in height. A dense growth of forest trees covers the declivity, hiding the rock ledges from view, when at a distance from the bluff.

On Bois Blanc the exposures are on the southwestern shore, rising in bluffs to about 15 feet above the water level. Under a cover of boulder drift we find highest, thick ledges of a brittle, dolomitic, and partly cherty limestone; the lower beds are thinly laminated slabs of a bluish mottled lime rock with rough, earthy fracture; they are seen extending far out in the bottom of the lake. In the upper thick beds, not unfrequently the often-mentioned acicular crystals are found pervading the mass, which are characteristic of the lower horizons of the Helderberg group. Fossils have not been found. The lime rock of both islands is used to a small extent for the production of lime, but as a building-stone the rock has little value.

From the mouth of Oqueok River in Hammond's Bay, onward to Presque Isle, frequent rock exposures can be observed along the shore, which generally is occupied by sand or gravel beaches; the rocks come out at the ends of projecting land-spurs. The strata seen in these exposures have a higher position than those of McGulpin's Point; they are the transitory beds between the Helderberg and Hamilton groups, which insensibly merge into each other, without having any sharp line of demarkation.

I preferred to describe these latter beds in connection with the Hamilton strata, and have delineated on the geological map accompanying this report the Helderberg group as confined to the narrow spur of McGulpin's Point and to the islands north and west of it.

Rocks of the Helderberg group compose the surface of a restricted area in the southeast corner of the State, comprising

Monroe County, the southeastern part of Wayne County, and the same part of Lenawee County. This triangular segment is the northern terminus of a large body of the formation, which covers the northwestern part of Ohio, and is continued through the State of Indiana. It is on the west side of the Cincinnati axis of elevation; the beds are not disturbed by the uplift in their horizontal position.

In Monroe County the beds of nearly all the creeks present exposures of the ledges; in Lenawee and Wayne counties, the incumbent drift deposits are much heavier and the rock is not so often exposed. The surface of all the rock beds of this region which lie on top is worn smooth and scratched by drift marks.

The lower division of the Helderberg series, identical with the strata forming the base of Mackinac Island, and with the water-lime group of the Ohio reports, has a much greater surface extension in the district under consideration than the upper division corresponding with the limestones of Sandusky. This upper division is well uncovered in the quarries of Trenton village in Wayne County, and likewise in the quarries on Macon Creek, formerly owned by Judge Christiancy. The surface layers of the Trenton quarries are only covered by a thin coating of loamy drift. They are limestones of light color, segregated in thin beds, with uneven rough surface, containing an abundance of fossils, particularly Crinoid stems, Bryozoa, Cyathophyllum cornicula, various Favosites, Atrypa reticularis, Spirifer gregarius, Spirifer acuminatus, etc. The thickness of the beds is about six feet; they are used for lime-burning, and yield a white, quick-slaking lime of very good quality. The beds of the quarry have a very perceptible dip west by southwest, which is evidently caused by a local undulation of the strata. The direction of the dip of the formation at large can not be learned from the measurement and examination of single localities; it is generally hypothetically deduced from the distribution and sequence of the rock beds over areas of large extent. The next lower beds in the quarry are a compact gray, crystalline limestone, in beds from eight inches to two feet in thickness, and in all amounting to about eight feet, which represent the principal quarry rock. They are rich in fossils; the species which I collected there are: Cyathophyllum Hallii, Cyathoph. cornicula, Zaphrentis prolifica, Zaphrentis gigantea, Fa-

vosites turbinatus, Fav. hemisphericus, various species of Fenestella and Polypora, Stictopora Gilberti, Stromatopora textilis, Atrypa reticularis, Spirifer acuminatus, Strophodonta concava, Strophod. perplana, Orthis Livia, Lucina elliptica, Conocardium trigonale, Euomphalus Dekewyi, various large forms of Orthoceras, Gomphoceras, Gyroceras, Nautilus, Phacops bufo, Proetus crassimarginatus, Dalmania selenurus, and bones of fishes.

The base of the part of the quarries at present worked is formed of about 4 feet of very uneven, thin-bedded, concretionary limestones full of hornstone nodules, and coated over by a black, shining crust of bituminous shale; the peculiar segregations called styolites are also quite frequent in these beds, which (beds) are thrown away as worthless rubbish. Under them, in another part of the quarry, not now worked, are other limestone beds denuded to the depth of 12 feet; several of their thicker seams furnish material quite as good as the best ledges in the upper part of the quarry. The owner of the place bored in the quarry a drill hole through solid limestone for a depth of 60 feet, in search of well-water, but did not succeed in finding any. Selected blocks of the lime rock are cut into door-steps, sills, water-tanks, etc., the rest being used for foundation walls and for the lime-kilns. An analysis of the principal quarry stone gave:

Carbonate of lime.....	87.5
“ “ magnesia	10.1
Quartz ore residue, besides small quantities of iron and alumina.....	2.0
	99.6

The quarries on Macon Creek, on Mr. Christiancy's former property, are opened in the same strata as the Trenton quarries. The rock there is more porous, absorbing water rapidly when dry, and considerably impregnated with rock oil, which exudes from its crevices, and often collects on the water pools of the quarry in a thick scum. In humid state, the rock is dusky drab-colored. The surface layers are rich in fossils identical with those of the Trenton quarries; certain seams are perfectly crowded with Chonetes yandellana, and others with Tentaculites scalaris. Below these fossiliferous beds, the useful ledges of the quarry, about 6 or 7 feet in thickness, follow; they are of the above-mentioned

porous character. The better quarry-stone furnishes sills, door-steps, etc., but most of it is used for the production of lime. Its composition is:

Carbonate of lime....	84.0
“ “ magnesia	13.0
Iron oxide hydr.....	0.4
Quartz and bitumen.....	2.2
	99.6

The deeper strata of the quarry become worthless from a copious admixture of white, cherty concretions. The exudation of rock oil from the crevices induced some persons, a number of years ago, to form a company to bore for rock oil at this locality. A drill hole was sunk to the depth of 700 feet, but without the hoped-for success. The record of the boring I could not obtain. I was informed that not many feet below the rock beds opened in the quarry, a bed of sand rock was struck. This sand-rock deposit seems to be a very constant stratum found at that horizon, not only in Michigan, but all over the Helderberg area of the State of Ohio. Natural outcrops of this sand rock can be observed in the bed of Raisin River, six miles above Monroe; it is there very hard and compact, rich in calcareous cement; several fossils, casts of spirifer, etc., are inclosed in some blocks of the rock, but they are too imperfect for specific determination. The sand-rock stratum, in a soft, friable condition, and occasionally perfectly white, is found in the northeast corner of Raisinville township, on the farm of Mr. Bond, where it forms the surface rock over a good many acres of ground; in places it is overlaid by dolomitic limestones about 8 feet in thickness, which contain the casts of numerous fossils, Zaphrentis, Favosites, several forms of Bryozoa, Atrypa reticularis, Orthis Livia, Conocardium trigonale, Phacops bufo, Dalmania selenurus. Quantities of this sand, which is almost pure quartz without admixture, have been shipped to Pittsburgh for glass manufacture, for which purpose it is said to be of excellent quality. The thickness of the deposit is not seen in this place; only 6 or 7 feet are denuded in the diggings. In Section 16 of Ida township, a sand rock of about 6 feet in thickness forms the top layers of a limestone quarry. The upper strata are friable

and soft, their calcareous cement seeming to have leached out while the deeper sited strata are hard and rich in calcareous matter.

The rock contains some casts of bivalve shells and of gastropods; its fissures and druse cavities are filled with strontianite, coelestine and calcspar. The sand rock reposes on a hard, compact dolomite rock, mottled with light and dark blue cloudy specks resembling castile soap. The dolomite is composed of

	Per Cent.
Carbonate of lime.....	54
“ “ magnesia.....	42
Quartz sand.....	4

The lower hard cemented sand-rock beds contain

	Per Cent.
Carbonate of lime.....	46
White quartz sand.....	54

Sand-rock ledges of a somewhat different character from those mentioned, but evidently equivalent with them, are exposed on both sides of a road passing the north end of Ottawa Lake. The rock is hard, fine-grained, of dark bluish, or, in weathered condition, of ferruginous brown color, and contains 65 per cent of calcareous matter by 34 per cent of quartz sand. It is quarried for building purposes; intermediate between the harder layers are seams of a coarse-grained, softer sand rock with only a small proportion of calcareous cement. Inclosed in these softer seams, I found dermatic plates of macropetalichthys. South from there, across the State line, near Sylvania, in Ohio, a similar seam of sand rock is found intercalated between the upper and lower Helderberg limestones; and from the geological reports of Ohio we learn that throughout the entire Helderberg area of that State a sand-rock deposit is constantly found in such position. In some localities the sand rock seems to be replaced by an oolith. In the quarries of Plum Creek, near Monroe, and near Little Lake, in Bedford township, the mottled dolomite rock which lies at the base of the sand rock in the Ida quarries, Section 16, is found in the same characteristic form, but instead of sandstone, in the two mentioned localities, oolitic rock beds are superimposed. Their chemical composition is: carbonate of lime, 61 per cent, and carbonate of magnesia, 37 per cent. The thickness of this sand-rock stratum

tum has, within the State of Michigan, never been found to exceed 8 or 10 feet, and in Ohio, also, it forms only a comparatively thin seam. No fossils are known to have been found in it except the few fragmentary specimens which I mentioned, so that a palaeontological comparison with other beds is forbidden; but considering its relative position between the upper and lower divisions of the Helderberg group and its lithological character, its equivalency with the Oriskany sandstone of New York becomes very probable, an identification which was first made by the Ohio geologists. A marked change in the nature of the deposits above and below this geological horizon is perceptible. The rock series below the sandstones which has been identified with the water-lime group of New York, is altogether composed of dolomites and contains entirely different fossils from those found in the strata above the sand rocks, which have more of a true limestone character, and rarely contain a high percentage of magnesia. I have previously made the statement that this lower water-lime division has a much greater surface extent within this southeastern corner of Michigan than the higher beds. All the exposures of Raisin River, in Plum Creek, belong to this lower rock series; the quarries in the townships La Salle, Ida, and Bedford are worked in the same beds, and the outcrops on Point-aux-Paux, at Gibraltar, in Swan Creek, and Stony Creek, all represent this water-lime series. The upper strata of this group are frequently but not always found in a brecciated condition, with fragments of various ledges intermingled and re-cemented. The lower, non-brecciated beds have evidently the same lithological characters as the fragments composing the breccia.

By what force the strata were shattered into fragments, it is difficult to suggest, but the cause of the disturbance can not have been a local one, confined to this district only. We find this rock in brecciated condition all over the northwestern part of Ohio and on the islands of Lake Erie. The same occurs again in the equivalent beds of Mackinac, and in the exposures of Goderich in Canada.

A natural section through the whole thickness of the water-lime group is nowhere in the district exposed, and the artificial excavations by quarrying generally comprise vertically only a small series of beds, and they are nearly always of one and the

same horizon. Of deep artesian borings, several have been made within the city limits of Monroe to a depth of from 150 to 300 feet, and the boring records of some have been noted down. Such notes are very useful for comparison of strata, if we were only beforehand informed of the geological structure of a locality, in its details; but to learn these details by the results of borings alone is very unsatisfactory.

