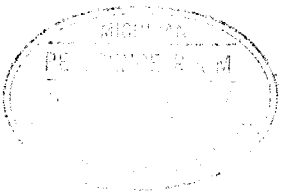
G E O L O G Y
of
C H I P P E W A C O U N T Y
M I C H I G A N

By Walter A. Ver Wiebe March 21, 1927



G E O L O G Y

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C H I P P E W A C O U N T Y

M I C H I G A N

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GEOLOGY OF CHIPPEWA COUNTY MICHIGAN

Part 1. Stratigraphy

The data presented in the following pages are based upon materila collected and work done during the summer of 1926. The field work was done as part of an inventory of the natural resources of Chippewa County made by the Land Economic Survey of Michigan.

The earliest comprehensive work on the geological formations in this county was done by Carl Rominger. He published his findings in volume I of the Geological Survey of Michigan in 1873. It appears from a careful reading of this report that Rominger visited practically every one of the isolated outcrops on the mainland portion of the county, and a good many of those located on the islands which belong to the county. He studied the shore line of Drummond Island, but does not record any observations made in the interior portion of the island. This seems unfortunate as the stratigraphic section from the top of the Engadine, through the Niagara and the Cataract, down to and well into the Richmond, is singularly well displayed almost layer for layer. With this section well in mind he would have been able to trace the various units of the section with more ease and accuracy. Thus he would have been able to avoid confusing the Engadine with the middle Manistique on p. 37 and 38 of the volume cited.

Subsequently R. A. Smith made some studies on the limestones of Chippewa County (24). He described the important outcrops on the mainland and also de-

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(24) Numbers in brackets refer to bibliography at end of paper)

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scribed several of the quarries on Drummond Island. He also discovered the error in Rominger's correlation and corrected it. Many of the names of formations as used in this report were first suggested by Smith.

A good deal of geological work of a fragmentary nature had been done on Chippewa County before Rominger did his work. Robert Bell (1) described the

formations which appear on Drummond Island in a general way. His work will be referred to again. Much valuable information about the areal geology of the county was gathered and published by Owen, Jackson (10, 11, 12, 13), Foster (7), Whitney (20), and Locke (14). In the following pages all these data will be reviewed and evaluated.

LAKE SUPERIOR SANDSTONE

The oldest Paleozoic formation exposed in Chippewa County is a sandstone of variable thickness and character. At one time it was the subject of a great controversy in which European as well as American geologists were involved. Even now the age of this formation is not satisfactorily defined. Probably the first attempt to delimit its stratigraphic position was made by Bayfield, who stated in 1828 that it rests on the granite. This seems to imply that he regarded it as the basal member of the sedimentary (Paleozoic) series. Dr. Owen in his report on the Chippewa district, published in 1848, thought it was younger than the Carboniferous. Whitney in his earlier work on the Keweenaw peninsula suggested that it might be younger than the adjacent limestone. This hint was seized upon by Marcou (16) who published a very dogmatic summary of the facts involved in the year 1851. In this he states that he made two trips to northern Michigan primarily with the object of reaching a decision as to the age of the sandstone. As a result of these trips he is able to agree with Jackson who believes that the sandstone is Triassic! It so happens that Jackson had never seen the outcrop where Whitney found evidence of a supposedly older limestone. Furthermore, the fact that the sandstone was younger than a Silurian limestone did not prove it to be of Triassic age. Finally, Whitney as well as Jackson had published reports in 1848 and '49 in which they indicated pretty clearly that they then regarded the sandstone as of Cambrian age.

Marcou's article called forth a reply from Foster in 1851 (7) and from Whitney in 1860 (20). In the latter the whole question is taken up from all

angles and Mr. Marcou is arraigned in a somewhat scathing and merciless fashion. The reader of this reply is not left in doubt as to the position of Mr. Whitney and his associates, Jackson, Locke, and Foster. They believe that the sandstone is of Potsdam age. (See Locke 14, p. 197). Owen, in his report of a "Geological Survey of Wisconsin, Minnesota, and Iowa" is also quoted as saying that "this formation is at least as low in the series as the Potsdam sandstone." He also quotes Dr. Houghton as concluding that "all of the sandstone east of Keweenaw Bay passes under a limestone equivalent to the Trenton of New York, while the conglomerate and sandstone west of Keweenaw Point is probably contemporaneous with the New Red". This remark is probably the beginning of a later phase of the controversy in which still others were of the opinion that the western sandstone might be of a different age from the eastern sandstone. We get a hint of this in an article by N. H. Winchell (22) who discusses recent conclusions of Irving and Chamberlain. The latter say that the Keweenawan series is older than the eastern sandstone. Winchell believes their arguments inconclusive and that the question is left more open than ever.

The age of the sandstone can only be determined when undoubted fossils in a good state of preservation and of critical value are found. In the absence of these its age may only be inferred from the stratigraphic position. Fossils from the Lake Superior sandstone were reported by a number of geologists. Locke, for example, reports finding a plant which he calls Fucoides duplex (14, p. 192). This fossil was later described by Hall who named it Paleophycus. (See 7) Foster also mentions a Lingula found by Shepard. Whitney (20) tells us that Shepard found this fossil in situ on Iroquois Point, that he gave the specimens to Dr. Houghton, who in turn gave them to Mr. Hall, by whom they were described and figured. Iroquois Point is located in section 12, T.47N., R.3W., in Chippewa Co. At present there is no outcrop of sandstone to be seen. It is doubtful whether Mr. Shepherd found it in situ as Whitney reports.

Another fossil reported from the sandstone is a Dikellocephalus found in

loose arenaceous rock fragments by Mr. Desor in the bed of the Menominee River. Rominger (18) quotes Hall as saying that the rock fragment in which the trilobite was found is calcareous. This makes it appear that it may not have come from the sandstone as it is nowhere calcareous in the outcrop. At another place Rominger states that the rock is the brecciated limestone of the Calciferous. The writer has studied the outcrops in the Menominee River and has been unable to find any fossils in the sandstone. From the above considerations it develops that no fossils had been found in situ up to the time the present survey of Chippewa County was started. The writer feels, therefore, that he was particularly fortunate in 1926 when he came upon some fossils in the Lake Superior sandstone [at Sault Point]. These fossils were sent to Dr. Ulrich for identification. [He states that they belong to the genus 'Ophileta' and that probably three species are represented. In his opinion the rocks are of Canadian or Ozarkian age. In this connection see Rominger (18 p.74) regarding Ophileta levata in conglomeritic limestone blocks]

Outcrops in Chippewa County:- In Chippewa County outcrops of the Lake Superior sandstone are not numerous. The most extensive outcrops appear in the Tahquamenon River, about 14 miles above its mouth. The rock is a nearly pure siliceous sandstone in thin beds, and with considerable crossbedding. About fifty feet of rock is exposed in the rapids. In the upper falls of the Tahquamenon another sixty or seventy feet of sandstone appears. This section is more variable, showing some soft sandstone, some coarse layers, some shaly layers, and some deep red shale layers.

Another outcrop of considerable extent is the well known and much discussed outcrop in the rapids of the St. Mary's River at Sault Ste. Marie. The rapids have been largely eliminated by a number of locks, but the sandstone is still to be seen on the American side below the first lock. An irregular thickness of mottled sandstone crops out in patches along a distance of several hundred yards. The sandstone is partly red, but has a sprinkling of white in layers, in spots,

and in small dots. It is very much cross-bedded. No fossils were seen here, although a search was carried on for several days.

The most interesting outcrop in the county appears along the shore line of Lake Superior at Sault Point. The outcrop begins near the northeast corner of section 30, T.47N., R4W., and extends almost to the north line of section 19. There is a total thickness of about fifteen feet exposed in this distance. At the base the sandstone is soft, greenish, shaly, and thin-bedded. One foot above the base Ophileta occurs in considerable numbers in a soft, friable sandy matrix. Above this level the sandstone is harder, but irregularly bedded. The best way to reach this locality is to set out from the Dollar Settlement. A passable sand road leads along the shore to Pendell's Creek. From there a trail leads north to the lake, whence easy travelling will take one to the outcrop.

In the glacial drift of Chippewa County, boulders of the sandstone appear frequently. On practically all the moraines one or more pieces were noted. This indicates a wide belt of outcrop for the formation as shown on the areal geology map that accompanies this report.

The thickness of the sandstone varies greatly, because it fills the depressions in a late Algonkian land surface, which appears to have been quite rugged. In the well drilled by A. W. Palmer for the American Alkali Co. near Sailor's Encampment T.45N., R.2E. (section 36?) the sandstone is 194 feet thick. The upper 161 feet is white and the lower thirty-three feet red. In the Pickford well the thickness is uncertain; it may be 800 feet thick, but is probably much less.

ORDOVICIAN ROCKS

The rocks which can be assigned to the Ordovician system were found and described at an early date. In Jackson's report of 1847 (11) Locke describes the outcrops in the St. Mary's River at the lower Neebish rapids. Robert Bell in 1869 (1) states on p. 111 that "the Trenton strikes and enters Michigan at Neebish Island", also on page 113 that "On the north side of Drummond Island the

upper beds of the system are exposed which as usual are of a massive calcareous nature and form a strip about seven miles long and two broad". Rominger in his report of 1873 (18) describes the outcrops quite completely on pages 54 to 79. He finds a thickness of 50-60 feet of Hudson River shale on the north shore of Drummond Island and lists fossils from these beds on page 55. The Waiska River outcrop (Which he calls Carp River) is referred to on page 56. The rocks in this exposure he calls Trenton. He mentions the locality again on page 63. On page 56 he also says a few words about the outcrops in the St. Mary's River at Neebish Island. The fossils he finds at this locality are listed on page 64. On the same page he describes the very good rock succession on Encampment d'Ours Island. In his excellent summary of the Paleozoic rocks of the upper peninsula, Rominger describes a number of localities where he found rocks of Calciferous age. His best locality is the Grand Rapids of the Menominee River. Since there is now a power plant at this point and the rocks are no longer to be seen, it is necessary to rely on his description. He traced similar rocks across the upper peninsula toward the east and found good outcrops in the upper reaches of the Escanaba River and along the Au Train River. In Chippewa County he differentiated the lower part of the section at Neebish Island as belonging to the Calciferous.

Black River (?) of Chippewa County:- The author of this paper is inclined to believe that the formations of the lower part of the Ordovician will be found to differ somewhat from west to east across the upper peninsula. He has studied the formations in Menominee County as well as in Chippewa County and believes that the typical part of the Calciferous called Hermansville in Menominee County, is missing farther east. Few fossils are to be found in the Hermansville, but its lithologic character is very distinctive. It is a coarse, sugary, friable, porous dolomite, with greenish cavity filling at many places. Such a rock is not to be found in Chippewa County. Not only are there no outcrops of such a rock, but also no trace of such a rock is to be found in the rather numerous drift

boulders. On account of the paucity of outcrops in the county the author took special pains to note the boulders in the drift. Every marginal moraine was studied with this object in view. The old lake beaches from an elevation of 880 feet which is one of the highest Algonquin lake levels down to 615 which is the Algoma level, were also examined closely.

Instead of the Hermansville, a different kind of rock appears below the Trenton. It is a fairly hard dolomite, of dark grey color, which breaks into large rectangular pieces and which can readily be distinguished from the typical Trenton. This rock is to be seen on the outcrop in three places only. It is more probably the equivalent of the Black River than the Calciferous.

Waiska River Outcrop:- The most remarkable outcrop is in the Waiska River southwest of the village of Brimley in the northwest ¼ of section 29, T.46N., R2W. The river runs over rapids which begin close to the section line between 29 and 30, and extend toward the east for about half a mile. Toward the eastern end of the rapids the solid ledges of limestone may be seen, but farther west they are obscured by alluvial material and fallen blocks. The two or three feet thus exposed may be described as very massive and hard limestone. Ir resembles the lower part of Rominger's Trenton, as revealed in the Menominee River, closer than any rock seen in the upper peninsula. Some fossils are present. The river has cut down through the Algonquin lake clay nearly fifty feet along the rapids. At one point the river has bared an ancient wave cut cliff. In this cliff additional layers of the Black River may be seen, but in a peculiarly jumbled condition. The cliff looks as though it had been undercut by waves and large blocks of the overhanging portion had tumbled down. In the upper part of the cliff the typical Trenton limestone crops out.

Neebish Island Outcrops:- The same kind of rock crops out on both sides of Neebish Island. Along the western side of this island a narrow channel has been blasted out for the ships that pass down the St. Mary's River. Great piles

of rock thirty to forty feet high line the channel for a distance of over one quarter mile on both sides of the channel in sections 20, 28 & 29 of T.45N., R.2E. This is hard, dark, massive and coarsely crystalline limestone. Walls have been built in the channel with blocks of the same limestone. It breaks up into large rectangular blocks ideal for building such a wall. In the wall the most common fossil is a large Orthoceras, five to six inches in diameter and four feet long. Other fossils are not at all numerous, but in certain places some black, shaly limestone blocks are common. These are usually well filled with a large variety of invertebrates. On the other side of Neebish Island, there is another outcrop of the same rock. It forms the floor of a small stream of water which separated Neebish Island from Sailor's Encampment Island in times of higher water. The outcrops are in section 36, T.45N., R.2E., and 31, T.45N., R.3E. Only the flat surface of a hard, buff crystalline limestone is to be seen at present. Farther east there are some low cliffs which probably are rock cliffs with a very thin cover of glacial material. Numerous blocks of Trenton lying about indicate that we are not far from the stratigraphic boundary between the Black River and the Trenton. A well drilled near this outcrop is recorded by Lane in the state geo-ogist's report for 1901. According to this version it penetrated 111 feet of limestone which is divided into Trenton 47 feet, Chazy? 52 feet, and Calciferous? 12 feet. More likely only 17 feet should be included in the Trenton, the remaining 94 feet being Black River. At any rate a well at this point must begin close to the bottom of the Trenton. The record of this well is also given by Smith (23 p. 244) and in this case the details are quite different from the former version. The Trenton is given a thickness of 190 feet with 161 feet of St. Peter sandstone. More than likely what is here called the St. Peter is the upper or white portion of the Lake Superior sandstone.