As an illustration, I give one of the records of a drill hole sunk in the Court-House Square of Monroe to a depth of 140 feet. It reads:

Clay and sand.....	6 feet.
Gray limestone.....	3 "
Blue limestone.....	6 inches.
Dark gray limestone.....	3 feet.
Blue limestone.....	1½ "
Gray limestone.....	14 "
Blue limestone.....	2 "
Gray limestone.....	39 "
Blue limestone.....	5 "
Gray limestone.....	2 "
Blue limestone.....	32 "
Blue shale.....	39 "

We see here a number of limestone beds, varying in color and compactness, amounting to over 100 feet in depth, and below, a deposit of calcareous shales, which could perhaps be taken as representing a part of the Onondaga formation; but the information we receive by this record is insufficient to enable us to form a clear idea of the special qualities of the rock beds, or to distinguish positively certain horizons. From another boring made in the same place, I received, through the kindness of Judge Christiancy, specimens of the rock brought up by the pump, by which I can see that, to a depth of 300 feet below the surface, limestone beds are almost exclusively following each other in continued superposition; but these limestones, of a dolomitic character, sometimes light-colored, sometimes dark, partly laminated, or other specimens of a cellulose structure, full of irregular cavities, clothed with spar crystals, or pieces pervaded with acicular spar crystals, are all without prominent peculiarity by which one can tell

whether the boring has passed the water-lime and entered the Onondaga or Niagara group or not. Rocks exactly similar to those brought up from the deepest portion of the drill hole are found in the superficial beds of the quarries near by, and acicular limestones, not distinguishable from those mixed with the upper brecciated limestones, come up from a depth of over 200 feet.

We learn by the borings that no gypsiferous shales are found in the strata underlying Monroe, and that for several hundred feet downward limestones of dolomitic character alternately follow each other; but we have no guiding rule by which to learn exactly where we are.

Among the exposures of the water-lime group, the quarries of Gibraltar, situated about four miles south of the Trenton quarries, are the most northern. There this lower rock series comes to the surface in the bed of the creek where it enters the lake near Gibraltar, and west of the village, at the point crossed by the Michigan Southern Railroad. The surface of the upper ledges is polished by drift action. The rock is a somewhat absorbent, minutely crystalline dolomite of gray color and a laminated structure, sometimes deceptively resembling an obsolete *Stromatopora*. The beds are even, from 1 to 2 feet thick, answering a good purpose as a building-stone. They frequently contain large, spherical, concretionary masses, very hard and compact in the centre, but successively becoming more and more porous toward their periphery, which merges into the general rock mass without a defining line separating the concretion from the plasma of the ledge. About 8 feet of the rock beds are denuded in the quarry; no fossils were observed in the place.

West of this locality, near Flat Rock, Huron River runs in rapids over ledges which belong to the water-lime horizon, a drab-colored, crystalline, somewhat porous, but hard dolomite, with flinty concretions. Of fossils, I noticed casts of crinoid joints, vegetable stems, and a small elongated body with email surface, serrated on the edges, which can only be the remains of a fish or crustacean. Similar corpuscles I found in the brecciated limestones of Point-aux-Paux, a locality which will subsequently be described. The rock in the vicinity of Flat Rock is covered by drift of considerable thickness, and does not come near enough to the surface to be opened in quarries. At New-

port on Swan Creek, the water-lime strata are found everywhere close under the surface of the level country, polished by drift action. The rock is a light, drab-colored, fine-grained, absorbent dolomite; the surface of the bed is rugose, pitted, as if the strata in soft condition had at one time emerged from the water and been exposed to rain-drops. Seams of black carbonaceous shale separate the ledges and cover their surface with a shining, thin coat. Stylolitic segregations are very common; they are evidently a peculiar sort of shrinkage cracks formed by the contracting of the mud mass during its consolidation into rock; their striated surface is likewise blackened with this shaly coating. In the quarries, only about 8 feet of the strata are uncovered; the upper superficial ones are the best; some of them break in good-sized blocks about a foot in thickness, which are used as a building-stone. However, most of the rock is quarried for lime-burning. The lower beds in the quarries are thin, uneven slabs interstratified with seams of black shale. Fissures and druse cavities in the rock mass are filled with fine crystals of *cœlestine* and of *calcspar*. Of fossils, casts of *Meristella lævis*, and vegetable stems are the most common. The surface of certain seams in the rock is often densely crowded with the shells, which are frequently coated with asphaltum or surrounded by liquid rock oil. The vegetable remains are of various kinds. Some are band-like, compressed stems, which sometimes bifurcate, and are of jointed structure. On certain portions of these stems, annular cicatrices are disposed in remote rows, in shape resembling the pores of the tube of a *Favosites*. Another kind of stem is narrower, more remotely jointed, and each joint is surrounded by a verticil of long, narrow leaves. I have transmitted specimens of these remains to Prof. Leo Lesquereux, of Columbus, leaving it to him to give his opinion on them at pleasure. He thinks they are of considerable scientific interest, and will probably say something about them in one of his scientific publications.

Three miles southeast of the Newport quarries, we find along the shore of Point-aux-Paux a very good natural exposure of the same rock beds which here are in brecciated condition, while the beds of the Newport quarry are undisturbed. The rock beds project only about 4 feet above the water level, but by undulations of the strata about 15 feet

of successive ledges become exposed. The breccia is formed of angular rock fragments; sometimes larger masses, composed of several consecutive layers, retaining their regular stratified position to each other, lie inclosed in it, often also a regular, unbroken seam of limestone alternates with the brecciated layers.

The principal part of the ledges resembles in all particulars the rock of the Newport quarries; the same fossils are found in them, only in greater abundance and variety. *Meristella lævis*, *Leptocœlia concava*, *Megambonia aviculoidea*, casts of several forms of bivalves and gasteropods, and a small spirorbis-like shell, are the usual forms met with, besides a profusion of the above-mentioned vegetable remains pervading the rock beds. Druses of *cœlestine* and *calcspar*, and veins of these minerals, filling the fissures of the rock, are very abundant.

Eurypterus remipes and *Leperditia alta*, the two typical forms of this horizon, I could not find in this locality, but on Put-in-Bay Island both fossils are found in association with the others above mentioned, and in beds which, by their lithological characters, leave no doubt of the identity of the strata in both places. Of the enameled corpuscles with serrate edges, which I found in the dolomite of Flat Rock, and suggested might be the remains of fishes or crustaceans, I found several at Point-aux-Paux. South of Point-aux-Paux, toward Monroe, we find the same rock beds everywhere close under the surface, with only a few feet of drift on them. The quarries alongside of Raisin River, up to Dundee, are all opened in beds of this horizon. In the quarries of Plum Creek, a short distance south of Monroe, by the undulations in which the strata rise and sink, about twenty feet of rock beds come to an exposure. Uppermost are fine-grained, light-colored dolomitic limestones in beds a few inches thick, and in the aggregate reaching six feet. Next below is a compact stratum of oolith from eighteen inches to two feet in thickness, which makes a good building material. Lower are thin, rugose ledges of limestone with intervening narrow seams of a black shale mass; these are succeeded by about two feet of a gray and blue mottled dolomite rock, after which are again thinly laminated limestone slabs with intermediate black shale seams. The surface of these limestone slabs is covered by ramified relief forms, apparently of vegetable origin. The lowest beds in the

quarry are bluish gray dolomites in moderately thick ledges, opened to the depth of about eight feet, and representing the principal quarry-stone used for ordinary building purposes. In the whole series of rock beds, fossils are rarely seen, but in nests or in a thin seam, locally, they may be found in abundance. Among the rocks which came out on excavating the cellar of a brewery situated within the quarry, certain blocks are crowded with casts of *Meristella laevis*, *Retzia globosa*, *Leptocoelia concava*, *Megambonia aviculoidea* and several other bivalves, several *Gastropods*, great numbers of a spirorbis-like shell, besides the vegetable stems found elsewhere in the same strata.

In the southwest corner of La Salle town, about six miles west of the lake shore, the brecciated limestones, which in Monroe are in a position on a line with the lake level, are found in the quarries at an elevation of about 100 feet above the lake.

In the quarries near Little Lake, in Bedford township, similar strata to those of the Plum Creek quarries are uncovered. In the upper part of the quarry we find an oolitic stratum identical with the one in the other locality. The lower part is formed of brecciated limestones, seams of which are fossiliferous; besides the already-mentioned forms, a *Cyrtoceras* and some *Gastropod* casts are found there, which I have not noticed in the other localities.

Two miles west of Ida village, close to the railroad track, extensive quarries are opened and lime-kilns erected. Close under the surface, light-colored, almost white dolomites, of finely crystalline grain, and of absorbent, porous structure are found; they are much intersected by veins of calcspar, and inclose druse cavities lined with the same material. Certain layers are completely filled with small acicular spar crystals, or the crystals have been dissolved by a partial weathering of the rock, and the places formerly occupied by them are now found as open, narrow slits pervading the rock in all directions. By the same process of weathering, the rock, which originally was a hard mass composed of dolomite spar crystals, cemented together by calcspar, the more soluble calcspar being dissolved by the percolating waters, is left, according to the degree of weathering, either a porous but yet hard mass of minute dolomite spar crystals, or a mealy, crystalline substance friable between the fingers.

An analysis of the dolomite with acicular crystals gave,

Carbonate of lime.....59 per cent.

“ “ magnesia.....39 “

Insoluble residue not weighed.

The acicular spar crystals are very characteristic of the limestones of this lower horizon of the Helderberg group, everywhere to be found in this district, in Ohio, in Goderich, Canada, and in Mackinac Island where these beds are uncovered. Similar acicular limestones are found in lower geological position in the dolomite beds of the Onondaga group, and in certain beds of the Niagara group. (See report on the Upper Peninsula, page 35.)

Prof. A. Winchell identified the dolomites of the Ida quarries with the Onondaga group, but the position of these beds is not lower than that of the other quarries considered to represent the water-lime group, and no difference in the lithological characters of the strata exists which would justify a distinction. In the deep boring made in the Court-house yard of Monroe for a depth of 300 feet, no particular change in the nature of the rock was observed; nearly all this thickness was made up by dolomites, some of which, by their cellulose character, with cavities once filled with crystals, are similar to beds found in the Onondaga group, but no gypsum beds nor shale deposits, which are significant of this group, were noticed.

The gypsiferous rock beds have been found in the State of Ohio at Sylvania, but in Michigan no positive evidences of the development of this formation have been discovered in the southeastern end of the State. Remarkable in this region are the numerous sink-holes found over it. Some of them are small, abrupt, funnel-shaped depressions; others are larger and sink more gradually. Many of them are filled with water and form respectable lakes, as Ottawa Lake and Little Lake, while others are dry or filled only for a part of the year. The water in all these lakes is subject to considerable fluctuations during the different seasons. Ottawa Lake, which covers about a square mile of surface, has in the spring of the year a depth of 50 feet; toward the fall it has lowered its level about 25 feet below high-water mark, and its shallowest parts lie perfectly dry. The water usually disappears rapidly when it begins to sink, which is not the effect of

evaporation. It escapes by subterranean crevices, which become visible after the water has run off. The steep embankments of the northeast end of the lake are formed by the brecciated limestones of the water-lime group, which are quarried there and burned into lime.

Little Lake, in the town of Bedford, Section 15, is another sink-hole of large dimensions. It sometimes becomes perfectly dry, which never happens with Ottawa Lake. The rock crevices through which the water disappears were quite conspicuous in the emptied lake bottom at the time of my visit. Four miles north of Ottawa Lake, on the land of Mr. Cummins, in the town of Whiteford, between Sections 1 and 2, another large sink-hole is observable, which during the summer and fall-time is perfectly dry and partly overgrown with grass. The centre of this depression is about 18 feet below the level of the surrounding country; a part of its bottom is formed of naked rock ledges fissured by deep, vertical crevices. The owner of the place informs me that during the spring this depression is filled with water which contains large fish, although I saw not a drop of water in it at the time of my visit. When the water begins to sink, it escapes quickly, and at the spot where the crevices are, a whirlpool draws them in with a distinctly audible, rushing noise. The larger fish being unable to get off with the water, are left on the dry bottom to die. From the fact of the appearance in these periodical water-basins of full-grown fish of the kind usually found in Lake Erie, it has become the general belief of the inhabitants that a direct connection exists between these sink-holes and that lake, which suggestion has in it much of probability. All limestone formations are apt to be undermined and eaten out by the water flowing through their crevices, which is more or less charged with carbonic acid, and thus rendered a powerful solvent for the limestone. The old sandy beach-lines encircling this district bear clear testimony to the fact that all this part of the country was at a period not very remote a part of the bottom of Lake Erie, whose waters leached out the softer, more soluble ledges of the lime rock, and left the harder layers as roofs over the eroded cavities. After the receding of the water from this ground, leaving behind a deep, muddy sediment, which forms the present rich soil, the roofs of these subterranean cavities broke down, in some cases forming sink-holes that remain in connection with

intricate subterranean channels which doubtless lead into the lake.

The connection of the Helderberg group with the superincumbent younger formations is in this part of the State entirely hidden by drift deposits. At Blissfield, Deerfield, and Petersburg, localities which are only a short distance from the actual outcrops of the Helderberg strata, in ordinary wells, dug to a depth of seventy and eighty feet through drift deposits, no rock ledges have yet been touched, and at Detroit, 130 feet have to be sunk through before the lime rock is reached. In Prof. Winchell's geological map, published in Walling's Atlas of Michigan, the southwest corner of the State is represented as underlain by the Helderberg group, through a great portion of Cass and Van Buren counties and all over Berrien County. This is an error; the Helderberg strata have nowhere been found as the surface rock underneath the drift in any of the deep borings made at Niles, Cassopolis, Michigan City, or other places.

In a deep boring lately made at the Indiana State Prison, at Michigan City, the drift was found to be 170 feet deep; below it, the black shales of Ohio were struck in a thickness of 76 feet, and, finally, at a depth of 246 feet from the surface, the first limestone beds of the Helderberg group were penetrated. A natural outcrop of the Waverly group is north of New Buffalo, near Brown's Station, not far from the Lake Shore. It is the same case south of the Michigan boundary-line, on Indiana territory, where for many miles no trace of a limestone formation underlying the drift can be found; it is always the subcarboniferous sand rock and its intermediate shale beds which are first encountered.

CHAPTER VI.

HAMILTON GROUP.

ON the map of Prof. A. Winchell, just mentioned, a belt of the Hamilton group is represented as extending from Wyandotte southwestward through Monroe and Lenawee counties, and on the southwest side of the State another belt is laid down as stretching from the southwest corner of St. Joseph County to the north end of Berrien County.

In the southern part of Michigan no strata have ever been discovered which could be claimed as representing the Hamilton formation, and even if such existed, the belt laid down as running through St. Joseph and Berrien counties would be positively misplaced, as its hypothetical course would be not less than 40 or 50 miles further to the southwest. The Hamilton group is, all through Ohio and Indiana, scarcely developed; in the exposures, the beds usually found next incumbent on the Helderberg limestones are the black shales of Ohio, considered as equivalent to the Genesee shale of New York. Only in a few localities of Ohio are some shaly strata of inconsiderable thickness, containing Hamilton fossils, intercalated between the limestone formation and the black shales.

In the northern part of the Michigan peninsula we find the Hamilton group developed as a heavy formation of over 500 feet in thickness. The southern limit of the surface extent of this group, in the region spoken of, is indicated by a line drawn from Partridge Point, in Thunder Bay, northwestward to intersect the principal meridian in the southern part of Town. 34; from there the line goes directly west, through Bear Lake and Pine Lake, and then bends southwest, terminating near Norwood on the shore of Big Traverse Bay. The land-spur across the bay is covered by drift, and presents no outcrops of rock. The continuation of this belt of the Hamilton group, across Lake Michigan and Lake Hu-

HAMILTON GROUP.

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ron, to the shores of Canada and Wisconsin, has previously been mentioned. North of the indicated line, all of the surface of the peninsula is formed by the Hamilton strata, excepting the small strip of shore at McGulpin's Point, which is described as composed of the upper Helderberg limestones. The Hamilton group in New York is pre-eminently a shale formation, with subordinate beds of limestone; in Michigan it has more the character of a limestone formation with but a subordinate development of shale beds.

Natural sections of large extent, by which the thickness of the formation can be estimated, do not exist; by borings made in Alpena, its thickness is found to be much greater than formerly had been supposed. One of the borings was made more than ten years ago, but no accurate record was kept of it. At that time a bed of rock salt was struck in the bottom of the well, and I myself saw more than a bushel of salt in yellowish crystals which was brought up by the sand pumps; still no further use was made of this discovery, and it is only within the last few years that the strong stream of mineral water discharged from the bore-hole has received attention and been used for its strong medicinal properties. At present it is led by tubings to a bathing institution close to the landing-place at the bay. The mineral water is strongly impregnated with hydrosulphuretted gas. It flows from a higher level than the bottom of the well, but has a considerable proportion of chloride of sodium in solution, which probably rises from the lower part of the bore and mingles with the upper sulphurous water. An analysis made by Dr. Duffield gave 237 grains of solid matter to a gallon of the water, as follows:

Bicarbonate of soda.....	15.736	grains.
“ “ lime.....	55.136	“
“ “ magnesia.....	62.920	“
“ “ iron.....	1.840	“
Sulphate of lime.....	30.056	“
Chloride of sodium.....	68.256	“
Silica and alumina.....	3.088	“
Organic matter.....	0.928	“
Sulphuretted hydrogen	3.91	cubic inches per gallon.

Another boring was made four years ago close to the bed of Thunder Bay River. It commenced in rock beds which are at least 100 feet lower than the strata composing Partridge Point. The boring commenced in limestones, which continued, without much interruption by other beds, to a depth of 400 feet below the surface, when blue shales were struck, and a powerful stream of mineral water rose to the top, carrying with it many well-preserved fossils of the shale beds. The fossils were: *Cyathophyllum Houghtoni*, *Cyathoph. Hallii*, various species of *Favosites*, *Cladopora*, and numerous *Bryozoa*, *Crinoid* stems, *Atrypa reticularis*, *Spirigera concentrica*, *Spirifer mucronatus*, *Cyrtina Hamiltonensis*, etc. The thickness of the shale was found to be 80 feet. Below it, limestones of variable hardness and color were penetrated to the depth of 600 feet from the surface, and from there to 1025 feet, light-colored, partly dolomitic limestones were found. At this depth a bed of solid rock-salt was struck, after which the boring was discontinued. The upper 480 feet of this drill-hole are positively made up by strata of the Hamilton group, which, with addition of the 100 feet of higher strata, would give 580 feet for the thickness of the Hamilton group, and in all probability a part of the limestones below the shales also belong to that group. The lower light-colored limestones represent the Helderberg group, and their dolomitic strata may be equivalent with the lower beds of Mackinac Island, and with the subjacent Onondaga group. The deposit of rock-salt is at all events identical with the rock-salt deposits of Goderich in Canada, and with the Onondaga salt deposits of New York State. The salt brine of Saginaw valley belongs to an entirely different and much higher horizon, to the Waverly formation. After the boring was finished, pumps were set in the tubed hole, and a concentrated brine was lifted to the surface, which, after pumping for a while, became weaker and weaker, until at last a very weak brine only came up. If the pumping was interrupted for some hours and commenced again, a strong brine could be obtained for a while, when the weaker grades would reappear. This discouraged the owners of the well, so that nothing more was done. I told them the reasons for this, explaining to them that the salt being in solid condition, had to dissolve first in the water which runs upon it from above, and required time to become saturated, so that after the strong solution, the quantity of which could

only be small, proportionate to the surface of salt rock exposed to the solvent, was pumped out, it was to be expected that only a weak brine could be obtained. But this would have soon remedied itself; by constant pumping a larger cavity would have been formed, and the surface offered to the water for solution would constantly have increased, so that a reservoir would finally be formed capable of furnishing a supply of strong brine which could no longer be exhausted by the pumps. Whether any use was made of these hints, I do not know, but the fact is that this very valuable discovery has lain idle for several years, which is much to be regretted, as I have not the least doubt that, by a little patient application of the pumps, it would soon yield a constant supply of strong brine. The highest beds of the Hamilton series at Thunder Bay are seen at Partridge Point, on the south side of which, in Squaw Bay, the bituminous black shales of Ohio directly overlie them. Sulphur Island, in front of Squaw Bay, is also covered by the black-shale formation.

The top layers on Partridge Point are thin-bedded, hard limestone slabs, seen in the thickness of a few feet; they contain no fossils. Next below them follow calcareo-arenaceous shales of bluish or greenish color, alternating with seams of limestone, which face the lake in a bluff along the north side of the point, projecting about 12 or 15 feet above the water level. The shales and limestone beds are crowded with fossils in a good state of preservation. A great variety of *Bryozoa*, particularly of the genera *Fenestella*, *Polypora*, *Hemitrypa*, *Stictopora*, *Fistulipora*, and *Trematopora*, belong to the most abundant forms, besides corals, *Cystiphyllum Americanum*, *Cyathophyllum geniculatum*, *Cyathoph. Hallii*, *Diphyphyllum Archiaci*, and various forms of *Favosites*, *Syringopora*, *Aulopora*, *Dendropora*. *Crinoids* are very well represented by the genera *Megistocrinus*, *Dolatocrinus*, *Nucleocrinus*, *Pentremites*, *Lepadocrinus*. Of *Brachiopods* occur: *Atrypa reticularis*, *Spirifer granuliferus*, *Spirigera concentrica*, *Cyrtina Hamiltonensis*, *Terebratula romingeri*, etc.; of *Trilobites*, *Phacops bufo* and a species of *Proetus*. In front of these bluffs, at a distance of about one mile, are two islands, Bear Island and Grass Island, on which I expected to see the next lower beds exposed, but all their surface is composed of boulder drift.

Likewise on the main shore, the rock strata below the shales of

the bluffs are hidden from view; between the next point northward, Stony Point, and Partridge Point, a low, swampy space about a mile in width extends, on which no rock ledges can be seen; it is, however, evident, from the strike and dip of the strata, that the beds composing Stony Point are below those of Partridge Point, and that no great mass of rock strata can intervene between them. The ledges of Stony Point are first noticed submerged, while northward, by a gradual rise of the strata, they project about three or four feet above the water level. They are a light-colored limestone, full of large convex masses of various species of *Stromatopora*, particularly *Str. monticulifera* and *Str. Wortheni*. Some deeper ledges of darker color and of a nodular structure, with intermingled shaly seams, are rich in many species of fossils, chiefly *Cyathophyllum Houghtoni*, *Cyathophyllum Hallii*, *Cystiphyllum Americanum*, *Diphyphyllum Archiaci*, *Cyathophyllum profundum*, *Favosites Hamiltonensis*, *Favosites nitella*, *Alveolites subramosus*, various forms of *Syringopora* and of *Aulopora*, and numerous *Bryozoa*. Of *Brachiopods*, I may mention *Atrypa reticularis*, *Spirigera concentrica*, *Spirifer mucronatus*, *Spirifer zigzag*, *Cyrtina Hamiltonensis*, *Pentamerus aratus*, *Strophodonta demissa*, *Strophodonta erratica*, *Crania Hamiltoniae*, *Crania crenistria*, with a number of others.