Pickford Well: In 1906-07 a deep well was drilled at Pickford for oil. Dr. Lane compiled the record from a partial set of samples and this record is published by Smith (23, p. 245). Lane shows 132 feet of Algonquin lake deposits

down to the Niagara (Lockport limestone). To this he gives a thickness of 128 feet, then the Lorraine 215 feet, and the Utica 50 feet, down to the Trenton. These correlations are subject to revision in the light of present knowledge. The author found the Pentamerus oblongus zone (middle Manistique) at an elevation of 730 feet above sea level in the hilly region four miles south of Pickford (see Taylor Mill section in plate I). The elevation at Pickford is 605 feet above sea level. Allowing 132 feet in depth for the distance down to solid rock gives us a figure of 473 feet for the top of the so called Niagara. Assuming a dip to the south of 40 feet to the mile, or 160 feet, would mean that the Pentamerus layer lies at 890 feet above Pickford. Now, according to a carefully measured section which the author made for Drummond Island (see plate II) the interval between the lower Pentamerus layer and the base of the Manitoulin dolomite (top of the Ordovician) is equal to not less than 240 feet and probably not more than 290 feet. Subtracting 290 feet from 890 feet would place the top of the Richmond at 600 feet or about at the surface of the ground at Pickford. At a depth of 132 feet, therefore, we should be well within the Richmond after allowing liberally for a thickening of the formation from Drummond toward the west. The 128 given as the thickness for the Niagara must therefore belong to the Richmond. The revised section would then reas as follows:

	Thickness	Depth
Clay	113	119
Sand	13	132
Richmond	128	260
Lorraine	215	475
Utica	50	525
Trenton & Black River	275	800

Glacial Boulders: - A careful examination of the boulders on the marginal moraines of Chippewa County adds considerable to our knowledge of the areal distribution of the Black River. A number of large pieces were seen at the southwest corner of section 33, T.46N., R.1E. Others were seen in the southeast quarter of section 35 of the same township, and again on the angling road through

section 27, T.46N., R.1W. In the northern part of section 34 of the same township are many blocks of this kind of rock. By means of such occurrences, it was possible to draw the line on the map which shows the boundary between the Ordovician and the Lake Superior sandstone.

Trenton Limestone: - The Trenton limestone is exposed at only one locality in Chippewa County. This is the outcrop described in the foregoing pages as occurring in the Waiska River, southwest of Brimley. At this locality the upper part of the ancient sea cliff uncovered by the Waiska River shows some layers of a very white limestone, which has lumps of clay scattered through it that produce greenish spots. It is a very even and thin bedded limestone and contains many fossils. This limestone is exactly like the Trenton so well shown one-half mile north of the town of Bark River in Delta County. (Galena limestone of Wisconsin?).

Glacial Boulders: - In Chippewa County boulders of this rock are found at widely scattered points in the glacial drift. The pieces are so distinctive that they may be recognized without difficulty. The weathered pieces are still very white and show a strong tendency to weather into thin sheets due to greater solution along parting planes. The pieces are tabular with jagged edges. The muddy spots are prominent and fossils are common. One mile west of Barbeau in the southwest of section 15, T.45N., R.1E., the boulders in the moraine are 90% limestone and most of these are Trenton blocks of large size. An isolated block may be seen on the Roosevelt highway on the south line of section 16, T.46W., R.3W. A number of blocks were seen in the moraine on an old beach ridge in section 31, T.46N., R.5W., and along the north line of section 36 of T.46N., R.6W. Two miles northwest of Hulbert near the southwest corner of section 22, T.46N., R.7W., is another block which furnished a control point for the boundary line between the Trenton and lower rocks. For, north of the line established by these blocks no pieces of Trenton were seen, but south of it they are quite numerous.

When paleontological studies have been completed on the fauna contained in these Ordovician strata it will probably be found that they represent the the Lowville, Black River and Trenton of the New York section.

Foerste in Guide Book #5 (Excursion in the Western Peninsula of Ontario and Manitoulin Island) described the Mohawkian (middle Ordovician) on Manitoulin Island and the small islands between it and the mainland. He differentiates the following members:-

Trenton		
Black River	80'+	dark limestones
Lowville (Leray)		soft white limestone and 11' fine grained hard limestone at top.
Lowville (lower)		70'+ red shales

Cincinnatian:-The uppermost portion of the Ordovician is the Richmond formation. In other areas, notably in New York and Canada, the Richmond is separated from the Trenton by the black Utica shale and the blue Lorraine shale. These appear to be present also in Chippewa County. A piece of black shale was found on Drummond Island in section 6, T.42N., R.7E. It is difficult to see how this bituminous shale should appear in this strip unless the black shale is present farther north. Some pieces were also seen in a gravel pit in the southeast quarter of section 10, T.44N., R.1W. Bell mentions finding fragments of Utica shale on St. Joseph's Island. On Manitoulin Island east of Chippewa County some sixty miles, he reports an outcrop at Maple Point. In the Pickford well fifty feet of black shale is reported and 215 feet of Lorraine shale.

In Chippewa County the Richmond crops out only along the north shore of Drummond Island, where it appears at frequent intervals over a stretch of seven miles. In this stretch there are cliffs twenty or more feet high and the outcrops continue below water level for an equal thickness. These outcrops were described by Bell (1, p. 111) under the name of Hudson River. Later, Rominger (18) described them more fully and listed the fossils. The rocks exposed along the north shore of Drummond Island may be described as shaly limestones or argillaceous limestones. The color is dark grey and they are not very hard. Fossils are rather plentiful.

Thickness of Cincinnatian: - In the Pickford well discussed in the preceeding pages the Richmond appears to be at least 128 feet thick. The blue shale

below the 'hard dolomites' is called Lorraine in Dr. Lane's record and is 215 feet thick. The fifty feet of black shale below that is probably correctly correlated with the Utica. In the Mackinac Lumber Co. well #2 drilled at St. Ignace (23, p. 243) the Richmond seems to be present at a depth of 1020 feet and has a thickness of ninety feet. Some of theoverlying "brown and mixed dolomite" probably belongs to the same formation. Below the Richmond limestone some 56 feet of shaly and cherty dolomite may represent the Lorraine or possibly a portion of the Richmond.

Correlation of the Cincinnatian: - The rocks which occupy the section between the Trenton below and the Silurian above may be called the upper Ordovician or the Cincinnatian. In New York, Emmons early (1842) suggested the terms Oswego, Lorraine, Utica, and Vanuxem substituted Hudson River group (consisting of Pulaski and Frankfort) for the Lorraine. Somewhat later geologists working in southwest Ohio subdivided this interval into Richmond, Maysville, and Eden. The sediments deposited in such widely separated basins have been correlated through the work of a number of geologists. August Foerste has summarized the results in a correlation table in Memoir 138 of the Canadian Geological Survey (6). The task of tracing the formations across Canada from New York to Michigan has been partly accomplished through the efforts of Grabau, Schuchert, Ulrich, Williams and Foerste.

We should, therefore, examine their conclusions carefully in order to determine what we might logically expect to find in Chippewa County.

Beginning at the base, the Utica formation seems to continue across this space with its characteristic lithology and some of its diagnostic life forms. Its thickness varies from about 200 feet at St. Catherines to only 22 + feet at Little Current on Manitoulin Island. Here it is called the Collingwood formation (Raymond). To the southwest the Eden formation has a basal portion which Ulrich and Bassler believe represents the Utica.

The Lorraine of New York can be traced across Canada to Manitoulin Island where Foerste says "horizons lithologically resembling the Pulaski part of the Lorraine and containing in the upper parts at least Pholadomorpha pholadiformis" are present. He believes that the Lorraine included equivalents of the Eden and the lower part of the Maysville. The Eden on Manitoulin Island consists of clays, greenish and soft above and darker and more fissile below with a thickness of 107 feet near Little Current.

The Maysville in the same region consists of clay shale with occasional limestones having a thickness of 114 feet at McLean Hill south of Little Current.

The Oswego sandstone is correlated with the upper Maysville by Foersts. This takes care of the New York section with the exception of the Queenston shale. In 1909 Grabau suggested that these shales are merely an estuarine representative (delta phase) of a part of the Richmond. In this he is followed by Williams and Foerste. The latter states, however, that "on Manitoulin Island there are no red clay shales corresponding to those belonging to those of the Queenston section". The correlation is established on the basis of ostracod horizons. East of Manitoulin Island the Queenston shales always lie above beds equivalent to the Waynesville, (lower Richmond) horizon. The red color begins at different places but always above the Waynesville.

The Richmond formation is also present on Manitoulin Island. In a section northwest of Kagawong Foerste measured 127 feet of this formation most of which is solid limestone with some argillaceous limestone. If we total the thicknesses found by Foerste on Manitoulin Island we can construct the following table:-

Richmond	- - -	127	
Maysville	- - -	114 to 170	
Eden	- - -	102	excluding Collingwood
Collingwood	- - -	22?	(Guide Book #5 p. 89)
Total	- - -	365 to 421	

Well Record: - A number of deep wells have been drilled on Manitoulin Island. Two of these are referred to by M. Y. Williams in Guide Book #5. He states that one taps the Trenton at 440 feet. This well according to the map which accompanies the Guide Book begins near the top of the Richmond. This would indicate that Foerste's measurements made on the surface are corroborated by well records. /At another place Williams (30) gives 435 feet as the thickness of the Cincinnatian/.

An interesting well record is one reported by Smith (23, p. 246). This is a record of a well drilled near Gore Bay (west end of Manitoulin Island) and is given by M.J.L. Ward. If we rearrange the record in the light of our present knowledge it reads as follows:-

Formation	Thickness	Total
Pleistocene	1	1
Richmond, Limestone	45	46
Maysville - Eden	270	316
Utica	15	331
Trenton	250	581

THE SILURIAN ROCKS OF CHIPPEWA COUNTY

The Silurian rocks of Chippewa County are very interesting, partly because they are better developed on the outcrop and therefore more easily studied, and partly because they have been more extensively described than the other rocks.

Bell (1) was probably the first to describe them in his "Report on the Geology of Manitoulin, Cockburn, Drummond, and St. Joseph Islands". He described the lowest Silurian rocks as the 'Clinton Formation' and states that "on Drummon Island this formation occupies a strip rather more than 2 miles broad. The line marking its base runs westward acr oss the island from Colton Bay to Vermont Harbor. As on Manitoulin, it consists of grey and drab, somewhat argillaceous limestone, mostly thin bedded. It is characterized here as elsewhere, by irregular

chalky nodules." Later he mentions the fact that fossils are scarce.

Manitoulin Dolomite: - This description of Bell's corresponds very closely to the characteristics of certain rocks examined by the author on the south side of a marsh located in the north part of section 3, T.42N., R.6E. Here 12 feet of dolomite crops out in a bluff which extends for some distance east and west. The dolomite is greyish blue on a fresh exposure, but it weathers very quickly to a dull yellow color. It is medium grained in texture and breaks into fairly regular pieces 8 inches thick and rectangular in shape. It is marred by nodules of chert which also decay rapidly on exposure to weathering.

The same rock may be seen at lake level on Walter Stevenson's far, (south-west of section 3, T.43N., R.6E.). Here it is very hard and weathers very deeply with a concentric deep brown shell.

M. Y. Williams (21) describes a similar kind of rock from Manitoulin Island about 60 miles east of Drummond Island. According to his own description it is a "thin to thick bedded, grey or buff weathering dolomite which when fresh is hard and of light blue grey colour. Near the base the dolomite is thin bedded and argillaceous; midway up beds 10 feet or more in thickness occur; and thin beds are again present near the top." To this formation Williams gave the name Manitoulin Member which he proposed in 1913 (Ott. Nat. vol. 27 p. 37). He given a thickness of 50 feet for this member near Manitowaning Bay and also states that local coral and bryozoan reefs occur in the upper 20 feet of the dolomite.

On Drummond Island the rock is not exposed in its full thickness but enough is shown to establish its equivalence. Here also the upper 20 feet or so are a massive coral and bryozoan reef. The best place to study this reef is in the centre of section 9, T.42N., R.6E. where the waters of Potagannissing Bay have washed it clean and brought it into prominence. It may be described as a very hard limestone which is porous and extremely massive. Some of it is blue and some is buff. Scattered through the mass are small siliceous pipes or stems of bryozoan

and coral fragments. Crystals of quartz and calcite are also present in cavities. The only fossil seen is a species of Favosites. This old reef can be traced over a considerable area as it produces low rocky mounds devoid of vegetation. One of these mounds is located on the road through the center of section 10 of T.42N., R.6E. in the exact center of the section.

Williams gives a long list of fossils from the Manitoulin dolomite. On Drummond Island fossils are rare. The author saw only Favosites, however, a careful search might be rewarded by a fairly complete set for correlation purposes.

Cabot Head Shale: - Above the Manitoulin dolomite Williams found red and green shales to which he applies the name Cabot Head shale, a name proposed in 1913 by Grabau. The Cabot Head shales were formerly included in the "Clinton Formation' of Ontario, but Schuchert, in 1912, suggested the term Cataract for these shales and the Manitoulin dolomite. At the type locality, it consists of 74 feet of shale (red and green). Above this there are two rather prominent dolomite zones of 15 feet and 8 feet thickness respectively, separated by 32 feet of green shale. These dolomites were included by Grabau in the Cabot Head shales and Williams makes no change except to give each a name. The lower one he calls 'Dyer Bay lentil' and the upper one the 'St. Edmund lentil'.