Analogous rock beds form the surface rock over an extended space west and northwest from Stony Point. The hillsides lining the south side of Thunder Bay River, in Sections 28 and 20 of Alpena town, present a number of exposures of the strata in question. The highest beds seen in these localities are light-colored limestones containing few fossils beyond some *Crinoid* stems and ramulets of *Bryozoa*. Under them follow nodular limestones abounding in irregular, flexuous seams of black bituminous shale matter. The mass of these limestones is almost entirely composed of different species of *Stromatopora*, *Favosites Hamiltonensis*, *Cyathophyllum profundum*, *Cyath. Houghtoni*, etc. Somewhat lower strata are of a lighter blue or drab color, with the shaly seams very prevalent throughout the ledges. They are very fossiliferous, containing about the same forms as have been enumerated as belonging to the lower beds of Stony Point, besides a few others not seen there, as *Cystiphyllum aggregatum*, and large lumps of *Chætetes* and of a *Fistulipora*

species. At the foot of the hills, below these shaly layers, about 15 feet of light-colored limestones, in beds six or eight inches thick, are the lowest seen in the outcrops; they contain but few fossils, and not any of them characteristic of a certain horizon. The total depth of strata composing these outcrops is from 50 to 60 feet. On the north side of Thunder Bay River another series of rock beds is found, which I suppose to be the next in succession below the section just described. The marshy, level surface on which the north half of Alpena village is situated is underlain by light-colored limestones inclosing a profusion of *Stromatopora plana* and many corals, as *Favosites*, *Cyathophyllum*, *Cystiphyllum*, partly in silicified condition. The next deeper strata, exposed on the side of the first lake terrace, contain, besides the aforementioned corals, silicified stems of *Favosites radiformis*, *Cladopora Alpenensis*, *Michelinia insignis*, *Favosites radiatus*, *Cyathophyllum Hallii*, and numerous other fossils. Among the lower ledges of this horizon a bed is almost exclusively filled with disconnected shells of *Cyrtina umbonata*. In further descending order, beds of a coarsely crystalline, drab-colored, and sandy-looking limestone occur, which contain only a few fossils, but interlaminated with them is a seam of much lighter-colored, smooth fracturing lime rock full of fossils, among which *Chonophyllum ponderosum* and *Strombodes Alpenensis* are peculiar to this stratum. Still below them we find compact dark gray or bluish-colored limestones of crystalline fracture, and almost entirely composed of broken shells and *Crinoid* stems. This rock is quarried in several localities, being the only good building-stone to be had in the vicinity of Alpena. The total thickness of the rock series described on the north side of Thunder Bay River is about 50 feet. The lowest of the beds, all of which were in nearly horizontal position, are visible in the circumference of a small, abrupt hillock on which Mr. Phelps's lime-kilns stand, in an uplifted position, dipping away from the central, bubble-like protrusion at an angle of 25 or 30 degrees. Several such hillocks are noticed within the space of half a square mile. The central mass of the hillocks is a whitish, fine-grained, pure limestone, of brecciated structure, and of smooth, conchoidal fracture, pervaded in all directions by fissures filled with *calcspar* and mottled by cloudy seams of light green or reddish color. It contains a great abundance of fossils,

particularly *Stromatopora Wortheni*, *Favosites Hamiltonensis*, *Cyathophyllum profundum*, *Strombodes Alpenensis*, *Chonophyllum ponderosum*, many Bryozoa and various Brachiopods of the usual Hamilton species, etc. The rock makes an excellent white, quick-slaking lime. Similar strata of less brecciated structure, and inter-laminated with soft, soap-like, whitish green clay are uncovered in the race of Mr. Broadwell's saw mill on Thunder Bay River. The clay incloses a profusion of splendidly preserved Bryozoa and corals, also some Crinoids (*Dolatocrinus*) and Brachiopods. The exact relative position of the strata exposed in this locality I was unable to ascertain. A bubble-like upheaval of the beds has its centre in the river bottom and by the dam thrown across the river—the most instructive portions of the section are thus set under water. Only a short distance up the river, on the side of the road leading to Trowbridge's mills, a small knob is formed by the same light-colored, smooth fracturing, brecciated limestones, which there seem to repose in undisturbed original position on blue calcareous shales, with seams of silico-argillaceous limestone. The river, which passes only about 100 steps from the hillock, has cut its bed through these subjacent shales to a depth of 50 feet, and for a whole mile the ledges are exposed in high bluffs. The shales inclose a great variety of well-preserved fossils: *Atrypa reticularis*, *Spirigera concentrica*, *Cyrtina Hamiltonensis*, *Cyrtina umbonata*, *Spirifer mucronatus*, *Spirifer divaricatus*, *Spirifer granuliferous*, *Spirifer fimbriatus*, *Terebratula Linklæni*, *Strophodonta demissa*, *Pentamerus papilionensis*, *Crania crenistria*, *Crania Hamiltoniæ*, and numerous Bryozoa, *Phacops bufo*, etc. A few inter-stratified seams of a silicious limestone are a conglomerated mass of silicified shells of *Cyrtina umbonata* and of a few specimens of *Spirigera concentrica*.

The argillaceous limestones interstratified with the shales were a number of years ago used for the fabrication of hydraulic cement. Expensive kilns stand abandoned at the foot of the river bluffs. Mr. Trowbridge, their former owner, informs me that sometimes an article of very good quality was produced, but the success was so uncertain that the cement never came into reputation in the market, and after a short time he gave up the undertaking. Whether the failure to make a uniform product was in the use of different beds, some of which would not

answer, or in the management of the burning process, I can not tell.

From Trowbridge's mills, higher up the river, the strata are hidden from view for several miles; they appear again under the bridge crossing the north branch of Thunder Bay River. Judging from the rock character and the fossils, the strata belong to about the same horizon as those near Trowbridge's mills.

In Township 32, R. 6, east, Section 34, on the farm of Mr. Marston, close to his dwelling-house, a large funnel-shaped sink-hole without an outlet attracts attention. It occupies the area of a few acres, and has a depth of about 25 feet; a strong spring issues from the side of the depression and disappears again in its bottom in the crevices of the rock.

The bottom strata, seen in a thickness of about 8 feet, are hard, bituminous limestones, with delicate laminar striation in the direction of the bedding and fissible into thin flags. Near the upper terminus of the rock strata a seam about one foot in thickness of a cellulose, brecciated quartz rock, mottled with various red, brown, or yellowish colors, and containing distinct casts of fossils, is intercalated. Above it follows a coarsely crystalline, tough, brownish-gray dolomite, which contains large *Euomphalus*-like coiled shells, *Cystiphyllum*, and indistinct specimens of *Stromatopora*; its thickness is from 8 to 10 feet. Next above is a silicious limestone full of silicified specimens of *Stromatopora Wortheni*, *Favosites digitatus*, *Syringopora nobilis*, *Spirigera concentrica*, and the same large coiled shell as in the dolomites below; its thickness is 4 or 5 feet, and over the top a few layers of compact, light-colored limestones are spread. About a mile from Marston's the road passes not far from the river, where it intersects the southwest corner of Section 34 in the same town. It flows there in a long series of rapids, over hard, bluish, crystalline limestones containing shell fragments and Crinoid joints. The banks of the river, about 18 or 20 feet high, are all formed of drift, and the relative position of these rock beds can not be made out. On Section 28 of the same township, on Mr. Johnson's farm, in a well 21 feet deep, blue-colored argillaceous limestones and intermediate shale beds were penetrated; of fossils, I noticed in them *Atrypa reticularis*, *Spirifer fimbriatus*, *Spirifer granuliferous*, and Crinoid stems; one of the layers was a

coarse-grained, gray dolomitic rock identical with the dolomite rock in the sink-hole on Mr. Marston's farm. The horizon of all these rocks seems to be below the strata of Thunder Bay River near Trowbridge's mill. For a circle of many miles around the localities described, rock beds of the same horizon seem to occupy the surface, covered by a more or less considerable coating of drift material. The drift soil of this region is a fertile, gravelly loam, which was densely covered with forest until a number of years ago fires swept through them, totally destroying them for many square miles. By this clearance of the productive soil, numerous settlers were attracted to the spot, whose fields have now a really promising aspect. Wheat, oats, grass, and potatoes give very good crops, which, from the vicinity of the lumbering districts, always find a ready market and good prices. Mr. Johnson told me he raised for three successive years nearly a hundred bushels of oats from an acre of land. I saw some of his oats, which were heavier than any I had seen before, and certainly, even if the hundred bushels to the acre were a slight exaggeration, indicated much fertility of soil. An interesting feature of this district are the numerous sink-holes found in it, hundreds of which may be counted along the headwaters of Thunder Bay River; some are small, funnel-shaped depressions, dry on the bottom, or containing waterpools; others are narrow, vertical clefts, described to me by the woodsmen as sometimes 80 and 100 feet deep; and it is said of one which I passed that a large stream of water rushes across its bottom. A few of these sink-holes, as mentioned before, are of very large size, and form lakes. One of the latter is Sunken Lake in Township 33, R. 6, Section 32. It is about one mile and a half long, and in its widest part 500 yards. During the wet season, it is filled with water, having a depth of 90 feet; its overflow forms a branch of Thunder Bay River, which at that time is used for floating logs from the surrounding pineries to the saw mills of Alpena. During the dry summer season, the water almost totally disappears from the lake, making its escape through the rock crevices in its bottom. Formerly the water flowed off very rapidly, making a strong whirlpool. The lumbermen, in order to keep the water in the lake, threw masses of brush and even whole trees and rocks into the crevices to stop them up, and partially succeeded, but the water soon again cleared its passage through those obstructions;

its efflux was retarded only, not prevented. At the time of my visit in June I found the lake 25 feet below high-water mark. At its west end a vertical rock wall about 15 feet high ascends from the water; the ledges are dolomitic limestone from 18 inches to 2 feet thick, of light gray color, separated by thin, intermediate shale seams; they contain *Atrypa reticularis*, *Spirifer granuliferous*, *Strophodonta demissa*, and Crinoid stems. The position of the beds is visibly inclined toward the lake. The beds next to these, in the ascending line, are exposed at the south shore of the lake; they contain an abundance of *Stromatopora Wortheni* and *Stromatopora monticulifera*, *Cyathophyllum profundum*, various species of *Favosites*, *Alveolites Goldfussii*, heads of *Dolatocrinus* and *Megistocrinus*, *Atrypa reticularis*, *Strophodonta demissa*, *Spirifer mucronatus*, *Spirifer granuliferous*, and other fossils. The outlet of the lake when its basin is full is at the south end. When I saw it, the bed of the creek lay perfectly dry, and before reaching its level the water would have had to rise at least 20 feet.

The outlet of Long Lake, in Township 32, R. 8, east, is formed by a similar large sink-hole. During the wet season this basin is full, and a large creek flows in rapids and small cascades toward Lake Huron. In summer-time, the basin, all formed of solid rock, lies perfectly dry, and the water, discharged from the main body of the lake above, runs off through subterranean crevices.

The surface rock of the shore-belt from Long Lake southward to the north point of Thunder Bay, inclusive of Thunder Bay Island and Sugar Island, belongs all to about the same geological horizon. It is composed of an alternation of limestones, partly of gray, partly of black color, with interstratified seams of shales, which are also black or dark gray. Some beds are of nodular, concretionary structure, almost entirely composed of various species of *Stromatopora*, *Cyathophyllum profundum*, *Favosites Hamiltonensis*, *Favosites digitatus*, and other corals and shells, particularly Brachiopods. The exuberance of fossils in the strata is most beautifully exhibited in the shoals of the lake north of Thunder Bay Island, where any one sailing over them can see for miles the whole bottom paved with corals in convex lumps, from a few inches to some feet in diameter, their white, sparry substance contrasting beautifully with the dark limestone which incloses them.

The fossils found at Stony Point, south of Alpena, are mostly identical with the fossils found in the Thunder Bay Island strata, but I believe the latter to be of a lower position than the first. The fauna of the Hamilton group remains through the whole period essentially the same, and a repetition of fossiliferous rock beds containing the same species in different horizons is a frequently observed fact. The position of the strata of Thunder Bay Island is below that of the shale beds in Thunder Bay River near Trowbridge's mills. The road from Alpena to Long Lake passes the lime-kilns of Phelps, where a whitish brecciated limestone forms the nucleus of several bubble-like hillocks; the same limestone is noticed resting on the shales of Trowbridge's mills. In going north from Phelps's quarries, the surface rock retains the same character for several miles, the various beds which happen to be exposed being sometimes fossiliferous, at other times not, while in places layers are filled with hornstone concretions. Two miles south of Long Lake, we come upon black, shaly limestones containing *Atrypa reticularis*, *Spirigera concentrica*, *Strophodonta demissa*, *Strophodonta erratica*, *Pentamerus papilionensis*, *Spirifer granuliferous*, *Cyrtina Hamiltonensis*, *Cyrtina umbonata*, and *Terebratula Linklani*, besides corals and Bryozoa. These beds evidently underlie the others. We find the black, shaly limestone continued from there as the highest stratum on the hilltops bordering Long Lake, which have an elevation of about 75 feet above its level. Descending to the lake, underneath the black strata, gray limestones are found, inclosing a few specimens of *Stromatopora*, *Favosites*, *Atrypa reticularis*, *Spirifer granuliferous*. Lower beds are a coarsely crystalline, crinoidal limestone, and the base of the hillsides, to within about 30 feet of the water level, is formed by an alternation of shales, nodular seams of limestone, and some heavier massive limestone ledges, all of which contain an abundance of specimens of several species of fossils. The fossils are partly in silicified condition. The following is a list of the collected specimens: *Stromatopora Wortheni*, *Stromatopora monticulifera*, *Cystiphyllum Americanum*, *Cyathophyllum profundum*, *Cyathophyllum scyphus*, *Favosites Hamiltonensis*, *Favos. digitatus*, *Cladopora*, *Syringopora*, various Bryozoa, *Atrypa reticularis*, *Spirifer mucronatus*, *Spirifer granuliferous*, *Cyrtina Hamiltonensis*, *Cyrtina umbonata*, *Orthis Tulliensis*, *Spirigera concentrica*, *Terebratula Linklani*, *Pentamerus costatus*,

Strophodonta erratica, *Strophod. demissa*, *Productella dumosa*, a large *Myalina Euomphalus*, etc.

A few miles east of Long Lake we find the shore of Lake Huron lined with exposures of the black, shaly limestones, agreeing with the strata on top of the hills near the former, everywhere containing an abundance of *Stromatopora Favosites*, *Cyathophyllum profundum*, as the prevailing fossil forms, besides other species common only in certain localities; as, for instance, a species of *Zaphrentis*, which I found in great quantities at Section 34, in Township 32, Range 9, east, but which, in all other localities north and south from there, was rare or missing. I also found *Favosites digitatus* more common there than elsewhere. On Thunder Bay Island, the variety of fossils in the black limestone strata is greater than I found it in any other place. Besides the above-mentioned leading forms of *Stromatopora* and of corals, the strata are rich in Bryozoa and in Brachiopods. Among the latter, I may mention *Atrypa reticularis*, *Spirigera concentrica*, *Spirifer zigzag*, *Spirifer mucronatus*, *Terebratula Linklani*, *Strophodonta erratica*, and *Pentamerus aratus*. *Orthoceras*, *Gomphoceras*, *Proetus crassimarginatus*, and *Phacops bufo* also belong to the more common fossils of the island. Sugar Island represents the same strata, but the rock beds there are mostly covered by drift. Little Thunder Bay is a deep recess in the coast, situated in Township 31, R. 9, Section 75. Its entrance is very shallow, not always deep enough to admit a Mackinaw boat. The head of the recess is formed by a large sink-hole, which in the middle has a depth of 100 feet. A semicircle of rocky bluffs of from 25 to 30 feet elevation surrounds this deep pot-hole. The external portion of the semicircle is formed by the edges of horizontal rock beds projecting in vertical walls; a belt in front of them is composed of loose masses of the same rock, broken off and dipping in rapid inclination or in irregular, uptilted position toward the margin of the water-basin. The strata are the same as on Thunder Bay Island, but of lighter color, and more interlaminated with soft, shaly seams.

One township further north, in T. 32, R. 9, Sect. 6, directly west of Middle Island, on the side of a small creek flowing southeastward into Lake Huron, a chain of vertical rock bluffs, about 16 feet in height, is found commencing about half a mile from

the shore, and extending thence about one mile up the stream. The bluffs consist of nodular, unhomogeneous beds of limestones, interstratified with thin seams of shaly substance of black color. Nearly the entire rock mass is made up of specimens of *Stromatopora* mingled with *Favosites*, *Cyathophyllum profundum*, *Diphyphyllum archiaci*, and other corals, which, by exposure, easily become disintegrated. At the foot of the bluffs, blue shales are exposed which contain many fossils: *Atrypa reticularis*, *Spirigera concentrica*, *Spirifer mucronatus*, *Spirifer zigzag*, *Spirifer granulosus*, *Rhynchonella*, *Strophodonta concava*, *Strophodonta demissa*, *Chonetes coronata*, *Cyathophyllum Houghtoni*, *Cystiphyllum Americanum*, *Stromatopora monticulifera*, *Stromatopora Wortheni*, Crinoid stems, and many Bryozoa.

The lumps of coral and *Stromatopora* composing the upper beds of the bluffs take a good polish. Deceived by some good-looking polished samples, parties in Detroit were induced to buy the land on which the specimens were found, with the intention of opening a marble quarry. The shattered condition of the rock bluffs, which should have warned them at the first glance, was totally ignored, and in the vain hope that, by digging deeper down, a sounder quality of the rock would be found, a shaft was sunk into the shale beds under the bluffs to a depth of 50 feet. It was then that those concerned came to me, asking for advice, which I gave them with sincerity, but a little too late to save their purses.

Another so-called marble quarry was opened a number of years prior to this experiment, by Mr. Crawford, in the vicinity of Adams Point, in Town. 35, Range 5, east, Sect. 24, which gave no better results. The rock has not the compactness and homogeneous qualities requisite for marble. The beds in both mentioned places seem to be identical. A belt of similar limestones, partly covered up by drift deposits, follows the northeastern shore of Grand Lake, connecting the two points. The blue shales below the rock in the one locality are not seen at Crawford's quarry, but there is a probability that the blue shales penetrated in the artesian well at Alpena, 400 feet below the surface, may be the equivalent of them. The next lower beds to this series compose Middle Island, and identical with the Middle Island strata are the outcrops on False Presque Isle, where the ledges project in a low

bluff from the east shore of the island, and where, when the lake is quiet, a huge stairway, formed by large rock tables, divided by vertical fissures into rhomboids, can be observed, leading down, step by step, into greater depths, until finally lost to view. Presque Isle Lighthouse Point is composed of the same strata, and intermediate between the lighthouse and False Presque Isle, on several parts of the shore, they come to the surface, the rest of the shoreline being a sand or gravel beach.

Significant of these strata are two fossils, which I found in every one of the outcrops observed. One is *Lucina elliptica*, the other a species of *Euomphalus*, closely related, or perhaps identical with *Euomphalus Dekewyi* of Billings. Associated with these fossils in the outcrops of Presque Isle are, *Stromatopora textilis*, *Stromatopora Wortheni*, *Diphyphyllum rectiseptatum*, *Favosites* (rare), *Spirigera concentrica* (small, globose form), *Spirifer gregarius*, *Atrypa reticularis*, and *Pentamerus*. On Middle Island, I found, in addition to the first, *Cystiphyllum*, *Atrypa reticularis* with very fine ribs, a new species of *Pentamerus* (*P. nucleolus*), a *Strophodonta*, two species of *Bellerophon*, a *Pleurotomaria*, and several other Gasteropods, a large *Myalina* (*M. carinata*), *Avicula flabella*, and casts of other bivalves, *Orthoceras*, and a *Nautilus* with quadrangular oblong diagram of volutions. The scarcity of *Favosites* and *Cyathophyllum* in the strata of all the localities under consideration is peculiar; in all the rock beds, above and below, these two genera are the predominating types. The rock ledges composing Middle Island are best exposed on the north side of the island; the ledges are uneven-bedded, not thick, a dark gray-colored, somewhat brittle limestone; some beds are mottled with porous, lighter-colored dots, and sparingly intermingled with flint concretions. The whole thickness of the exposed beds successively coming to the surface is not over 20 feet. The exposures at Presque Isle Lighthouse Point exhibit at the water's edge limestones entirely similar to those of Middle Island; higher beds denuded during the excavation of the foundation for the lighthouse are an easy weathering limestone with an abundance of cherty concretions.

At Crawford's quarry the shore-belt rises in two terraces, partly covered by drift, partly presenting rock exposures. At the water's edge, rock bluffs projecting to a height of from 10 to 15 feet are composed of drab-colored limestones mottled with darker, more

compact spots, while the surrounding lighter-colored rock mass has a certain degree of porosity. *Lucina elliptica* was the only fossil noticed. About 12 feet above the vertical bluffs is the level of the first terrace, the intervening space being apparently made up of limestone ledges of similar character to the lower beds. On this first terrace rises a second, its elevation above the first being about 25 feet. This likewise is formed of a continued series of lime-rock ledges, and these represent the quarry rock of the so-called Crawford's marble quarry.

The rock of this second bluff is deposited in uneven beds of quite unhomogeneous structure, not suitable for large blocks, and not susceptible of an equal polish; some portions are porous, with dull, earthy fracture. Nearly the entire bulk of these rock beds is composed of several species of *Stromatopora*, *Str. monticulifera*, *Str. Wortheni*, and *Str. textilis*. Other fossils observable are *Cyathophyllum profundum*, *Eridophyllum simcoense* (similar to), *Favosites* (various forms), *Atrypa reticularis*, *Strophodonta erratica*, *Lucina elliptica*, *Lucina* sp. nov. and *Orthoceras*. The top of the second terrace is covered by drift deposits. From this level, undulating highlands extend southward, meeting the highlands surrounding the head branches of Thunder Bay River. Rock beds similar to those of Crawford's quarry, or somewhat higher beds, are, all over these high plains, not very deeply covered by drift, and are frequently denuded. The principal denudations of the rock are confined to certain belts striking in a southeast and northwest direction. One of these belts may be indicated by a line drawn from the north end of Long Lake to the mouth of Oqueock River in Hammond's Bay; another limestone belt can be followed from the head branches of Thunder Bay River (north branch) to Rainy River and Sheboygan Lake.