Virgiana Mayvillensis: - One of these thin dolomite lenses assumes an importance not suggested by its thickness, because it contains Virginia mayvillensis. This is the Dyer Bay lentil. Williams finds that this lentil becomes thicker to the north, for at Kagawong, near the western end of Manitoulin Island it is 25 feet thick. On the road between West Bay and Kagawong, he finds 57 feet of shale mostly red (the rest green) between the Manitoulin dolomite and the Dyer Bay. It appears that the dolomite is gaining at the expense of the shale. This tendency evidently continued toward Michigan where the equivalent rocks are mostly dolomites. The Dyer Bay crops out also at Pitman Point on Cockburn Island.

Williams mentions many places between the type locality on the north end of Bruce peninsula and Cockburn Island and states that "these outcrops almost

invariably contain Virgiana mayvillensis which was thought throughout the field work to be a small form of Pentamerus oblongus, marking the base of the Lockport formation." "As a consequence the Dyer Bay was mapped with the Lockport. This error has been corrected so far as could be done in the office. The true Cataract age of the Dyer Bay beds is indicated by Bassler's determination of the ostracoda and the identification of Alexandrian fossils in the beds on Fitzwilliam Island." On page 37 of Memoir 111, Williams gives a list of fossils of which two brachiopods and three octracods are new species.

Cataract in Chippewa County: - As suggested in the preceeding paragraph, the Cataract can be traced directly into Chippewa County across Cockburn Island to Drummond Island. On the latter the outcrops are not so numerous as might be desired. The basal Manitoulin dolomite is present and has been discussed. The red and green shales of the Cabot Head are not to be seen on the outcrop. There is a suggestion of red shale in the Potagannissing River on the east section line of section 15, T.42N., R.6E. At this point 2 feet of a stiff red clay may be seen in the south bank of the river. But it might also be Algonquin lake clay of which there is so much on the mainland across St. Mary's River. The fact that the Potagannissing River is following an ancient topographic depression across Drummond Island suggests that this part of the island was underlain by a formation less resistant than the dolomites above and below the shales. In the geologic section for Drummond Island a thickness of 35 feet has been assigned to the shales which may be somewhat too small and a thickness of 95 feet to the Manitoulin dolomite which may be somewhat too large (See Plate 11).

The upper part of the Cabot Head containing the Dyer Bay and St. Edmund dolomites with intervening shales is represented by the Hendricks on Drummond Island. The 55 feet at the type locality is represented by 47 feet of dolomite on Drummond Island which, by stratigraphic methods, can be traced west to the type locality for Hendricks at Hendrivks quarry in Mackinac County.

Hendricks Formation: - R. A. Smith (24) subdivides the Niagara into the

following members - (1) Engadine (2) Manistique (3) Fiborn (4) Hendricks. The last named is defined as "the series of limestones and dolomites from the base of the Fiborn limestone down to the Rochester shale." The thickness is given as over 100 feet and probably 145 feet based on test holes drilled near the Hendricks quarry. This thickness of 145 feet, however, includes the Fiborn and overlying strata to a thickness of about 49 feet. It would seem from all the evidence brought together above that the Hendricks of Smith includes the Cabot Head and possibly some of the Manitoulin of Ontario or, in other words, is roughly equivalent to the Cataract formation as defined by Schuchert. On Drummond Island [The Hendricks and] the Cataract [together has] a thickness of 182 feet with a probably zone of shale (of 35 feet) at a depth of about 50 feet from the top. The analysis of the Union Carbide Co. test hole referred to in the foregoing discussion shows dolomite and limestone to a depth of 100 feet below the top. It thus appears that the shale interval has become more calcareous and we should not expect, therefore, to find the red and green shales so typical of the Cabot Head in Ontario.

Hendricks on Drummond Island: - The Hendricks does not crop out on the mainland of Chippewa County, but appears in a number of places on Drummond Island. Fortunately, the rock was early found to have great value for building purposes, because of its tendency to break into perfect rectangular blocks. Hence quarries were opened up in it and these are still in such condition that the formation may be conveniently studied. One of these quarries is the L. Seaman quarry near the village of Drummond in section 24, T.42N., R.5E. This quarry was well described by R. A. Smith (24, p. 208). His number 5 (buff, cherty, and massively fossiliferous dolomite) is the top layer of the Hendricks formation. This layer can be traced from one point to another and is very important because it is such a good key horizon. It weathers out with a peculiar nodular or gnarled surface because of differential weathering. Also it is coarse grained and deeply iron stained to buff, cream or brown. The writer named it the lower nodular layer since there are two others above it and just like it in every respect. These were named the middle and upper nodular layers.

Below the lower nodular layer there is a somewhat monotonous succession of strata which may be described in general as very even bedded, hard, light grey to pale buff, fine grained dolomite. A somewhat striking characteristic is the presence of thin, dark, to black carbonaceous bands parallel to the bedding, which give the rock the appearance of a 'ribbon' structure when freshly fractured. Another striking feature is the fact that the jointing is so well developed in two sets of joints at right angles, producing rectangular blocks. For this reason the stone was sought after for breakwaters and piers in the Great Lakes and in the construction of the early locks at Sault Ste. Marie.

Lime Kiln Quarry: - These same characters distinguish the rock in the lime kiln quarry which is located in section 18, T.42N., R.6E., near the shore line of Potagannissing Bay. The following section was measured by the writer. The Hendricks begins with number 3 and extends down to water level, a thickness of about 50 feet.

Section in Lime Kiln Quarry, Drummond Island
Elevation at top 653 A.T.

		Thickness	Total
1.	Middle nodular layer, coarse, cream colored, porous, weathers with gnarled, lumpy surface	1 ft.	1 ft.
2.	Interval mostly covered, but typical white broad-banded limestone of the Fiborn may be seen and other layers of buff hard phase also Hendricks series.	22 "	23 "
3.	Lower nodular layer, coarse, cream colored, porous, weathers with gnarled, lumpy surface	2 "	25 "
4.	Covered	4 "	29 "
	Top of quarry		
5.	Dolomite, thin bedded, even bedded, grey, fine grained	3 "	31 "
6.	Dolomite, brownish, medium grained	4 "	35 "
7.	Dolomite, yellow, medium grained	5 "	40 "
8.	Dolomite, light cream color, saccharoidal, weathers easily to brown.		
9.	Dolomite, brownish, moderately coarse and friable	5 "	47 "

10. Dolomite, thin and even bedded, rectangular jointing and thin bituminous partings to lake level, partly covered 25 ft. 72 ft.

Other Outcrops of Hendricks: - Portions of the Hendricks formation crop out at a number of places. On the point one half mile west of Drummond village, it forms the shore line for some distance and fossils are present. Again, on the point one and one half miles east of Drummond village (section 17 & 18, T.42N., R.6E.) the lowest part of the Hendricks formation may be studied. It crops out at many places in a narrow strip running through sections 16, 22, 23 of T.42N., R.6E.; 19, 26, 27, 28, 29, 36 of T.42N., R.7E.; and section 31, T.42N., R.8E. A convenient place to study it is along the road to Maxton, especially in the northeast corner of section 21, T.42N., R.6E.

Fiborn: - The third division in Smith's classification of the Niagara is the Fiborn, named after the Fiborn quarry in section 21, T.44N., R.7W. Smith describes it as a "buff to grayish buff, dense grained to lithographic limestone, generally containing small disseminated crystals of calcite. These characters and its perfect conchoidal fracture make field identification easy. It is nearly 30 feet thick in the Fiborn quarry."

In Chippewa County, there is only one place on the mainland where the Fiborn crops out. This is near the logging camp called "Willowinn". The outcrops in this vicinity cover a considerable area in sections 17 & 18 of T.44N., R.6W. and 13, T.44N., R.7W. The rock is dull grey, but weathers out white, is lithographic and filled with streaks and crystals of calcite. A total thickness of slightly over 15 feet is present here. Fossils are abundant in certain layers.

Fiborn on Drummond Island: - No more outcrops are to be seen to the east until Drummond Island is reached. On this island the Niagara may be studied in its entirety, from the top of the Engadine down to the base of the Hendricks (see Plate 1). In this thickness of 285 feet there is a zone of 22 feet which resembles the Fiborn in every respect except that it lacks the calcite crystals. The best place to see it is in the old quarry one mile west of Drummond village in section 23,

T.42N., R.5E., although only 15 feet are to be seen. A carefully measured section was made in this quarry and the cliffs behind (south) of the quarry. It will be noted that the uppermost 5 feet are most typical and that thin dolomites are interspersed with the lithographic rock farther down. Layer number 11 is a layer which can be identified immediately by anyone who studies the Niagara section on Drummond Island. It stands out because of its striking white color first of all and secondly because it weathers out in broad ribbon bands from one inch to three inches wide. There is no other layer just like this one in the whole 285 feet of the Niagara.

Section in Old Quarry One Mile West of Drummond

Location: - East half of section 23, T.42N., R.5E.

Elevation: - 615 feet above sea level at base of quarry

		Thickness	Total
1.	Upper Pentamerus layer, Massive dolomite cream color, coarsely crystalline, filled with casts of Pentamerus oblongus, weathers dark chocolate brown	7 ft.	7 ft.
2.	Dolomite, thin bedded, brownish, medium grained, weathers into thin white sheets	5 "	12 "
3.	Dolomite, one layer, very hard, medium grained, buff	8 in.	12 " 8 in.
4.	Dolomite, thin bedded, pale grey, very fine grained	3 ft.	15 " 8 "
5.	Covered	15 "	0 " 8 "
6.	Dolomite, one layer, saccharoidal, brownish, weathers with rounded edges	1 "	31 " 8 "
7.	Covered	10 "	41 " 8 "
8.	Dolomite, thin bedded and even bedded, buff and grey medium grained and lithographic	11 "	52 " 8 "
	Top of quarry		
9.	Dolomite, Middle nodular layer, coarse, cream color, porous, weathers with knotty surface	4 " 6 in.	57 " 2 "
10.	Dolomite, fine grained, buff	2 " 10 "	60 "
11.	Dolomite, lithographic texture, weathers out in broad bands and white	3 "	63 "
12.	Dolomite, medium grained, buff, wavy lines, coralline	2 " 4 "	65 " 4 "

		Thickness	Total
13.	Dolomite, lithographic, light brown wavy lines	6 in.	65 ft. 3 in.
14.	Dolomite, like No. 12	5 "	66 " 3 "
15.	Dolomite, like No. 13	2 ft. 2 "	68 " 5 "
16.	Dolomite, pale yellow	1 " 4 "	69 " 9 "
17.	Dolomite, like No. 13	8 "	72 " 1 "
18.	Dolomite, medium grained, buff, hard	1 " 8 "	73 " 9 "

One mile east of the old quarry is the L. Seaman quarry mentioned previously. The layer No. 11 of the above section crops out there also. In the partly covered hill slopes above the nodular layer which forms the top layer of the Seaman quarry, the white banded rock crops out over quite an area. In fact it can be traced across from one quarry to the other either by outcrop or by float rock. A few feet above it - the middle nodular layer, which forms the lowest layer of the Manistique, comes to the surface. Because of its critical importance in correlating the lower part of the Manistique, this section was carefully measured and is given on page 28. Here also the middle nodular layer appears again to serve as a check on the exactness of the correlation.

The white banded layer with the rest of the Fiborn, appears again in a cliff in the northern part of section 22, T.42N., R.6E. The section at this point is as follows: -

Section near Maxton, Drummond Island

Location: North half of section 22, T.42N., R.6E
Elevation: 655 feet above sea level at top of section.

1.	Dolomite, middle nodular layer, coarse, cream color Fiborn	5 ft. 6 in.	5 ft. 6 in.
2.	Limestone, thin bedded and even bedded, alternating buff and grey, some medium grained and some very fine grained. The typical white, broad banded lithographic rock is prominent near top of cliff	12 "	17 " 6 "
3.	Covered by talus	11 "	28 " 6 "
4.	Dolomite, one layer, saccharoidal, brownish, weathers with rounded edges, pillow rock	1 "	29 " 6 "

5.	Dolomite, lower nodular layer, coarse, cream color	2 ft.	31 ft. 6 in.
6.	Dolomite, thin bedded and even bedded, blocky, occasional sacharoidal layers, partly covered	23 "	54 " 6 "

The cliff which furnished this section, can be followed along on foot for a distance of over a mile into section 23. In this stretch the middle nodular layer is the cliff forming layer and has protected the Fiborn from erosion. Behind it, to the south, other rock terraces appear held up by higher members of the Manistique. By means of related rocks, the Fiborn can be traced along as far as Marblehead, on the eastern extremity of the island. (Section 31, T.42N., R.8E.)

Marblehead: - The stratigraphic sequence at Marblehead was carefully determined by Rominger, whose section is reproduced by Smith (24 p. 207). Smith suggests that layer No. 10 is the probable equivalent of the Fiborn and cites a chemical analysis No. 237 (24 p. 284) to corroborate this conclusion. In the description of the analysis 'acervularia' is used instead of 'acicular'. This analysis shows 95% calcium carbonate. On the basis of chemical composition it does not seem unreasonable to include numbers 11 and 12 of Rominger's section. The analysis of No. 12 (24, p. 284 analysis No. 238) shows 94% calcium carbonate. Incidentally, there is another typographical error in the description of the analysis. Instead of'30 feet below acervularia bed' it should read '8 feet below acicular bed'. If we take beds Nos. 10, 11, & 12 together, we obtain a thickness of 16 feet for the Fiborn. Bed No. 9 in Rominger's section is the middle nodular layer so characteristically present above the Fiborn farther west.

Smith suggests (24) that the Fiborn may be a lens in the Niagara and largely confined to the limits of the upper peninsula. The fact that it varies from 18 feet at Hendricks quarry to 30 feet at Fiborn quarry, and again, to 16 feet (?) at Marblehead, bears out this statement. In Williams' description of rocks on Manitoulin Island we look in vain for any rock that can be called the equivalent of the Fiborn. For, above the St. Edmund lentil, which forms the top of the Cabot Head, (Cataract) he finds only 14 feet of strata (21, p. 33). This interval is occupied by shale and thin bedded dolomites.

Manistique: - The second division of the Niagara Smith calls the Manistique, from the abundant outcrops of dolomite near the city of Manistique in Schoolcraft County. He defines it as "a thick succession of dolomite and high magnesian limestones extending from the base of the Engadine dolomite downward to the top of the Fiborn limestone."

The writer, on the basis of his observations, is inclined to divide the Manistique into three portions, which will be called simply, upper, middle, and lower. This subdivision becomes desirable on account of the lithologic and faunal differences which set off these groups from each other.

The lower Manistique consists of 37 feet of fine grained and medium grained, and medium grained, hard, even bedded, buff dolomite. The top layer is the upper nodular layer five to ten feet thick and the lowest layer is a similar one, the middle nodular layer, three to five feet thick. It appears from this that the lower Manistique bears a close resemblance lithologically, to the Fiborn and Hendricks below.

The middle Manistique is the most distinctive part of the formation. It consists of two thick beds of coarse, brown, porous dolomite containing great numbers of Pentamerus oblongus. These two beds, which may be called the upper Pentamerus oblongus layer and the lower Pentamerus oblongus layer are each about 7 feet thick and hold this same thickness remarkably well over great areas. Between the Pentamerus layers are very thin bedded hard, white, lithographic limestones, averaging close to eight feet in thickness. The total thickness of the middle Manistique is about 21 or 22 feet.

The upper Manistique consists of very fossiliferous, cherty thin bedded dolomites having a thickness of about 95 feet. This division of the Manistique is also distinctive, although it rarely appears on the outcrop. The weathered outcrop resembles heaps of ashes; and great numbers of fossils, especially Halysites and Favosites are always present.

Outcrops of Manistique: - The best place to study the lower Manistique is above the old quarry on Drummond Island about one mile west of the village of

Drummond, and along the cliffs which extend east to the L. Seaman quarry. In Ontario the lower Manistique is found also, but is described only from one locality, that is, West Bay on Manitoulin Island. Williams (21, p.61) says "Here, above six feet of soft, green Cataract shale, 20 feet of fine grained dolomite occurs with shale partings near the base. No fossils were found in these beds, but they are probably basal Lockport."

The most convenient place to study the middle Manistique is on the Victor Hilden ranch, in the northwest quarter of section 26, T.42N., R.6E. The details of this section are given below:

Section on Victor Hilden Ranch.

Elevation at top of section is 695 feet above sea level

		Thickness	Total
	Middle Manistique		
1.	Upper Pentamerus layer, massive, light cream color, coarsely crystalline, casts of P. oblongus, weathers dark chocolate brown	7 ft.	7 ft.
2.	Dolomite, thin bedded, brownish, medium grained weathers into thin white sheets	4 "	11 "
3.	Covered	4 "	15 "
4.	Lower Pentamerus layer, like No. 1	2 "	17 "
5.	Covered	5 "	22 "
	Lower Manistique		
6.	Dolomite, one layer, saccharoidal, brownish, weathers with rounded edges	1 "	23 "
7.	Upper nodular layer, coarse, cream color, porous sugary dolomite, numerous silicified corals, weathers dark with lumpy surface	10 "	33 "
8.	Same as No. 6	1 "	34 "
9.	Dolomite, thin bedded, hard, buff, medium to fine grained	2 "	36 "
10.	Covered interval. Section continues one eighth mile to north on bluff	27 "	63 "

	Thickness	Total
11. Middle Nodular layer, coarse, cream color, porous weathers with lumpy surface	5 ft.	68 ft.

Fiborn Formation

12. Thin bedded and even bedded limestone, some buff and

(Page missing from our copy of the manuscript)

		Thickness	Total
	Fiborn Formation		
7.	Limestone, lithographic texture, weathers out in broad bands of strikingly white color	1 ft.	58 ft.
8.	Covered	17 "	75 "
	Hendricks Formation. Top of Quarry.		
9.	Middle nodular layer, coarse, cream color, porous, weathers with lumpy surface	3½ "	78½ "
10.	Hard, light grey to buff massive and crystalline dolomite	3 "	81½ "
11.	Hard light buff massive and crystalline dolomite	4 " 8 in.	86 " 2 in.
12.	Hard, buff densely crystalline dolomite, conchoidal fracture prominent in lower part of bed	8 "	94 " 2 "
13.	Dark buff crystalline dolomite with a drusy fossiliferous zone in the center of the bed	3 "	97 " 8 "
14.	Hard light gray to buff finely crystalline banded dolomite with prominent bedding planes	7 " 8 in.	105 " 4 "
15.	Hard bluish fine grained dolomite weathering to a pronounced blue color. Lowest bed quarried and floor of quarry is apparently a part of the same bed and just above lake level	2 " +	107 " +

In the section above the layers numbered from 10 to 15 are described by Smith (24, p. 208) and his description is used. Number 5 of the section is quite distinctive and may be used as a key horizon where other layers are covered. Caution is necessary because similar layers occur at other places in the sequence. There is a layer just like it, for example, above the lower nodular layer, and another one above the middle nodular layer.

The two Pentamerus oblongus layers are very important stratigraphic key horizons. They are very persistent both in character as well as in thickness. On account of their massiveness and resistence to erosion they are likely to form escarpment and terraces similar to those made by the Engadine. Coming as they do almost in the middle of the Niagaran they are valuable in giving the geologist a clue as to the position of the otherwise confusing strata above and below. They can be traced across Drummond Island from Marblehead almost mile for mile. A splendid exposure may be

studied in the northwest quarter of section 3, T.41N., R.7E., three miles west of Marblehead. This locality may be reached from Johnswood by following an old logging railroad grade. The upper Pentamerus oblongus layer, where first met, lies but a few feet above the grade. It has the typical white layers below it down to the grade. Higher on the side of a fairly high hill about 15 feet of the cherty, fossiliferous, upper Manistique crops out. The Pentamerus oblongus layer is 6 feet thick and lies at an elevation of 630 feet above sea level. Higher on the hill there are beach deposits of shingle which look like outcrops from a distance. The highest one of these is at 730 A.T.

Another good outcrop of the middle Manistique appears in the west part of section 30, T.42N., R.7E. The elevation at the top is 670 feet above sea level. This elevation may be in error as it was taken on a rainy day during the passage of a low area of pressure.

Sturgeon Point: - This locality was mentioned by Locke in his report to Jackson (11, p. 195). He states that he found the 'Cliff Limestone of Ohio' characterized by casts of the interior of Pentamerus oblongus (pig's foot fossils). On page 196 he mentions finding immense number of Pentamerus oblongus in section 17, T.42N., R.4E., on the St. Mary's River. Again, he finds them on Lime Island on the northwest shore in section 26, T.43N., R.3E. [According to G.M. Ehlers this is the Virginia maysvillian zone].

Stalwart: - West of this point on the mainland outcrops are rare. At Stalwart in the northwest quarter of section 30, T.43N., R.2E., there are some outcrops. They represent scattered portions of the lower Manistique from the upper nodular layer down about 20 feet. It appears that the Pentamerus oblongus layers are responsible for the hill at Stalwart for they protected it until very recently. In other words the Pentamerus oblongus layers were removed by erosion probably during Pleistocene times.

Taylor's Mill: - The next locality to the west where the middle Manistique

may be studied is near Taylor's lumber mill in section 20, T.43N., R.1E. Both layers of Pentamerus oblongus crop out here, the upper one at an elevation of 735 feet above sea level and the lower one at 715 feet. Both are about seven feet thick, but the interval between them has thickened to about thirteen feet. It is the same characteristic thin bedded, white weathering, limestone found farther east.

Mackinac County Outcrops of Middle Manistique: - The middle Manistique crops out at two localities in Mackinac County a few miles south of the Chippewa County line. Because of their importance in tracing the stratigraphy they are introduced here. In section 11 & 12 of T.43N., R.2W., large blocks of Pentamerus layers were seen. The Pentamerus layer was seen in place on the section line between 11 & 12 at an elevation of 790 A.T.

The other locality is in sections 8 & 9 ot T.43N., R.3W., along a very rough and rocky road leading from Dryburg south toward St. Ignace. Both layers are present here and crop out on both sides of the road for some distance. The elevation is approximately 770 feet above sea level.

Scott Quarry: - The next point of outcrop of the middle Manistique is at Scott quarry in section 29, T.44N., R.4W. The top of this quarry is 930 feet above sea level and, 95 feet lower, at 835 feet the Pentamerus layer may be found in the sides of the hill just east of the crusher. Only one layer is to be seen, but the appearance of the white thin beds below it leaves no doubt that it is the upper one. A slight difference is to be noted in the fossils. Instead of casts of Pentamerus oblongus we find mostly shells here, but, as usual, great numbers of them. Beyond Scott quarry to the west there are no outcrops of the middle Manistique in Chippewa County. The author has not seen it beyond this locality, but G. M. Ehlers reports finding it in Garden peninsula in Burnt Bluff.

Middle Manistique in Ontario: - The Pentamerus layers are to be found over a long stretch of outcrops as attested by the findings of M.Y. Williams on Manitoulin Island and on Bruce peninsula. He states (21, p. 61) "At Owen Sound the

lower five feet of Lockport beds are crowded full of Pentamerus oblongus - - - about 15 feet of basal dolomite at Wiarton is similarly crowded with this interesting brachiopod." He does not seem to differentiate two layers such as we have on Drummond Island. Either de did not see two, because one was obscured, or possibly, one has disappeared from the stratigraphic section, which is unlikely. But evidently he found the white thin bedded layers between the two Pentamerus layers at places, for, he says, "At Lionhead and Cabot Head, however, eight to ten feet of thin even bedded, dolomite occurs beneath the Pentamerus beds". "The contact is sharp, the thin beds containing few fossils and the Pentamerus beds being very fossiliferous."

Upper Manistique: - The Best place to study the upper Manistique is at Taylor's lumber mill in section 20, T.43N., R.1E. Practically the whole interval of 95 feet is shown with the Engadine above and the Pentamerus below. It is a regular paradise for the fossil hunter. Chert is abundant at practically every horizon. The thickness as measured here is considered reliable as the slope of the hill in which the outcrops occur is quite steep. Nowhere else in Chippewa County is the whole formation shown so well.

At Scott quarry in section 29, T.44N., R.4W., we probably have the complete section also, as the interval from the top of the quarry (930 A.T.) to the Pentamerus layer below is exactly 95 feet. However, the Engadine is missing and therefore, we have no proof of the fact. In the face of the quarry which is 60 feet deep, there is offered a good opportunity to study the character of the component layers and to search for faunules. The most abundant fossil is Pentamerus oblongus, but Halysites and Favosites are also abundant in certain layers, especially near the top.

Other outcrops occur on the mainland at scattered points. In sections 19 & 30 of T.44N., R.5W., are a few thin beds of the Manistique. In the southeast quarter of 20, and the southwest of 21 are some fairly good exposures of the uppermost part of the division. These outcrops continue and cross the highway M-48 on the line between 21 & 28. One mile farther east on the line between 22 & 27 are good outcrops of this division, but lower stratigraphically. Fossils are quite abundant

Near Rockview, five miles south of Pickford, outcrops are fairly abundant and extend around to the section at Taylor's mill mentioned previously. Again, in section 27 & 28 of T.43N., R1E. (2 miles farther east) there are extensive exposures, of the upper Manistique. South of Raber, in section 32 & 33, T.43N., R.3E., a fairly extensive area shows outcrops of the formation. A small, but important outcrop, occurs in the southeast quarter of section 20, T.42N., R.4E. (two miles northwest of Detour). This outcrop shows a portion of the division near the top, for the Engadine crops out just south of it.

On Drummond Island outcrops of the upper Manistique are also numerous. About twenty feet of the topmost portion makes narrow terraces along the west side of the island, in section 36, T.42N., R.4E. and section 1, T.41N., R.4E. Farther east a few layers crop out in the southeast quarter of section 34, T.42N., R.5E. In the southwest quarter of section 26 of the same township, a good cliff may be studied. Fossils are numerous here and a great variety of species may be collected. Quite a large area is underlain by the formation in the southwest quarter of section 20, T.42N., R.6E. An interesting area lies in the southeast quarter of section 28 of the same township, about one eighth mile south of the farm house of Emil Nevanen. Silicified corals are abundant.

Thence toward Marblehead outcrops are numerous at scattered localities, most of which are difficult to reach.

Upper Manistique in Ontario: - In Ontario Williams has mapped and described the Lockport without establishing any subdivisions north of the Niagara peninsula. He includes in it the Engadine and all the divisions of the Manistique. On page 60 of Memoir 111 (21) he describes beds containing chert and mentions a few localities where they may be seen such as at Cabot Head (15 feet above the beds full of Pentamerus). At Campbell Bay, in Bayfield Sound, on Manitoulin Island, he finds 12 feet of chert about 180 feet above the base of the Lockport. Again north of Old Quarry Point on the south side of the island near the west end he finds 15 feet of chert which belongs near the top of the formation. His Fossil Hill Coral Horizon

described on page 61 clearly belongs to the upper Manistique. He finds that corals occur in great profusion at fossil hill about seven miles southwest of Manitowaning and states that this horizon is about 70 feet up in the Lockport dolomite.

In order to compare the strata in Chippewa County with those in Ontario, two sections were chosen from those pictured by Williams in fig. 3 of Memoir 111. They are the Campbell Bay section and the Manitowaning section shown on Plate II. These sections are not described in the text and it was therefore necessary to match up sections from scattered remarks. In the Summary Report for 1912 of the Canadian Geological Survey, Williams says on page 275 "In the 240 foot section measured north of Fossil Hill (On Manitoulin Island south of Manitowaning) a sparing coral fauna starts about 80 feet up in the formation and attains its maximum about 100 feet above the base. The upper 30 feet of the Lockport is massive and nearly unfossiliferous."