The surface rock most frequently seen on these high plains is light-colored, of crystalline grain, and principally contains the already-mentioned species of *Stromatopora*; a species of *Diphyphyllum* is also quite common (*Diphyph. rectiseptatum*). In some localities, shaly beds, intermediate between the limestones, are very fossiliferous. On McArthur's farm, 8 miles southwest of Crawford's quarry, I collected from the material thrown out in digging a well, *Favosites Hamiltonensis*, *Favosites digitatus*, *Cyathophyllum profundum*, *Chonophyllum ponderosum*, *Aulopora conferta*, *Stromatopora*

Wortheni, *Fistulipora*, *Atrypa reticularis*, *Pentamerus costatus*, *Streptorhynchus*, *Strophodonta concava*, *Strophodonta naerea*, *Productella navicella*, *Cyrtina Hamiltonensis*, *Spirifer granuliferous*, *Spirifer mucronatus*, *Lucina elliptica*, several casts of *Gasteropods*, and dermatic plates of fishes. A continuation of the same range of rock exposures of the lower division of the Hamilton group is seen on Rainy River, 4 miles from its entrance into Black Lake (Sheboygan Lake), and in the rock bluffs facing Black Lake in Town. 35, R. 2, east, Sect. 7. In both localities, from 30 to 40 feet of strata are exposed. Highest are light-colored limestones, with *Stromatopora* and *Cyathophyllum profundum*, 20 feet in thickness, and somewhat variable in the structure of the single beds. Below these are about 12 feet of calcareous shales full of well-preserved fossils, viz.: *Cyathophyllum profundum*, *Cyathophyllum Houghtoni*, *Cyathophyllum* resembling *C. cornicula*, *Cystiphyllum*, *Americanum*, *Favosites digitatus*, *Favosites Hamiltonensis*, *Zaphrentis*, *Syringopora nobilis*, *Fistulipora*, *Chætetes* and other *Bryozoa*, *Atrypa reticularis*, *Spirigera concentrica*, *Strophodonta demissa*, *Strophodonta concava*, *Spirifer zigzag*, *Spirifer granuliferous*, and fragments of *Prætus*. Lowest are hard, smooth-bedded limestone strata containing few fossils.

Westward from Black Lake, the environs of Mullett Lake and Burt Lake, and all the district north of them, up to the Straits of Mackinac, are deeply covered with drift deposits, with the exception of the foot of the promontory at McGulpin's Point, which, as we have seen before, presents the upper strata of the Helderberg group. Much the larger portion of this district is covered by hard-wood timber and has a rich soil, which has attracted a good many settlers, and amply rewarded the labor bestowed on it. North of Burt Lake and in the vicinity of Turtle Lake, the land is sandy and poor, covered by pine forests, but toward Little Traverse Bay it becomes much better again. The soil in the vicinity of Sheboygan is a heavy but fertile clay. The clay of the drift formation furnishes an excellent material for brick manufacture. The north shore of Little Traverse Bay has no rock exposures. High drift bluffs ascend from the lake, and terrace by terrace the land rises into a plateau of about 250 feet elevation, which extends from the bay up to Cross village.

The south shore of the bay ascends likewise in terrace form,

and the hilltops are composed of drift, but the lower levels along the shore are formed by an almost uninterrupted string of rock exposures, from the head of the bay clear round to Big Traverse Bay, where the last beds of the Hamilton group dip under the black shale at the village of Norwood, in the south corner of Town. 32, Range 9, west. The Hamilton group, as developed on the west shore, is chiefly a limestone formation, but its rock character differs in many respects from the Thunder Bay series. The first outcrops at the head of the bay are found about a mile and a half east from the mouth of Bear Creek, which enters the bay at the foot of the newly built village of Petosky, the present terminus of the Lansing and Saginaw Railroad. Below the railroad depot, vertical rock bluffs of 45 feet elevation face the bay; eastward the bluffs become lower, and finally disappear altogether, giving place to a sand and gravel beach which lines the east end of the bay.

The lowest strata of these bluffs are seen on its eastern end, a blue, argillaceous, hard lime rock cropping out at a level with the water-line. The higher beds have almost the same lithological character, being light drab-colored, porous dolomites, with a dull, earthy fracture. The lower strata are very even-bedded, of finely laminated structure; they contain numerous band-like, compressed, carbonaceous, vegetable stems, similar to *Psilophyton*, and bones of fishes; the casts of small bivalve shells, or branching forms of *Favosites* also cover the surface of some ledges, but generally fossils are rare in these lower beds. The upper strata forming the vertical part of the bluffs are not always so regularly stratified; by weathering, the seams of the bedding become obliterated on the surface of the exposed walls, which sometimes appear to be one solid mass. By digging into them, however, the stratification becomes clearly observable. Some parts of the rock are mottled with darker, more compact blotches than the rest of the substance, which in a dry state rapidly absorb water. These blotches seem to be portions of the rock unaltered from their original condition, while the lighter-colored surrounding mass has been leached out by percolating waters, which dissolved the sparry calcareous cement, whereby the fine crystals of the less soluble dolomite spar were held together, leaving the latter a soft, porous skeleton.

Fossils are very abundant in these upper layers, but are not

equally distributed in the horizontal extension of a bed. We may, in one part, for a distance of many yards, scarcely see a fossil imbedded, when suddenly the same stratum becomes so completely crowded with them that the whole rock mass is a compact agglomeration of fossils, leaving no room for any inorganic limestone particles between. It is *Stromatopora pustulifera* in particular which is so abundant; it grows in strumose, globular masses, often several feet in diameter, tightly crowded together, and sparingly intermingled with other fossils. About 8 or 10 feet above this seam of *Stromatopora pustulifera*, another band follows, which is equally rich in a different species of *Stromatopora*, *Stromatopora cespitosa*, a form of similar structure to the first, but growing in clusters of ramified stems, or in more massive, globose form, and with much larger pustules, and always with well-preserved tissue fibres, which in *Stromatopora pustulifera* are nearly always obscure. The massive forms of *Str. cespitosa* resemble *Stromatopora monticulifera*, but I do not believe them to be identical. Associated with the *Stromatoporas*, a number of other fossils are found in this locality, viz.: *Favosites Hamiltonensis*, *Favosites digitatus*, *Cyathophyllum juvenis*, *Cystiphyllum Americanum*, *Diphyphyllum rectiseptatum*, *Atrypa reticularis*, *Spirigera concentrica*, *Terebratula Linklaeni*, *Pentamerus papilionensis*, *Spirifer fimbriatus*, *Strophodonta erratica*, *Conocardium* (a small form), *Pleurotomaria cavumbilicata*, *Phacops*, *Gomphoceras*, *Orthoceras*, etc. A few years since, on the shore in front of the rock bluffs of Petosky, lime-kilns were built, which at the time of my visit were not so far finished as to be in working order; but the experiments made with the rock on a small scale proved it to be well adapted for the purpose. As a building-stone it has not much value; it does not sufficiently resist atmospheric influences.

Prof. A. Winchell considers the position of these beds as lowest in the rock series of Little Traverse Bay, but from my own observation I am inclined to consider them as representing the upper part of the series, and as equivalent with other strata which by Winchell have been designated as buff magnesian limestone. The rock bluffs just described are interrupted at the location of Petosky village, and replaced by a drift terrace. A quarter of a mile southwestward, close to the railroad bridge across Bear Creek, a few ledges of the same rock seen in the

bluffs are uncovered in the ditches of the road bed, and descending at this point to Ingall's mill, situated about 40 feet lower, we find, next under these ledges, hard, bluish-colored limestones containing *Stromatopora monticulifera*, *Stromatopora Wortheni*, and *Cyathophyllum profundum*. At Porter's old mill site, below the limestones, 6 or 8 feet of blue shales come out in the bed of the creek, filled with specimens of *Cyathophyllum profundum*, *Favosites Hamiltonensis*, *Atrypa reticularis*, *Strophodonta erratica*, etc. Then follow limestones again, which form the bed of the creek downward to the foot of the race at Ingall's mill, amounting to about 20 feet in the outcrop. They contain nearly the same fossils as the shale beds above. Following the bed of the creek down to its mouth, rock ledges are again several times uncovered, but their exact position with regard to the ledges of the upper part of the section is not seen. The total descent which the creek makes from the top of the railroad bridge to the lake shore is 90 feet, all of which is made up by limestone beds, with the exception of the mentioned seam of shales. About one mile west of the mouth of Bear Creek, an ascending section through the strata can be observed by following the lake shore westward, commencing about at the bottom of the section given above. The lowest ledges seen, partly submerged under water, are hard blue limestones of rugose surface, and interlaminated with seams of black bituminous shale. They contain *Cyathophyllum profundum*, *Stromatopora Wortheni*, *Stromatopora monticulifera*, and *Atrypa reticularis*. A few hundred steps farther, in a low bluff, about 12 feet of the next higher ledges are seen resting on the former; they consist of light-colored, brittle limestones, of fine-grained, conchoidal fracture, interstratified with calcareous shales. In places, the rock beds contain only few fossils, while the same strata may be crowded with them some steps farther on. The most common forms inclosed are *Cyathophyllum profundum*, *Cystiphyllum Americanum*, *Favosites Hamiltonensis*, some *Bryozoa*, *Spirifer pennatus*, *Spirifer mucronatus*, *Cyrtina Hamiltonensis*, *Strophodonta erratica*, *Strophodonta naerea*, *Pentamerus papilionensis*, and *Atrypa reticularis*. The outcrops are then interrupted by a high drift bluff which comes up to the shore; at its foot sometimes one of the ledges of the beds referred to sticks out. On the other side of the drift bluff, which is only a few hundred yards wide,

another outcrop of rocks faces the bay, which are the next higher beds succeeding those last mentioned. The lowest portion of them is a drab-colored, porous dolomite, full of *Stromatopora monticulifera* and *Stromatopora Wortheni*, *Cyathophyllum profundum*, *Favosites Hamiltonensis*, etc. The upper portion is laminated with seams of a black, calcareous, combustible shale, which contain an abundance of *Strophodonta erratica*, ramulets of *Favosites digitatus*, and other fossils. The thickness of this dolomitic series is about 8 or 10 feet. Above it is a stratum of soft blue shale of variable thickness, from 1 to 4 or 5 feet, which contains many finely preserved fossils, such as: *Cyathophyllum profundum* (*Acerularia profunda*), *Cyathophyllum Houghtoni*, *Cyathophyllum Hallii*, *Cystiphyllum Americanum*, *Favosites Hamiltonensis*, *Favosites nitella*, *Aulopora conferta*, *Syringopora*, *Stromatopora plana*, *Stromatopora monticulifera*, *Stromatopora Wortheni*, a great variety of *Bryozoa*, *Atrypa reticularis*, *Spirigera concentrica*, *Spirifer mucronatus*, *Spirifer granuliferous*, *Cyrtina Hamiltonensis*, *Strophodonta erratic*, *Terebratula Linklani*, *Crania Hamiltonia*, *Crania crenistria*, *Crania(?) radicans* Winchell, *Pholidops*, *Phacops bufo*, etc. Above these shales follow drab-colored, porous dolomites similar to the beds at the base of the section, and containing about the same fossils; from 10 to 15 feet of them terminate the outcrops in that locality.