The upper part of each section is represented as massive limestone with layers containing fossils and chert below it. This is interpreted to mean that the Engadine forms the top of each, and the upper Manistique forms the cherty layers below. Unfortunately, the Pentamerus layers do not appear in either section although the assumed horizon is shown by the dashed line which is Williams position for the base of the Lockport.

(Insert Plate II)

Engadine: - The highest division of Smith's Niagaran is the Engadine. He named it after the village in Mackinac County by that name because of the good outcrops in that vicinity. He describes it (24, p. 151) as "an extremely massive, hard, and very crystalline dolomite, distinctly bluish or mottled and streaked with blue. The stone is very poorly and massively bedded, and except where greatly weathered shows very few distinct bedding planes."

In Chippewa County this formation has distinct lithologic characters which make it easy to recognise. Among these are its massiveness, hardness and the position above cherty fossiliferous beds below. Because of its superior resistance to erosion it has formed an escarpment facing mostly north and quite high in places. Its height

previous to the Pleistocene ice invasion was even greater. This does not mean that the ice eroded off much of it. The writer believes that the amount of ice erosion was practically negligible. But the relief was greater because at that time there existed drip stream channels which are now filled with drift and with glacial lake deposits.

Outcrops of Engadine: - The line of outcrop of the Engadine is shown on the map which accompanies this report. Most of it lies just south of Chippewa County in Mackinac County. The first outcrop, therefore, in the county is the one in sections 20, 21, 28 and 29 of T.44N., R.6W. (3 miles east of Trout Lake). Nearly the full thickness is to be seen in the southeast quarter of section 20. The base of the Engadine is at an elevation of 970 feet and the top layer at 1010 feet making a total of 40 feet. This amount together with the 15 feet under the fire tower makes a thickness of 55 feet. Outcrops are almost continuous to the northwest quarter of section 26 of the same township. Here it forms prominent cliffs again with the base of the formation at 965 feet A.T.

At Scott quarry the Engadine does not appear, but it probably capped the hill at that point in the very recent past as the elevation at the top is 945 feet which is about right for the base of the Engadine allowing for the dip. Also the thickness of the Manistique is 95 feet which is about its full thickness.

Maple Hill: - A very interesting outcrop is the hill locally known as Maple Hill, in the northeast quarter of sec. 3, T.43N., R.4W. Nearly the full thickness is again shown here as the base of the Engadine is at 955 feet and the top at 1005 feet as measured by barometer. On the top of this hill there is a U.S. G.S. benchmark with a wooden observation tower built above it. Thence the escarpment may be traced by numerous outcrops to the line between section 4 and 9 of T.42N., R.3W., where the Engadine seems to enter Lake Huron, having formed in ancient times the west wall of a northward flowing stream. On the other side of this ancient stream valley is an outlier of the Engadine in sections 1 and 2 of the same township. Here the base of the formation is 645 feet A.T. and the top 675 feet above sea level.

Three miles farther east the escarpment again comes into view with a 40 foot bluff, the base of the formation lying at an elevation of 640 feet above sea level. Shortly the outcrops turn north and northwest until in sections 20 & 29, T.43N., R2W, high cliffs again appear, (Base 705 - top 755) and can be followed to sections 9 & 3 where the full thickness is also present in high north facing bluffs (Base 850).

Rockview: - Between these bluffs and Rockview outcrops are scarce because of glacial drift. The enormous boulders so characteristic south of the outcrop line, are very abundant in this strip. In sections 29 and 30, T.43N., R.1E., about four miles south of Pickford, the Engadine makes a very prominent line of bluffs with the base of the formation at 815 and the top at 875, thus showing the full thickness. Practically all of section 30 is underlain at shallow depth or at the surface by Engadine rock.

Two miles east in section 34 and adjacent sections, of the same township, the Engadine makes lower bluffs with the base at 790. About four miles southeast is a peculiar locality, for here the dip of the Engadine is quite exceptional. The section line road between sections 11 and 10 of T.42N., R.1E. crosses over quite a bit of Engadine (15 feet or more). The dip is northwest which is unusual, as the dip is generally to the south 40 to 50 feet per mile. But here the rocks dip 30 degrees to the northwest. This may be due to a concealed coral reed or to faulting. If it is due to a coral reef it is one of the few places where such a reef exists in the Engadine. The elevation at the base of the formation is 705 feet at this locality.

East of this place high cliffs of Engadine are practically continuous for five or six miles as far as section 9, T.42N., R.2E. This whole township is rather rocky. There are prominent cliffs in sections 23 and 26. The elevation of these indicate that there may be a fault through the center of the township, with the upthrow on the south side. The next point where the Engadine crops out is a quarter of a mile east of Gatesville. About 15 feet of the formation are shown

with the base at 740. Quite a remarkable thing is the presence of a considerable number of large Engadine boulders on the Gatesville moraine in section 27, T.43N., R.2E. This is about 2½ miles north of the line of outcrop in an area where the preglacial topography was much too low for the Engadine. For the Nipissing waters have cut a steep cliff into this moraine and the Nipissing water level is about 635. The cliff is perhaps 30 feet high which makes an elevation of only 660, which would be 120 feet too low for the Engadine in this latitude. The highest part of the moraine between here and Stalwart is only 725 feet and to the north and northeast the land is much lower. It therefore, is somewhat puzzling to account for Engadine boulders at this point, unless a fault be postulated. It is just barely possible that the central part of St. Joseph's Island is held up by Engadine, for the elevations are remarkably high (934 + feet). These hills may have furnished the blocks of Engadine.

An interesting outcrop of Engadine is in the southern part of section 14, T.42N., R.3E. (six miles northwest of Detour). Again, the full thickness of the formation is shown with its base at 700 and top at 755. The outcrop in the southeast quarter of section 20, T.42N., R.4E. was mentioned previously. At the town of Detour, the Engadine is quite prominent. All the northwest part of the town is underlain by it. A quarry was once operated in the southeast quarter of section 27. Just west of the quarry, a road goes up a fairly steep grade to the top of the formation. The base of the Engadine is at 640 here and the top at 695.

Engadine on Drummond Island: - The Engadine formation crops out at many points on Drummond Island. A goodly share of the south shoreline is rocky and wherever layers are to be seen, they are the typical Engadine rock. Outcrops occur farther north more or less regularly for one fourth the width of the island. At the western end it crops out from section 30, T.42N., R.5E. in a southwesterly direction for a distance of three and a half miles to the point known as Crab Island. One half mile north of Crab Island, fifteen feet show up on the shore line, and farther north the entire thickness of 55 feet may be found. For about three miles the thin

surface coating of ground moraine, washed out by lake waters, covers up the rocks. Then the Engadine reappears in section 34, T.42N., R.5E., a few rods north of the gravel road. It reappears again on the north line of section 36. In the southeast quarter of section 31, T.42N., R.6E., it forms quite a cliff 15 feet high with the base at 660. Two and a half miles farther east is another low cliff where the base has an elevation of 700 feet and a total thickness of 15 feet are shown. Magnificent outcrops appear south of this locality nearly all the way to the shore-line. They can be most conveniently studied along the section line between 2 and 3 and 10 and 11. From here on toward the east outcrops are nearly continuous to Johnswood and beyond.

For the Paleontologist and interesting place to visit is the southwest quarter of section 1, T.41N., R.6E. Near the northwest quarter of this quarter section is a fork in the road and at that point the basal layers of the Engadine carry a fauna like that of the Manistique below. The same rock with the same fauna may be seen again in the northeast quarter of the same section on a small farm.

Along the south shore of the island an interesting place to visit is the site of the old British fort (SE of section 1, T.41N., R.4E. The parade ground is a flat pavement of massive Engadine rock which extends out into the waters of the bay for some distance. Jackson (13, p. 585) mentions this locality and states that the limestone shows a dip of 1 or 2 degrees to the south 35 degrees east. Another good locality to study the formation is around Huron Bay especially section 13, T.41N., R.5E. The limestones here show peculiar small potholes made by small pebbles swirled around by the waves.

The following composite section for Drummond Island was made after all the localities had been visited.

Composite Stratigraphic Section for Drummond Inland.

SILURIAN SYSTEM

Engadine Formation	Thickness

	Thickness
1. Bluish grey mottled dolomite, extremely massive, hard coarsely crystalline. Fossils not common, but in certain horizons Pentamerus oblongus, Haulysites Favosites, etc.	55 ft.
Manistique Formation	
Upper Division	
2. Grey and brownish grey thin bedded dolomite, weathers white, much chert so that disintegrated out crop often resumbles heaps of ashes, fine grained to medium grained texture, very fossiliferous with Halysites, Favosites, Strombodes, Syringopora, Cladopora, Homoeospira, Pentamerus, etc.	95 ft.
Middle Division	
3. Upper Pentamerus layer, one massive layer of buff dolomite, weathers easily to yellow brown and dark brown, coarsely crystalline, on outcrop dark colored and irregular, filled with casts of Pentamerus oblongus	7 ft.
4. Pale, brownish grey dolomite, weathers white, fine grained, resembles Fiborn in texture, hard thin bedded	8 ft.
5. Lower Pentamerus layer, same as number 3	7 ft.
Lower Division	
6. Upper nodular layer, cream colored dolomite, weathers brownish, nodular and dark, coarse texture, porous upper 1 foot is saccharoidal	7 ft.
7. Buff dolomite, fine grained to medium grained, thin bedded and even bedded	25 ft.
8. Middle nodular layer, dolomite like No. 6 weathers nodular	5 ft.
Fiborn Formation	
9. Grey and buff limestone, some lithographic texture, some medium grained, all thin bedded and even bedded. Layers in upper part weather out white and with broad ribbon bands	15 ft.

		Thickness
10.	Covered interval	7 ft.
11.	Lower nodular layer, dolomite like No. 8 & 6, except upper 18 inches, lwhich is similar but saccharoidal	5 ft.
12.	Grey to buff dolomite with thin dark carbonaceous streake (ribbon rock), hard, even bedded, fairly massive, breaks into rectangular blocks	15 ft.
13.	Brown dolomite, saccharoidal, massive	7 ft.
14.	Ribbon rock, like No. 12 partly covered	25 ft.

Cataract Formation

Cabot Head (?)

15.	Covered interval probably red and green shale	35 ft.±

Manitoulin Dolomite

16.	Grey and blue limestone, extremely massive without apparent bedding planes, weathers into dome like masses, very hard, porous, silicified fossils, (Coral reef)	35 ft.±
17.	Covered interval	15 ft.
18.	Yellow dolomite, some chert in nodules, even bedded, weathers deeply, Favosites, partly covered	45 ft.±

ORDOVICIAN SYSTEM

Richmond Formation

19.	Blue and grey limestone, calcareous mudstone, quite fossiliferous at many horizons	100 ft.±

Correlation of Silurian: - The correlation of various members ot the Silurian has been touched upon, in the foregoing pages under the heading of individual formations. A few remarks are necessary regarding the Silurian as a whole and regarding the Engadine in particular. In Ontario (Manitoulin Island) Williams (21, p.) divides the Silurian into (1) the Niagara group, including the Lockport and Rochester, and (2) the Cataract, including the Cabot Head with the Dyer

Bay lentil and the Manitoulin dolomite.

Beginning at the top with the Niagara group and the Lockport division, it appears from Williams' description that his Lockport is equivalent to our Engadine, upper Manistique and middle Manistique. The thickness of his Lockport is 200 feet on Manitoulin Island. The Engadine, upper and middle Manistique have a total thickness of 170 feet. A study of plate II, in which two Manitoulin Island sections are matched up as well as possible, makes it appear that Williams 200 feet includes strata equivalent to the lower Manistique as well as the Fiborn and possibly a part of the Hendricks. The line marking the base of the Lockport is usually based on the position of the Pentamerus layers by Williams, but these are not indicated in either the Campbell Bay or Manitowaning sections. It appears, probable therefore, that the line marking the base of the Lockport was drawn by reference to the Virgiana mayvillensis zone (Dyer Bay lentil). In that case, the Pentamerus oblongus layers are probably present at a higher level. These considerations lead to confusing results.

Attacking the problem form another angle we may start at Cabot Head where the details of the section are well worked out and described. There the Lockport is equal to the Michigan Niagara, down to and including a portion of the lower Manistique (14 feet below the Pentamerus layers). The Hendricks formation is taken care of by comparing the corresponding strata from the Manitoulin dolomite upward. This would leave the Fiborn unaccounted for. It is not unlikely that the equivalent strata are missing at Cabot Head. Farther north, however, the writer feels, they should come in. He believes that they will be found on Cockburn Island and also on Manitoulin Island. They may not be present as high calcium limestones, but they should be represented by dolomites or dolomitic limestones.

The above correlations have not satisfactorily accounted for the equivalence of the Engadine. Williams description of his Lockport from Cabot Head north is not very definite. He describes it (21 p. 62) as "generally thick bedded to massive typical dolomite, blue, grey, or less commonly buff on fresh fracture and weathering white". This description applies better to the Engadine formation than

to any other part of the Niagaran. In the Summary Report for 1912 (p. 275) Williams says "In the 240 foot section measured north of Fossil Hill a sparing coral fauna starts about 80 feet up in the formation and attains its maximum about 100 feet up in the formation and attains its maximum about 100 feet above the base. The upper 30 feet of the Lockport is massive and nearly unfossiliferous." In this article he also gives a list of fossils of the Engadine and concludes that it is probably NOT of Guelph age. He also mentions that Dr. H. M. Ami shares the same opinion.

A clue may be gained from the Eramosa beds which Williams says "occur at the top of the Lockport formation throughout the western peninsula of Ontario and on the islands to the north as far as Fitzwilliam Island. --- On Manitoulin Island the Eramosa beds have not been recognised and appear to have been eroded away. The Eramosa beds are thin even bedded argillaceous, arenaceous and bituminous dolomites. They are just the kind of rock which would form a striking contrast to the Engadine after prolonged erosion. The latter would resist erosion and produce an escarpment with a steep face to the north in upper Michigan and a long gentle, southward dipping slope because of the removal of the less resistant Eramosa beds. This is exactly the condition in Manitoulin, Cockburn, Drummond Islands and the mainland as far as the St. Ignace peninsula. It is this condition which has made possible great pre-glacial valleys in the areas to the south which are now occupied by the Great Lakes.

Again Williams says (21 p. 57) "this dolomite (Lockport) gives rise to the most conspicuous of the Paleozoic cliffs, and outcrops in almost unbroken extent from Niagara Falls where the water pours over its very top, to Cockburn Island at the head of Lake Huron." Certainly this description must apply to the Engadine in Michigan, as no other part of the Niagaran or any other adjacent formation could form cliffs 200 feet high such as are present at Manitowaning and Campbell Bay. Hence it seems safe to assume that the Engadine is the top part of the Lockport of Williams on Manitoulin and Cockburn Island.

As regards the correlation of the Cataract, the reader is referred back to the discussion under Manitoulin dolomite and succeeding pages. It is shown that a portion of the Cataract is probably equivalent to the Hendricks in Michigan with the very critical Virgiana mayvillensis zone coming in about 30 feet from the top. Williams says (21 p. 44) "The presence of Virgiana mayvillensis in the Dyer Bay dolomite clearly establishes its equivalence with the Virgiana zones described by Savage. As the Dyer Bay dolomite which is near the top of the Cataract formation is of upper Edgewood age, it seems probably that the remainder of the Cabot Head shale and the Manitoulin dolomite are of lower Edgewood age."

Savage and Crooks (19) make the statement that the Hendricks and Fiborn are really equivalent to the Mayville of Wisconsin. They list fossils from the Fiborn and Hendricks which indicate equivalence with the Edgewood of Illinois. They compare the thickness of the Hendricks (145 ft.) with that of the Mayville in Wisconsin (149 ft.) as being a suggestion along similar lines. They mention finding Virgiana mayvillensis atBlaney and north of Hendricks. All of which leads to this final conclusion, that the Fiborn and Hendricks of Michigan correspond to the Edgewood of Illinoi and are thus much older than the Niagaran. Incidentally, one statement is made which was verified by G. M. Ehlers. They state that on the west side of Lime Island casts and moulds of Virgiana mayvillensis are abundant in a bed of coarse cream colored dolomite which corresponds to the Hendricks. The writer Has not visited this locality personally, but G. M. Ehlers states that he visited the locality and reported his find to Savage.

In 1921 G. M. Ehlers (4) suggested a new classification for the Silurian rocks of northern Michigan. He proposes the following names in descending order (1) Racine (2) Manistique (3) Burnt Bluff (4) Mayville. The Racine is to include the Engadine and a considerable thickness of overlying strata. This seems wholly in accord with Savage? (1) who correlates the Racine of Wisconsin with the Guelph

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(1) Bull. G.S.A. XXVII, #2, 1916.

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of Ontario.

The Manistique is to include what is called in this article the upper and middle divisions of the Manistique down to the base of the lower Pentamerus layer. This also seems a logical enough arrangement, because these beds are both faunally and lithologically distinct from the rest of the section.

The Burnt Bluff formation then would include what is here called the lower Manistique, the Fiborn, and a part of the Hendricks, down to the Virgiana Mayvillensis beds (Dyer Bay of Williams). The Mayville would include what is called in this report the Hendricks from the top of the Virgiana mayvillensis beds down to a lower limit, which is not given because Ehlers says the base has not been seen. Williams includes this interval in his Cataract, but Ehlers thinks it is younger. Ehlers also thinks the Burnt Bluff is Niagaran in age in distinction to Savage & Crooks (19) who believe it is Alexandrian in age.

Summary: - In conclusion it may be well to summarize briefly the main points developed in the preceeding discussion. The following table of formations in Chippewa County will help to clarify the stratigraphy of this part of Michigan, and, it is hoped, serve as a basis of comparison for other regions. In this table the writer has tried to show the boundaries of the various formation names suggested by previous writers. It will be seen that in Chippewa County the names suggested by Smith were used as far as possible. Smith based these on studies which he made on the mainland, but there outcrops of layers lower than the very top of the Hendricks are missing. On Drummond Island the lower Hendricks crops out as well as portions of the section below the Hendricks. The names used for these formations are largely taken over from Williams as a result of his studies on Manitoulin Island, which lies close to Chippewa County in Ontario. The writer still feels that more careful work on the 200 foot cliffs on Manitoulin Island will reveal the presence of the lower Manistique and the equivalent of the Fiborn. Hence the writer has taken the liberty to indicate that a portion of Williams Lockport is equivalent to these two. The Hendricks in Chippewa County has been limited to the dolomites about the above the Cabot Head shales. It has been subdivided into two parts on account of the Virgiana mayvillensis zone.

TABLE OF FORMATIONS IN CHIPPEWA COUNTY

Smith	Ver Wiebe	Williams	Ehlers	Savage
Engadine	Engadine 55	Lockport	Racine	
Manistique	Upper Manistique 95 Middle Manistique 25 Lower Manistique 37	Lockport	Manistique	
Fiborn	Fiborn 22	Lockport (?)	Burnt Bluff	Alexandrian
Hendricks	Upper Hendricks 40 Lower Hendricks 12	Cabot Shale		
	Cabot Head Shale 35±	Dyer Bay Cabot Head Shale	Mayville	
	Manitoulin dolomite 95±	Manitoulin dolomite		Edgewood

ORDOVICIAN SYSTEM

Rominger etc.	Ver Wiebe	Foerste
Richmond	Richmond 150±	Richmond 127
Lorraine	Lorraine 215	Maysville 150±
Utica	Utica 50	Eden 102
		Collingwood 22
Trenton	Trenton 100±	Trenton
Calciferous	Black River 190±	Black River 80
		Lowville (Leray div. 11 ft.) " " (Lower " 70 ft. shales)
Potsdam	Lake Superior	

The Ordovician rocks do not crop out very satisfactorily in Chippewa County. The records of the Neebish well, Pickford well, & St. Ignace wells have therefore been used to make up the deficiency, guided, however, by Foerste's section on Manitoulin Island. It is felt that the conclusions as to thickness and character of the individual formations are as good as can be reached without further paleontological studies.

The writer believes that the Lake Superior sandstone represents horizons from the Cambrian up to and including the St. Peter. The fossils found in this sandstone at Sault Point help to clear up its stratigraphic position, considerably as they indicate a Canadian or Ozarkian age according to Ulrich. They will not be conclusive, however, as this sandstone appears to have been laid down over a very irregular pre-Cambrian topography. Therefore it may begin in a portion of the stratigraphic column which would be equal to the Potsdam of New York, at one point while at another point it may represent a portion of the column much higher up. Because of the general absence of fossils it will always remain a difficult problem to determine its age at any given place.

GEOLOGY OF CHIPPEWA COUNTY.

Part II. Surface Geology

Introduction:- After the last Silurian sediments had been deposited and had been lifted above sea level, a very long period of erosion began in Chippewa County. For the county does not show any evidence of having been submerged below sea level subsequently. The work of weathering and stream erosion gradually changed the almost flat area to one of considerable relief. At a much later date, and comparatively recently, an ice sheet encroached upon the area from the north and filled up a great many of the depressions with rock fragments that had been gathered on its southward advance. During the retreat of the ice sheet, temporary lakes were formed which soon gave way to much larger bodies of water that occupied the site of the present great lakes and portions of Chippewa County as well. The deposits made in these lakes filled up the depressions in the ice deposits and are responsible for the rather level topography of most of the county.

Pre-glacial Topography: - Before the continental glacier covered Chippewa County the topography was quite rugged. An almost unbroken line of cliffs extended along the southern line of the county or just across the line in Mackinac County. These cliffs were 50 feet high at many points and as much as 150 or more at some places. They were due to the superior resistance to erosion of the Engadine dolomite, which produced long southward sloping terraces and a steeply sloping face to the north. Somewhat farther north was a lower line of cliffs and hills extending from a point about five miles north of Hulbert toward the east past Brimley, through Dafter and McCarron to Neebish Island. Between these two lines of hills the path of an ancient stream is clearly marked out by the records of many artesian wells. It flowed approximately west to east into the embayment now known as Munuskong Bay, thence southeast toward the sea. Numerous short tributaries came into it from the high cliffs to the south. One of the largest of these flowed north just a little west of the site of Rudyard. Another flowed past Pickford on the west and still another past Stalwart. The position of these smaller streams is clearly suggested by the reentrant angles in the boundary lines between the stratigraphic formations.

The difference in relief of pre-glacial times compared with the present is brought out by two examples. In the hills 6 miles southeast of Rudyard the elevation is 895 feet a t the top of some limestone cliffs. In Rudyard the present elevation is 685 feet showing a difference of about 210 feet. The G. F. Thornton well, drilled down to rock, is 367 feet deep. Therefore, the pre-glacial relief amounted to 577 feet between the two places, and it was more than twice as great as at present. Another good illustration is furnished by the Pickford well. The hills south of Pickford, about four miles, rise to an elevation of 875 feet. At the village the present elevation is 605 feet above sea level. A well drilled for oil penetrated 132 feet of surface deposits before striking hard rock. The present relief therefore, is 270 feet and the relief during pre-glacial times was 402 feet. Rudyard was probably close to the line of the ancient stream which therefore had an elevation of about 138 feet, but Pickford, with a rock elevation of 473 feet, was probably three miles south of the stream.

The only illustration of the relief north of the northern line of cliffs which the author can mention is the information furnished by two places near Brimley. The Trenton rock comes to the surface at a point three miles south of Brinley where it has an elevation of about 665 feet. Brimley has an elevation of 666 feet or practically the same. A deep well drilled within the village limits (creamery well) shows 392 feet of clay. The rock is probably not far below the bottom of the well. This would indicate a relief of at least 392 feet in a distance of three miles. Incidentally, another well drilled only one and one half miles west of Brimley is on the line of a north flowing tributary of another stream or of the ancient Lake Superior. Furthermore, it indicates a great difference of relief (about 240 feet in a mile and a half) provided the shallower well is as close to the rock basement as the deeper one.

Glacial Deposits

The record of the Wisconsin ice sheet in Chippewa County is not as complete as might be desired on account of a cover of lake deposits. Yet enough of the typical ice deposits are present so that we can reconstruct a picture of conditions that

existed during Pleistocene times. A more or less continuous zone of marginal moraine suggests that the ice stood across the county from northwest to southeast for some time. The till plains which were formed at the same time or previously have been obscured almost entirely by lake sands and clays. One large area of outwash material is still to be seen. One esker three miles long and a portion of another one have been preserved. Each of these features will be described briefly.

Gatesville Moraine: - One rather prominent marginal moraine extends from section 28, T.42N., R.3E., in a northwesterly direction to section 28, T.44N., R.1E. a distance of fourteen miles. At its widest point it is only three miles wide and on the average it is about one mile wide. It has been reduced in size considerably by the action of waves as well as by deposits made in lake waters. For instance, on the northeast side there is a beautiful wave cut cliff which can be followed a distance of over six miles. It is 35 feet high along most of this stretch and was made by the waters of Lake Nippissing. One rather noticeable fact about the Gatesville moraine is its remarkable flatness especially in the northern part. No doubt this is due to the levelling influence of the waters which have covered it. A great deal of the northern part lies at an elevation of 670 feet, farther south the elevations rise, until, west of Gatesville, an elevation of 760 is reached. Erratic boulders are not very common on this moraine except at isolated points. In section 27, T.43N., R.2E., there are quite a number of large blocks of Engadine dolomite. This rather remarkable occurrence was discussed in part 1 of this report. Farther south most of the erratic boulders are intimately associated with the old lake beaches of which there are quite a number. In composition it may be said that this moraine is predominately sandy.

Kinross Moraine: - The Kinross moraine consists of five fragments which were once connected extending from section 13, T.45N., R.3W., on the northwest to section 36, T.44N., R.1W., on the southeast. The largest fragment is the one which runs from the village of Kinross to the northwest. It covers about nine square miles. It also has suffered by the attack of waves of Lake Algonquin, for the 730

foot water level may be followed around it without trouble. Its western end is very flat lying at an elevation of about 750 feet. Erratics are scarce except at favored localities as for example at the quarter corner between 15 and 16 of T.45N., R.2W., where they are numerous. One enormous jasper conglomerate was observed in the northwest corner of section 25, southeast of Kinross. The second fragment ofthis moraine lies in section 21, 22, 27 and 28 of T.45N., R.1W. The third fragment is somewhat larger and lies along the Meridian road centering around section 1, T.44N., R.1E. It is rather lower than the other two fragments described lying at an elevation of about 670. Erratic boulders are fairly common and are well distributed. The fragment which lied in sections 20, 21, 22, 27, 28 and 29, T.44N., R.1W.is also low and poorly defined. Quite a few boulders of Trenton limestone were noted on this part of the moraine. Finally there is a tiny remnant left in section 36, T.44N., R.1W., one half mile from Pickford. It is but a few acres in extent and is chiefly interesting because it shows how moraines can be buried by lake deposits, for this one is surrounded on all sided by Algonquin lake clay.

Donaldson-Dafter-Morainic Group: - Another moraine which has been so covered by later deposits that only small areas remain will be called here the Donaldson-Dafter morainic group. It comprises one large area and fifteen small fragments extending from section 5, T.46N., R.1W. southeast to section 30, T.45N., R.2E. Most of these fragments show unmodified sandy boulder clay with numerous erratics. In other words, they have more silt and clay than the moraines previously described and are chiefly identifiable by the presence of erratic boulders. On the large area in Bruce township the erratics consist largely of Black River and Trenton limestone. The rest is made up of Lake Superior sandstone fragments and crystalline rocks.