Several outcrops comprising about the same series of strata are found by following the shore westward for two or three miles. About three miles east of Khagashewung Point, the section through the heretofore considered beds is continued into higher strata (the so-called buff magnesian limestone of Winchell), which I believe to be equivalent with the *Stromatopora* beds composing the bluffs of Petosky. The section is as follows: Lowest, partly submerged under the water, are blue, hard limestones full of *Stromatopora*, *Cyathophyllum profundum*, and *Favosites Hamiltonensis*; above them are alternating seams of nodular limestones and of black, combustible shale, crowded with fossils similar to those in the former stratum. Next follow several feet of gray limestones; some beds of them are of very fine grain, like lithographic stone, but brittle; they contain but few fossils; a fossiliferous seam, with *Cyathophyllum profundum*, *Favosites*, and other fossils, overlies them; then come again from 6 to 8 feet of the brittle, smooth-

fracturing limestones, interlaminated with shaly seams, and fossiliferous in nests. The limestone with smooth fracture like lithographic stone contains 98 per cent of carbonate of lime, 1 per cent carbonate of magnesia, and 1 per cent of insoluble silicious matter. Superimposed on these beds are drab-colored, porous dolomites, with *Stromatopora monticulifera*, *Stromatop. Wortheni*, *Cyathophyllum profundum*, *Favosites Hamiltonensis*. The outcrop is at this horizon interrupted; it is the place where the fossiliferous blue shales of the other sections should be found, with the incumbent fossiliferous dolomites. A short distance behind the top of the bluffs which exhibit this section, a second terrace rises, which is composed of dark, drab-colored, crystalline dolomites, identical with those composing the rock bluffs of Khagashewung Point, or with the buff magnesian beds of Prof. Winchell.

Khagashewung Point, for more than a mile's length, is lined with vertical rock bluffs about 15 feet high. The lowest strata exposed along this point are light-colored, smooth-fracturing limestones, interlaminated with thin seams of shale, and with a bed of a crystalline limestone almost entirely composed of Crinoid joints. Fossils are not numerous in them, and are of the usual kinds found in the other outcrops. Above them are some beds of a blue, argillaceo-arenaceous lime rock, containing many specimens of *Cyathophyllum profundum*, *Favosites Hamiltonensis*, *Cystiphyllum Americanum*, and *Atrypa reticularis*. Then follow light-colored limestones with earthy fracture and of thinly laminated structure, linear carbonaceous seams pervading them in the bedding plains. Their thickness is only a few feet, and they resemble the laminated, dolomitic beds at the foot of the Petosky bluffs, inclosing the same fish-bones and a few stems of *Favosites*. The higher part of the Khagashewung cliffs is formed by layers of a porous, crystalline dolomite, of a brownish yellow color, in thick, homogeneous beds, of variable finer or coarser grain. Fossils are generally rare, but in certain seams casts of Brachiopods, or dispersed specimens of *Favosites*, *Cyathophyllum profundum*, etc., are noticed. Other beds are a coarsely crystalline, crinoidal limestone, with many other fractured shells besides the Crinoid joints. *Atrypa*, *Spirifer*, *Cyrtina*, *Strophodonta*, *Rhynchonella*, are the recognizable forms; *Prætus* and *Phacops* are likewise to be found.

The highest beds observed on Khagashewung Point are thin-bedded, light-colored, brittle limestone ledges, lying in a few places on top of the brownish dolomite rock. From the saccharoidal, compact beds of the dolomite can be obtained good-sized blocks, which would answer for building purposes, being of sufficient durability and easily dressed. The position of the outcrops near the lake shore is very favorable for the opening of quarries, and for the transportation of the rock by vessels.

An analysis of this dolomite gives:

Carbonate of lime.....	58 per cent.
“ magnesia.....	38 “
Alumina and iron oxide hydr....	1.5 “
Insoluble residue.....	0.5 “

West of Khagashewung, to the mouth of Pine River, the shore presents numerous other outcrops of the beds below those forming the point, which, however, rarely emerge more than a few feet above the water level. Proceeding from the point westward, we first find the beds containing an abundance of *Stromatopora*, of which, in the dolomites of the cliffs, not a single specimen could be found. Further on, below the *Stromatopora* beds, light-colored, brittle limestones with conchoidal fracture are brought to the surface by the undulations of the strata; in places, these beds are rich in fossils, in others not. *Strophodonta naerea*, *Strophodonta demissa*, *Strophodonta erratica*, *Chonetes Emmetensis*, *Spirifer pennatus*, *Spirifer mucronatus*, *Cyrtina Hamiltonensis*, *Terebratula Linklæni*, *Atrypa reticularis*, *Spirigera concentrica*, *Pentamerus papilionensis*, several forms of Bryozoa and corals, and some rare forms of Trilobites have been collected from them. In a few spots the still lower beds of hard blue limestone with *Cyathophyllum profundum* and *Favosites Hamiltonensis*, in alternation with black shale seams, are noticed. The blue fossiliferous shale beds (acervularia beds of Winchell) just reach the surface in the lake bottom half a mile west from the dock of Charlevoix. On the point, 3 miles west from the dock, some larger outcrops border the lake shore in low cliffs, elevated 5 or 6 feet above water-mark. Lowest is the blue, hard lime rock with *Cyathophyllum profundum*, *Favosites Hamiltonensis*, *Atrypa reticularis*, etc., and above are light-colored, smooth-fracturing, brittle limestones with seams of shale, which are

in this locality very fossiliferous. There are: *Spirifer pennatus*, *Chonetes Emmetensis*, *Strophodonta nacrea*, and all the other fossils enumerated previously as existing in equivalent beds exposed west of Khagashewung Point and east of Charlevoix. From the frequent occurrence of a species of *Stictopora* in these beds, Prof. Winchell termed them Bryozoa beds. The shore line has here a north and south direction. Three miles south of the locality just treated of, some other exposures are found, and at about five miles from it we see the Hamilton group for the last time, exposed near Norwood.

The beds at Norwood are higher than any of those in the sections yet described. In the bluffs which have about 12 feet elevation above the water level, we can observe about 25 feet of strata brought to the surface by an undulation. Lowest are dark, bluish gray, rough-fracturing limestones, with intermediate seams of shale, inclosing many specimens of *Favosites*. Above are thinly bedded, hard limestones, alternating with ledges or nodular seams of flint limestone, and flint beds of a laminated, banded structure; their thickness is about 8 feet. Some thicker ledges of limestone follow, having a smooth, conchoidal fracture. Next higher are gray, compact limestones with many fossils: *Stromatopora* similar to *Str. Wortheni*, *Caunopora* (thin stems with a ventral canal, of thickness from a straw to a goose-quill), *Favosites Hamiltonensis*, *Favosites digitatus*, *Cyathophyllum Houghtoni*, *Cyathophyllum geniculatum*, *Aulopora*, *Strophodonta erratica*, *Pentamerus* (a large, globose form), and several others. The highest strata are coarse-grained, crystalline dolomites, of light gray color, some 4 or 5 feet in thickness, which contain *Stromatopora* and other fossils in very imperfect preservation, while numerous druse cavities, once the beds of fossils, are lined with spar crystals and partially filled with rock oil.

A chemical analysis of the dolomite gave:

Carbonate of lime.....	56	per cent.
“ magnesia.....	39	“
Alumina and iron.....	2.8	“
Insoluble residue.....	0.4	“

In immediate superposition on the dolomite beds, the black shale

formation, the equivalent of the Genesee shales of New York, is deposited.

In the drift composing the lake terraces on the south shore of Little Traverse Bay, large numbers of slabs of a tough black shale are intermingled. The shale is easily ignited, burning with a bright flame, and is by many persons taken for coal, or as an indication of the existence of coal in that district. The shale contains a great abundance of well-preserved fossils of the Hamilton group, in calcified condition; fan-like expansions of *Fenestella*, *Polypora*, each genus represented by various species, *Stictopora*, *Fistulipora*, and other Bryozoa are in great perfection; several forms of *Stromatopora*, incrusting other fossils, or in laminar expansions, *Cyathophyllum Houghtoni*, *Cyathophyllum profundum*, *Cystiphyllum Americanum*, *Favosites Hamiltonensis*, *Favosites digitatus*, *Aulopora*, *Syringopora*, *Tentaculites*, *Conocardium*, *Atrypa reticularis*, *Spirigera concentrica*, *Pentamerus papilionensis*, *Terebratula Linklæni*, *Strophodonta erratica*, *Strophodonta nacrea*, *Phacops bufo*, and *Prætus crassimarginatus* have been noticed.

During the description of the Hamilton series of Little Traverse Bay, several seams of similar black shales interlaminated with the other strata have been pointed out, but in none of the outcrops were more than a few inches of such shale beds noticed, while the slabs found in the drift seem to have been parts of thick ledges. It is most likely the lower seam of the two, exposed below the horizon of the blue fossiliferous shales (acervularia shales), from which the drift specimens originate.

The thickness of the rock series of the Hamilton group exposed along the shore of Little Traverse Bay is not accurately determinable. No continued sections through more than 50 feet of strata are seen in one place, and the rock character of beds in their horizontal extension is subject to so many variations, that no sure conclusion on the identity of rock ledges in distant outcrops can be based on it. The palæontological features of the strata are also not strongly marked. Although certain forms of fossils are generally associated in certain layers, the majority of fossils characteristic of the Hamilton group are so equally distributed throughout its whole thickness, that all of them can be found in almost any position at the base or in the upper horizons. There are layers filled with the same species of *Stromatopora* found in repeated

superposition, which can not be distinguished if found in different localities, unless the sections exhibit the strata fully denuded so that their relative positions to other strata and to one another may be observed. The strata have retained their original position, but their horizontality is not perfect; they rise and sink in undulations, adapting themselves to the surface on which they were deposited. By means of these undulations, lower or higher strata come repeatedly to an exposure, or disappear again, if we follow the horizontal level of the shore line of the bay, which approximately runs parallel with the strike of the formation, and would consequently always present the same rock beds if the strata remained perfectly horizontal. I estimate the thickness of the exposed rock beds at from 125 to 130 feet. In the bluffs near Bear Creek, where we see the upper part of the series, 45 feet of rock beds are exposed in direct, vertical superposition, and by the slight rise of the strata toward the east, about 10 feet more of lower beds come to the surface. A continuation of this section downward is offered on Bear Creek, where we see, near the railroad bridge, some beds representing the rock of the bluffs, without being able to ascertain exactly which part of them. At all events, in the interval from the bridge to Porter's mill, about 15 feet of strata, lower than any in the bluffs, can be seen; then follow 6 or 8 feet of blue shale, and below are again limestones amounting to about 20 feet in thickness, reaching the base of Ingall's mill-race. Lower down the section can not be followed, but we find the same strata seen at Ingall's mill on the shore exposures west from the mouth of the river, which beds, all added, make a series of something over 100 feet in thickness. If we add to them the 25 feet of strata seen in the exposures of Norwood, which are higher than any of the others, we have an estimated total thickness of 125 feet, which estimate may be perhaps as little lower than the actual measurement would give. The direct superposition of the rock series of the Norwood exposures on the dolomites of Bear Creek bluffs or of Khagashewung Point is not seen; an interval of several miles separates the outcrops, which may hide some intervening ledges under its drift cover.