This morainic belt probably extends across Neebish Island to St. Joseph's Island. On Neebish Island there are some very small areas which have a morainic aspect. These are located in sections 25, 26, 35, and 36. There are seven distinct and abrupt hills which rise strikingly out of the flat lake plain. These knobs are all very bouldery, in fact some of them consist of nothing but boulders of large

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size. The most numerous boulders are quartzite and have obviously been derived from the ledges now to be seen in the small islands between St. Joseph's and the mainland. Next in abundance are blocks of Trenton limestone. Finally, the remainder is made up of crystallines, chiefly granite. Two large jasper conglomerate boulders were also observed on one of the knobs.

Bay-Chippewa Moraine: - The largest area of moraine lies in Bay and Chippewa townships. Hence the names of these two townships are used in giving it a name. It covers about 200 square miles in the western part of the county. The northern portion extends from the Taquamenon River southeast nearly to Raco or Weller. This portion gives us the highest elevations in the county in section 34, T.47N., R.5W. where a small area lies above 1000 feet. All this portion of the moraine shows the effects of wave action, partly in built features, partly in the general levelling effect of shallow waters. For, in township 46N., R.4W., it is very evident that the original irregularities of the moraine have been replaced by much more moderate sags and swells. Also the material shows the influence of standing water as the surface is now composed almost entirely of sand. Boulders are lacking. Farther west in Bay township (46N., R.5W & 47N., 5W.) the moraine shows a more characteristic topography with considerable relief, occasional kettle holes, and abrupt knobs. The material also is closer to the original, inasmuch as there is a considerable amount of clay and silt mixed with the sand. Erratics are quite common. These consist almost entirely of crystalline rocks with an occasional piece of Lake Superior sandstone.

The southern portion of this moraine which lies mostly in townships 45N., R.6W. and 45N., R.7W. is strikingly flat, lying at elevations between 900 and 920 except at the western end where it drops off rapidly to the 730 foot water level of the middle (Battlefield) Algonquin lake. No erratics were seen, but cobbles and gravel are common, the rest being sand.

From the descriptions given above it will be seen that the moraines of Chippewa County have a number of charateristics in common. The most striking one is the fact that they are remarkably flat. Secondly, they are relatively free from erratic boulders.

This is partly to be explained by the fact that the Lake Superior sandstone formed a wide band of outcrop just north of the moraines and furnished boulders which crumbled readily. It is also due to the fact that the moraines have been covered with lake water, which tended to form a veneer of sand over everything.

Till Plains: - The till plains which may have been formed in Chippewa County are mostly obscured by later deposits. They are usually formed under the ice during a continuous retreat and typically should be expected behind marginal moraines. In typical cases, also, they should differ from marginal moraines in composition, containing a greater proportion of clay. The only two areas of any size which show the characteristics of till plains are the region between Detour and Gatesville (see map, fig.) and the island of Drummond.

On Drummond Island there is only a thin veneer of glacial material as the rock crops out over large areas, and at other places is under thin cover. The till plain material was originally clay with boulders in which the clay probably predominated. Now, much of the clay is lacking so that the boulders predominate. These boulders have been rearranged into spits, bars and other shore features by the successively lower stands of water, so that now the island presents a very much mixed surface character.

The Detour area of till plain material is somewhat different. For one thing, the glacial material is much thicker than on Drummond although there are isolated places where the rock comes to the surface. It is fairly typical boulder clay or a mixture of silty clay with stones. The excessive stoniness of much of this area suggests that here also the currents of water which rushed through St. Mary's strait removed much of the finer material leaving the coarser cobbles and boulders behind.

Drumlins: - In this connection it is logical to refer to the drumlins of Chippewa County. They are usually looked upon as a peculiar variation of a till plain, being of the same composition and structure but differing in form only. The form of a drumlin has been compared to that of a cigar which is cut lengthwise so that only half of it shows on the ground.

Seven drumlins were mapped on Drummond Island, but there are probably more of them in the interior portion of the island. They vary in length from a half mile to

about one and one half miles. In height they also vary somewhat, but taken on the whole are quite high. For example, the one which begins on the gravel road, known as the Johnswood road, in section 4, T.41N., R.6E., is 35 feet high at the blunt north end. A fire tower is located on this drumlin because of its favorable topographic position. Some of the other drumlins are over 50 feet above the low lands on the sides. The material of which these drumlins are composed is a somewhat sandy boulder till. In other words, they are not as clayey as might be expected. Indeed some of them seem to be made up largely of pebbles which is somewhat puzzling. The drumlin described above on the Johnswood road has a cut in it from which gravel was taken for the road surface. The trend of these drumlins is quite uniformly toward the southwest or, more precisely, from N.30 degrees E. to S. 30 degrees W.

It is interesting to compare these drumlins on Drummond Island with those near Cedarville (The Snows in Mackinac County). The latter differ in almost every respect. They are higher for one thing, reaching a height little short of a hundred feet. They are also broader and longer. In fact they are of immense size as drumlins go. In composition they are quite typical for they are made up of clay, largely, with boulders scattered through it promiscously. It is in trend, however, that they differ most radically. For the Cedarville drumlins point southeast instead of southwest. If this is an indication of the direction of ice movement as is usually believed to be the case, then we have a remarkable deflection of the ice for this part of the country.

Outwash Plains: - When the ice stands practically in one place for a long time, the water, which results from the melting of the ice, carries forward a great deal of the material laid down by the ice. Numerous streams form which are choked with sediment and wind about in tortuous channels in front of the ice. They are overloaded and therefore aggrading streams, depositing sediment in their own channels. As one channel is filled up the water flows along at one side until this new channel is also filled up. Near the ice front only coarse material, such as cobbles and gravel, is accumulated. Farther away small pebbles and sand accumulate; finally, only

sand is laid down. The latter is likely to form large, broad, flat areas stretching away for miles. Such deposits are called outwash plains.

In Chippewa County outwash plains are present at two places only. One of these is a strip averaging about four miles in width extending from the vicinity of Nodoway Point southwest to township 44N., R.5W. It is characteristically flat and composed of gravel and sand. Yet it is no longer in its original condition. The waters of Lake Algonquin have modified it considerably. The 865 foot water level is evidenced by many long gravel spits. The less clearly defined levels of 885 and 925 are also indicated by shore deposits. Wave cut cliffs which have produced strongly defined benches have been made at a x level of 855 and 840. In fact all these features strongly suggest that this area should really be considered a zone of successively lower offshore terraces. The only thing that seems to invalidate this conclusion is the fact that so much of the material is quite coarse. It is difficult to see how the undertow could move it.

Another outwash plain has been mapped east and southeast of Kinross (see map, fig.). This also shows the characteristic flat surface topography of typical outwash and is composed of fine pebbles and sand. For mile after mile this plain scarcely varies 15 feet in elevation. A disturbing feature, however, is the fact that this outwash is higher than the moraine with which it is associated (Kinross moraine). We must either assume that the moraine has been washed down to a lower level by Algonquin waters, or, that the outwash plain is in reality a part of the moraine which has been completely transformed by the lake waters. The latter assumption would mean that Lake Algonquin had stood at an elevation of about 760 to 780 for some considerable time. The 730 level of the lake has made a deep impression on this outwash area. It has produced a cut cliff 45 feet high that runs practically around the whole area.

Eskers: - An esker is a deposit of sand and gravel made by a stream flowing above, within, or under the ice. When the ice melts it is left as a sharp, narrow ridge often of great length. Two such eskers were found in Chippewa County. One

of them is located close to Sault Ste. Marie and runs through sections 23, 24, 25, 26, 35 of T.47N., R.1E., into section 2, T.46N., R.1E. In section 35, two gravel pits were being drawn upon during the time of the writer's studies. One of these showed the structure rather well and is reproduced in the diagram, fig. . It will be seen from the drawing that the central portion is well stratified and consists of sand and gravel well assorted. On the left is material poorly assorted, and coarse, consisting of cobbles and pebbles. These were layers formed above the others originally, but slumped down the sides when the ice retaining walls disapeared by melting. Much later, when lake water covered the esker, clay was deposited around the esker, but not over the top of it. It does, however, reach up some distance on the sides. In this gravel pit the width of the esker is 200 feet, its height is 20 feet. Its surface is covered with erratic boulders of crystalline rock and Lake Superior sandstone. Farther north it gets much higher and wider. In section 24 it branches, the main branch going off to the west. Much gravel has been taken out of it at this end.

Pickford Esker: - Three miles west of Pickford, beginning in section 3, T.43N., R.1W., is another well defined esker. It is a little over three miles long and only a small portion of this distance is in Chippewa County. Where it enters Chippewa County it is very low and pretty well obscured by Algonquin lake clay. A further disturbing feature is the fact that the Nipissing water level which was a rising one and therefore marked by strong shore features, stood within a few feet of the top of this esker. It might therefore easily be mistaken for a strong beach ridge. However, a gravel pit on the line between section 5 & 6 solves the problem. Several pictures taken by the writer at this point show very clearly that the Algonquin lake clay reaches up on the sides of the esker, proving that the esker existed before Lake Algonquin. The remarkable thing in this case as well as in the case of the esker near Sault Ste. Marie is that the clay did not completely cover the esker.

Trout Lake Eskers: - The village of Trout Lake is located in the southwestern part of the county. In the northern part of the village there is a high sandy

ridge. It varies in height from point to point reaching a height of over fifty feet in places. It may be traced for a mile or more to the west of the village and nearly three miles toward the east. In width it averages several hundred feet, being quite uniform in this respect. For most of the distance it trends nearly east and west, but at three or four places little branches go off at nearly right angles. Two of these may be seen in section 24, T.44N., R.6W. As indicated above, this ridge consists entirely of sand. In section 30 there are two short ridges which may be the beginning of the Trout Lake esker. One of them has a gravel pit in it which reveals the structure. It is made up mostly of limestone boulders and pebbles. It is 30 feet high, 120 feet wide and 1500 feet long. This ridge does not connect directly with the Trout Lake esker but is separated from it by a small gap. A companion ridge to the last one described, starts in near the eastern side of section 30 and crosses the section line into section 29 finally ending in section 20. It is not unlikely that the presence of the Engadine cliff a mile away had something to do with the inception of this esker and may explain some of its peculiarities.

Kames: - There are no typical kames in Chippewa County. A typical kame is a mound or knob of gravel and sand formed by water which has resulted from the melting of a portion of a continental ice sheet. It is most commonly found along the front side of a marginal moraine, but may occur on a till plain also.

Two miles south of Dafter there is a hill of coarse gravel and boulders which may be a kame. It is located in the southwest quarter of section 34, T.46N., R.1W. Two miles farther west are several small knolls made up of sand and small pebbles. They have the shape of kames. They are located on the north line of section 5, T.45N., R.1W. Six miles west of Pickford in section 29, T.44N., R.1W. are two gravel pits in a possible kame.

History of the Great Lakes

Introduction: - The history of the Great Lakes is a splendid illustration of the instability of the earth's crust. We are inclined to look upon the earth as 'terra firma' and those of us who live in the eastern part of the United States, far away from the earthquakes more common on the Pacific side of our continent, are perhaps more firmly convinced of this. Everyone will grant, however, that beaches and other features formed along the shores of a lake should be of the same height from place to place, inasmuch as the water level which was responsible for them makes almost a perfect plane. Now, if we find a beach line some thirty feet above the present water level of a lake, it is not hard to see that the water was once at the higher level and for some reason or other has dropped to the lower level. If we should follow along this former beach line and find that it gradually departed from the level of thirty feet above the present level and attained a height of forty and fifty and even more feet, then we have no alternative left but to believe that the land has risen different amounts. If we find a progressive rising in the beach line toward the north we must believe that the land to the north has risen by greater amounts as we proceed toward the north. This is exactly what seems to have taken place around the Great Lakes. The shores of lakes Superior, Michigan and Huron offer abundant testimony of former shore lines which have been elevated by different amounts.

These ancient shore lines had been noted as early as 1837 by Mr. Thomas Roy in the region about Toronto. Although mentioned subsequently by scientific men, no systematic investigations were carried on to determine their meaning until J. W. Spencer did his work in 1887 and '88. In his report on his findings Spencer proposed the name Algonquin for the most conspicuous raised beach of the Huron-Georgian Bay region, Lake Algonquin for the extinct lake and Algonquin River for its ancient outlet. He showed that the shoreline is not horizontal but rises toward the northeast at the rate of 4.1 feet per mile north of Lake Simcoe and 3 feet per mile south of it. In 1893 Frank Taylor began a series of investigations which have given us data of immense value, inasmuch as they cover the shorelines of all the

Great Lakes. After several years he worked out the shorelines of Lake Algonquin as well as its successor the 'Nipissing Great Lakes' and showed that the tilting of the land first suggested by Spencer applies to the whole region of the Great Lakes. Both these men first believed that the deformed water planes pass beneath Lake level. Later, however, it was found that they flatten out instead and run parallel to each other and to the present water level over the southern half of Lake Michigan, the Lake Algonquin level lying at 607 feet and the Nipissing level at 596 feet. Much credit is due in this connection to J.W. Goldthwait who worked out the deformed water planes first in eastern Wisconsin and later in western Michigan and in Ontario.

Lake Algonquin: - The history of Lake Algonquin in Chippewa County is particularly interesting because practically the whole of the county was covered by water at its beginning and sections of it gradually came up out of the water during its existence. The islands thus formed show many evidences of wave and current action, so that we have a particularly complete and varied record of events.

Lake Algonquin is the grand ancestor of the present Great Lakes. It was one large lake covering the sites of the present lakes Michigan, Superior and Huron. Its shores were roughly parallel to the present shore lines of these lakes but more of the land was covered by water than is now the case. The shorelines corresponded to the present ones most nearly in the region south of the hinge line. The hinge line is the line below which the land has retained its original elevation above sea level. The region northeast of the hinge line has been raised above the position it had before the continental glacier left. This hinge line for Lake Algonquin passes through Grand Bend, Ontario, Richmondville, Bayport, Standish and Frankfort, Mich. to a point a little south of Green Bay, Wis. According to Taylor and Leverett's map (25, Pl. xxl) all of Chippewa County except a small area in the northwestern part was submerged. The straits then reached from the Canadian Soo to a point some distance south of Mackinaw City.