The Hamilton exposures on the east and west side of the peninsula exhibit not enough of lithological similarity to allow an identification of certain beds or groups of beds on the two sides; also

the palæontological features of certain horizons in the group are not well enough marked to enable us to make such identification. The fauna of the Hamilton area remained uniformly the same from the beginning to its end, as I have intimated once before in a previous page. We find differences in the association of fossils in various beds, but these are rather induced by local conditions favoring the development of certain forms and uncongenial to others, than by a change in the character of the fauna, whose standard representatives always make their appearance again, if they have been missing for a while in some of the layers.

My estimate of the thickness of the Hamilton series in Thunder Bay region, about 600 feet, is based on the results of the artesian borings heretofore given, which I will briefly recapitulate. I stated that the strata of Partridge Point and the next lower *Stromatopora* beds of Stony Point, with the intercalated fossiliferous shale beds, amount in the aggregate to at least one hundred feet, and that their superposition on the beds in which the artesian boring begins is directly observable. The drilling went first through 400 feet of limestone strata of not accurately specialized character in the records kept of the boring, and below them, through a shale bed of 80 feet in thickness, containing a great variety of characteristic Hamilton fossils, proving positively a thickness of 580 feet for the Hamilton series at this spot. This shale deposit I suppose to be identical with the blue shales penetrated to a depth of 50 feet under the limestone bluffs in Town. 32, R. 9, Sect. 6, by the exploring shaft of the attempted marble quarry. The rock series composing Middle Island, Presque Isle, and other localities, underlies the blue shales, and is in this report considered a part of the Hamilton group, and is not overestimated by allowing for it a thickness of 60 or 70 feet, which would give to the Hamilton series of Thunder Bay region a total thickness of 650 feet. According to the boring record, nearly 500 feet of lower strata in the drill-hole, down to the salt-rock deposits of the Onondaga group, should be claimed as representatives of the Helderberg group.

CHAPTER VII.

BLACK SHALES OF OHIO—GENESEE SHALES OF NEW-YORK.

By this name a series of black bituminous shales are designated, which in the States of Ohio and Indiana are found in immediate superposition on the limestones of the Helderberg series, and which in the north part of the Michigan peninsula rest on the beds of the Hamilton group, as do the Genesee shales of New York, which are generally considered the equivalent of the black shale.

By their lithological character, the black shales approach the shale and sand-rock beds of the Waverly group next succeeding them.

A change of the ocean bed, causing a total change in the [material of the deposits, had already begun while the black shales were forming; but the fossils inclosed within the shales, and in a series of shale and sandstone beds above them, in the so-called Portage and Chemung group, exhibit a yet greater affinity to the fauna of the subjacent limestone formation than to the fauna of the incumbent, lithologically nearer related beds of the subcarboniferous shale and sandstone formation. This is the regular order, in the succession of strata, within the State of New York, and as in the States of Ohio and Michigan a similar order in the character of the rock beds resting on the black shales was observed, they were naturally supposed to be the equivalents of the Portage and Chemung group.

By the study of the fauna found in the upper part of this arenaceous shale formation above the black shales in Michigan, Prof. A. Winchell came to the conclusion that those of the Chemung and Portage groups had a different character from the complex of fossils found in the supposed equivalent Michigan strata, which latter he declared emphatically to be of carboniferous type. He selected for this upper arenaceous rock series the name of

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Marshall group, and, subsequently, from studying the Waverly group of Ohio, he recognized the identity of his Marshall group with the Waverly group.

Between these fossiliferous Marshall sandstones and the black shales, in Michigan, nearly one thousand feet of rock beds of prevalently shaly, partially sandy, and sometimes calcareous character, are intercalated, which are claimed, by Professor Winchell as representatives of the Devonian fauna, with the same emphasis as he asserts the carboniferous character of the other. He combines them with the black shales into a separate group, which he names *Huron Shales*. We will subsequently have occasion to learn that the shales, above the black shale and below the Marshall sandstones of Michigan, inclose absolutely the same fossils as are found in the Cuyahoga shales of the Ohio geologists, and which by Winchell himself are considered as of a marked carboniferous faunal type, and as intimately connected with the fossiliferous sandstones of Marshall. The differences in the faunas are certainly not existing in this special case, and viewing the question from a general standpoint, the contrast between the fauna of the Chemung group and the fauna of the Waverly group is by no means so striking, that for the one a positively Devonian type can be claimed, and for the other a carboniferous.

The group of the *Huron Shales*, according to this view, shrinks back to the small basal portion of them, the black shales, which have been long known under this name, and are likely to continue to bear it for some time to come.

Another objection to the adoption of this name is its similarity to the name *Huron group*, in well-established use for the lower metamorphic rock series of the Lake Superior district, which would unavoidably cause much confusion.

A belt of the black shale formation intersects the north part of the peninsula. Its northern limits have already been delineated in describing the southern limits of the Hamilton group, extending in an arch from Partridge Point, in Thunder Bay, to Norwood, in Big Traverse Bay. The southern extension of this belt is all hidden under drift deposits. Approximately, the slate belt is supposed to extend on the west side to the neighborhood of Frankfort, in the central part of the peninsula to Otsego Lake, and

on the east side to touch the shore line some miles south of Harrisville.

In unweathered condition the black shale is hard and slate-like, of very even bedding, of finely laminated structure, fissible in thin leaves, which have some degree of elastic flexibility. Its color is usually a perfect black. In weathered condition, it becomes grayish, and splits open into paper-thin, laminar fragments; exposed to the fire, it burns with a flame, but it is rarely rich enough in bitumen to sustain the heat for its own combustion. Seams of iron pyrites, or nodular concretions of it, and fine granular crystals are invariably found pervading the beds; also subordinate seams of lime rock, which frequently have cone-in-cone structure, are found interstratified; but, most remarkable, are large, spherical, calcareous concretions, which not unfrequently are of almost mathematically true globe form, and sometimes of a diameter of from 5 to 6 feet—usually, however, of from 1 to 2 feet. The concretions must have formed while the shale mass was soft and bulky; by subsequent pressure of the incumbent sediments, the shale diminished its bulk, and was bent around the hard globes which did not yield to the pressure.

The concretions are sometimes formed of a granular lime-rock mass, and often inclose organic remains, as bones of fishes or pieces of wood; in other cases they have a sparry structure, with elongated fibrous crystals radiating in all directions from the centre to the periphery. The spar crystals are usually carbonate of lime darkened by bitumen, but in some localities it is a sparry carbonate of iron which composes the concretions. The analysis of concretions of granular limestone structure, from the shales of Norwood, gave:

Carbonate of lime.....	89 per cent.
“ “ magnesia.....	2 “
Insoluble residue, bituminous and silicious,	7.5 “

On the surface of some slabs of cone-in-cone structure interlaminated with the black shales, I found at Norwood large dermatic plates of *Aspidichthys* and specimens of a *Lingula*: fragments of wood (*Dadoxylon*) are likewise of common occurrence in that and other localities.

North of Norwood, the black shales form bluffs 10 or 15 feet in

height, which, rising a short distance back from the shore line, repose on the ledges of the dolomite beds of the Hamilton group described in previous pages. South of Norwood village, the shales come close up to the shore in vertical bluffs of similar height; the total thickness of strata seen in the bluffs, and in the hillsides rising behind them, is not over 35 or 40 feet. South of Norwood, the black shales are overlaid by light greenish, arenaceous shales which have frequent outcrops along the shore line for 9 or 10 miles southward, but this is all that can be seen of them; back from the shore, every thing is covered by drift. Fossils were not discovered in the light shales.

The black shales are exposed northeast of Norwood on Pine Lake, and near Bear Creek the railroad to Petosky has laid open several sections through them, showing sparry, globular concretions inclosed; pieces of *Dadoxylon* are likewise found there.

In the ravines of the creeks leading into Mullett Lake and Black Lake, the black shales are frequently exposed. In Thunder Bay district, outcrops are along the south branches of Thunder Bay River. In Town. 31, R. 7, Sect. 19, the large globular concretions of the shale formation are composed of carbonate of iron, and weathered specimens transform on the surface into a bright-colored, reddish ochre. A number of years ago some parties opened exploring ditches in search of that mineral paint, but abandoned the project when they found nothing but unaltered concretions of carbonate of iron below the outer superficial crust which contained the decomposed ochraceous masses. On Squaw Point, and on Sulphur Island near Thunder Bay, the black shales are well exposed; further south toward Harrisville, they are mostly covered by drift, and only here and there in a ravine can an outcrop be seen. On the opposite side of Lake Huron, at Kettle Point, in Canada, the black shales are splendidly exposed, where their superposition on fossiliferous limestones similar to those of Norwood can be seen. In this locality, the spherical concretions in the shale are larger and more abundant than I have seen them elsewhere.

In the south part of the State, the black shales are not well exposed; the drift, however, contains large quantities of the shale intermingled in the belt which is supposed to be underlaid by the shales, and in all the deep artesian borings the black shales have been found.

At Ann Arbor the drill hole sunk in the Court-House Square struck the black shales at a depth of 525 feet below the surface, their thickness there being 85 feet. In the south part of Washtenaw County, and in the northwestern corner of Monroe County, in well borings, the black shales are found usually not more than about 100 feet below the surface. Frequently a stream of hydrocarburated gas escapes from the drill holes after the black shales have been reached.

On the farm of Mr. Kinear, on Saline River, near Milan Village, a well was bored with an auger through 106 feet of drift deposits, partly clay, partly gravel. When the auger came upon the black shales, suddenly, with a sort of explosion, hydrocarburated gas escaped from the opening, carrying with it mud and water to a height of 30 feet above the surface. I visited the spot three weeks after, and found the gas still escaping in a continuous stream, which, at the opening of an inch iron pipe, burned with a bright, illuminating flame 8 inches high. On several other farms in the vicinity, similar gas wells were accidentally found while boring for water.

CHAPTER VIII.

WAVERLY GROUP.

THE light-colored, greenish, arenaceous shales, on top of the black shale exposed along the shore of Big Traverse Bay, may possibly be an equivalent of the Erie shales of the Ohio geologists, but no fossils have been found by which this question can be determined, and no outcrops of equivalent beds are seen in any other part of the State. The shales in the southern part of the peninsula, which were considered by Winchell as a part of his Huron shales, occupy a higher position, and must be identified with the Waverly group.

The Waverly group is the most important rock series on the lower peninsula—not only because it forms the surface rock over the greatest part of it, but for its economical value. It is the repository of the Michigan salt brine, and furnishes almost the only good building-stone we have on the peninsula. The Huron grindstones, famous for their excellence, are likewise taken from this group. The Michigan salt group of Prof. Winchell is a series of rock beds above the Waverly group, which I shall consider in connection with the subcarboniferous limestones; they contain large quantities of gypsum, but no salt brines of practical value.

The Waverly group forms, underneath the drift, the surface rock over half the extent of the peninsula, but its natural outcrops are very limited, either horizontally or vertically. The upper division of the group is much better exposed than the lower, which in part is only known through the results of deep borings, information of a very unsatisfactory kind. The vicinity of Port Austin and the shore belt east and west from it offer a very good field for the study of the upper part.

From the west end of the village, to Flat Rock Point, the shore is nearly all the way lined by low cliffs of a coarse-grained, soft, whitish sand rock, in thick, massive beds. The cliffs have an elevation of from 8 to 10 feet above the water-level, and on the rising ground back from the shore, additional ledges of a similar sand