Taylor divides the history of Lake Algonquin into a number of periods. The earliest period called 'Early Lake Algonquin' does not interest us because the area covered by water at that time lies south of Chippewa County (see map in 25). The second period is that of Lake Algonquin proper. This is further subdivided into three stages (1) Kirkfield stage, in which the waters escaped through a channel past Kirkfield, Ont., down to Lake Ontario; (2) Port Huron-Chicago stage, during which the water escaped through outlets at Chicago, Illinois and Port Huron, Mich; (3) closing transition stage leading to Nipissing Great Lakes in which the water started to flow eastward through Georgian Bay and past North Bay into the Ottawa River. The reason for this shifting of outlets is twofold. It was due partly to the rising of theland which began almost at the beginning of the Kirkfield stage and partly to the fact that lower outlets were uncovered by the gradually melting back of the front of the great ice sheet. Thus, early Lake Algonquin gave way to the Kirkfield stage of Lake Algonquin when the ice barrier which had covered the Kirkfield outlet retreated to a position farther northeast. The rising of the land, subsequently, raised the Kirkfield outlet higher than the outlets at Chicago and Port Huron, Mich. Therefore, the water flowed past these two places for a time although it seems that later most of it went past Port Huron, and the Chicago outlet was abondoned. This condition of affairs lasted for a long time, but finally the ice barrier which had blocked the low outlet past North Bay to the Ottawa River was removed and the water then started to flow to the Atlantic by that route.

Record of Lake Algonquin in Chippewa County: - The existence of Lake Algonquin in Chippewa County is proved by the presence of numerous features in the topography which can only be explained as the result of wave or current action in a large body of water. These features consist of sandy beaches, gravel spits and bars, cut cliffs and associated terraces formed at or near the shore, as well as great areas of sand and clay which were laid down in the deeper parts of the lake. We would naturally expect shore features to lie at the same elevation. However, as was explained previously, the rising of the land during the existence of the lake raised

the shore features so that they now lie in an inclined plane. This plane rises from south to north so that the same beach, for example, lies considerably higher in Mills township (T.47N., R.3W.) than in Rudyard township (T.44N., R.3W.). It is difficult to trace the same beach from place to place because of the rapid rate of rising. Therefore, such features as gravel bars which were built by shore currents from a prominent rocky cliff toward another one nearby furnish the best evidence of the position of the water level. In such places where there was an abundant supply of loose material the shore currents built spits or bars at successively lower levels as fast as the water dropped from one level down to the next. Perhaps the best place to study such a sequence is in the so called Dollar Settlement in the area surrounding section 19, T.47N., R.3W. On the section line north of sections 19 and 20 a series of beaches and cut cliffs can be made out which reaches from the Nipissing level at 640 to the fifth Algonquin beach at 865. These can be traced across to the north-south township line between ranges 3W. and 4W. Unfortunately one does not find a complete sequence at any one place, for the water level at a lower position may undercut one or more of the features formed at a higher level. The most nearly perfect sequence that the writer found is in Mackinac County a mile and a half below the county line in section 9, T.43N., R.2W. on a fairly high hill of Engadine dolomite locally called Sugarbush Hill. On this hill the following levels were recognized: -

890	Gravel	spit
875	"	"
855	"	"
845	"	"
825	"	"
810	Sand	"
780	Gravel	"
765	Sand	"

We seem to have here the ideal conditions for the preservation of a record of every level. There is a good supply of rock fragments at successively lower levels and the slope is steep enough to furnish a basement for the spits to form without being so steep that a lower water level will undercut a higher one.

This series of water levels was therefore chosen by the writer as a key series for all the other shore features found in the region. He believes that the 890 foot spit at this place represents the highest Algonquin level in this part of the upper peninsula. This hill does not extend much higher, but Maple Hill ten miles west reaches up to 1005 feet and the Engadine hill with the fire tower on it some four miles east of Trout Lake attains an elevation of 1020 feet. Neither of these have any shore features on them that would indicate a higher level except possibly the fire tower hill. This hill is covered with sand which probably has some relation to a shoreline. Most likely this sand is wind blown sand associated with the 890 foot water level.

Correlation of Beach Levels: - In deciding upon the identity and relative position of the beach levels found in Chippewa County the writer was guided by the excellent summaries given by Taylor in Mon. 55. On page 430 Taylor gives a list of wye-level altitudes of the highest Algonquin beach on the east side of Lake Michigan. The first four altitudes given are the following: -

Sault Ste. Marie, 6 miles north	1015 feet above sea level
Rexford, Michigan	930 " " " "
Hessel, Mackinac Co.	863 " " " "
Mackinac Island	809 " " " "

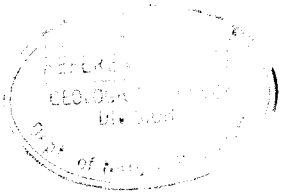
The first one of these the writer has not seen. The second one is probably a prominent gravel ridge and terrace which crosses the Roosevelt Highway in section 23, T.46N., R.4W., one half mile west of Weller station. The writer measured this elevation repeatedly on many different occasions and found that 925 would fit it as closely as could be determined by aneroid barometer. The elevation of 809 on Mackinac Island determined by Goldthwait is probably the highest to be found on

the island, but the writer does not believe that it is the representative of the highest Algonquin level. In other words Mackinac Island was probably under water when Lake Algonquin stood at its highest level. Mackinac Island lies about 18 miles south of Sugarbush Hill. The difference between 809 and 890 is 81 feet, or about 5 feet per mile rise in the intervening distance. This is too great to be logical, for the rate of ascent from Sugarbush Hill to Weller is only a little over 2 feet in a mile (890 to 925). More than likely the 809 beach on Mackinac is the same water level as the fourth (845) beach on Sugarbush Hill or possibly the third (855) beach at that place.

The beach at 863 at Hessel (three miles north?) also determined by Goldthwait, does not appear to be the representative of the highest Algonquin water plane either. It corresponds to the second Algonquin level at Sugerbush Hill.

In 1912 Leverett determined the highest Algonquin beach on St. Joseph's Island in St. Mary's River. He found a strong beach at 934 which he calls a storm beach. Another one at 930 he considers the average level of the highest Algonquin. These figures agree very well with the findings of the writer in Chippewa County.

Three Groups of Algonquin Beaches: - Taylor differentiates three groups of beaches, all of which were formed during the existence of Lake Algonquin (25, p. 415). The upper group on Mackinac Island covers an interval of 47 to 50 feet. Below these there is an interval of 25 to 30 feet without beaches. In the next succeeding interval are 3 or 4 beaches. These he names after the battlefield of 1814 on Mackinac Island, the Battlefield beaches. Still lower there is a group of 5 or 6 light beaches. These correspond to an interval found by Leverett in Sault Ste. Marie at Ft. Brady and therefore named by him Fort Brady beaches. Applying these group names the author has differentiated the following members of the upper or main group in Chippewa County.



Altitudes of Highest Algonquin Beach in Chippewa & Mackinac Counties.

Elevation	Location		Description
890	9, T.43N., R.2W.	Sugarbush Hill	Gravel spit
890	3, T.43N., R.4W.	Maple Hill	" "
880 ?	34, T.44N., R.5W.		" "
890	29, T.44N., R.5W.	Near fire tower hill	" "
905	17, T.45N., R.5W.	2 miles north of Strongs	" ridge
925	23, T.46N., R.4W.	1 mile west of Weller	" beach and terrace
930	10, T.46N., R.4W.	On moraine	Gravelly ridge

Altitudes of the second Algonquin Beach in Chippewa & Mackinac Counties.

875	9, T.43N., R.2W	Sugarbush Hill	Gravel spit
875	3, T.43N., R.4W	Maple Hill	" "
870	30, T.44N., R.4W.	Scott Quarry	" "
880 ?	34, T.44N., R.5W.	2 miles south of Dick	" "
890	27, T.45N., R.5W.	5 miles north of Dick	Sand ridge

Altitude of the third Algonquin Beach in Chippewa & Mackinac Counties.

855	9, T.43N., R.2W.	Sugarbush Hill	Gravel spit
860	30, T.43N., R.1E.	Rockview	" ridge
860	34, T.45N., R.5W.	Four miles north of Dick	Sandy "
880	31, T.46N., R.5W.	One mile south of Strongs	Gravel "
885	12, T.46N., R.6W	Four miles NW of Strongs	" spit
885 ?	15, T.47N., R.3W.	Near Nodaway Point	" ridge

Altitudes of the Fourth Algonquin Beach in Chippewa and Mackinac Counties.

845	9, T.43N., R.2W.	Sugarbush Hill	Gravel spit
860	31, T.46N., R.5W.	One mile south of Strongs	" ridges
885 ?	15, T.47N., R.3W.	Near Nodaway Point	" ridge

Altitudes of the Fifth Algonquin Beach.

Elevation	Location		Description
825	9, T.43N., R.2W	Sugarbush Hill	Gravel spit
825	20, T.44N., R.4W.	One mile N. of Scott Quarry	" ridge
830	(840?) 33, T.46N., R.6W.	4 miles E. of Hulburt	Cut Cliff
830	(840?) 26, T.46N., R.7W.	Hulburt, S. of station	" "
840	2, T.44N., R.5W.	3 miles N. of Dick	Sandy ridge
855	23, T.46N., R.4W.	Weller station (west of)	Cut cliff & terrace
865	30, T.47N., R.3W.	Dollar Settlement (S.)	Gravel bar strong
865	17, T.47N., R.3W.	" " (E.)	" " "
865	28, T.47N., R.3W.	Mills township	" ridge

Altitudes of the Sixth Algonquin Beach.

810	9, T.43N., R.2W.	Sugarbush Hill	Sand spit
830	21, T.46N., R.3W.	One mile E. of Wellsburg	Cut Cliff
840	15, T.47N., R.3W.	Near Nodaway Point	" " 45 ft. high

Altitudes of the Seventh Algonquin Beach.

780	9, T.43N., R.2W.	Sugarbush Hill	Gravel spit
775	6, T.42N., R.3E.	1 mile W. of Gatesville	" ridge very strong
775	20, T.43N., R.1E.	Taylor's Mill	" spit
815 ?	17, T.47N., R.3W.	Dollar Settlement	" bar

Altitudes of the Eighth Algonquin Beach.

765	8, T.42N., R.3E	1 mile s. of Gatesville	Gravel spit
760	3, T.42N., R.2E.	Four miles w. of Gatesville	" ridge strong
765	9, T.43N., R. 2W.	Sugarbush Hill	Sand spit
795 ?	17, T.47N., R.3W.	Dollar Settlement	Gravel bar

The Battlefield Group of Beaches: - This group of Algonquin beaches was first differentiated on Mackinac Island by Taylor. (25, p. 433). There the strongest member lies at an elevation of 719 feet with other members at altitudes from

703 feet to 734 feet. This group seems to have a well defined counterpart in Chippewa County. It was first recognized by the writer in the Kinross moraine. The main part of this moraine extending from a point 6 miles west of the village of Kinross, southeast and then across the outwash (?) to sections 4 & 11, T.44N., R.1W. about 6 miles southeast of the village seems to have suffered severe wave erosion and levelling at the time of the eighth Algonquin water level. It is quite flat on top and the elevations run around 750 to 780 over most of its area. The plateau thus produced is surrounded on practically all sides by a magnificent cut cliff 30 to 40 feet high. The base of the cut cliff lies at 730 feet.

In the Sugarbush Hill the beaches cease rather abruptly with the sand spit at 765, no others occurring in the interval between that elevation and 720. A very strong gravel ridge at 720 crosses the section line (quarter section line) in the north part of section 8, T.43N., R.2W. Later the writer found some very strong gravel ridges along rhe same isobase in the area between Gatesville and Detour. A gravel ridge which crosses the section line between 20 & 21, T.42N., R.3E. is 15 feet high and 50 feet wide at the base. It can be traced for a distance of three miles. A similar one crosses the main highway about one mile south of the first.

In the Dollar Settlement the Battlefield level seems to come at an elevation of 735. Above this level there is a complete absence of shore features for a considerable interval, thus corresponding to the interval found on Mackinac Island. The 735 foot level is marked by a cut cliff with a broad terrace in front of it upon which a number of parallel sandy barriers were noted. It thus develops to be a level marking a prolonged stand of the water of Lake Algonquin. A list of the principal places in Chippewa County where the Battlefield beach was found is as follows:

Altitudes of the Principal Battlefield Beach.

Elevation	Location		Description
730	SE¼ 4, T.41N., R.7E.	Drummond Island	Gravel ridge
720	NE¼ 7, T.41N., R.7E.	" "	" " on drumlin
720	NW¼ 3, T.41N., R.6E.	" "	" ridge

Elevation	Location		Description
720	SE¼ 29, T.42N., R.4E.	2 miles W. of Detour	Gravel ridge high
720	W½ 28, T.42N., R.3E.	8 miles W. of Detour	" " "
720	SW¼ 21, T.42N., R.3E.	9 miles W. of Detour	" " "
720	S½ 17, T.42N., R.3E.	10 miles W. of Detour	" " low
720	SE¼ 33, T.43N., R.2E.	5 miles SE of Stalwart	" "
730	NW¼ 35, T.45N., R.1W.	6 miles E. of Kinross	Cut cliff 40 ft. high
730	SW¼ 11, T.44N., R.1W.	8 miles SE of Kinross	" "
730	NE¼ 36, T.45N., R.2W.	1 mile S. of Kinross	" "
730	S½ 8, T.45N., R.2W.	5 miles NW of Kinross	" "
730	S½ 16, T.45N., R.2W.	3 miles W. of Kinross	Sand spit
730	SW¼ 29, T.45N., R.2W.	4 miles W. of Kinross	Gravel ridge
730	NE¼ 1, T.44N., R.4W.	3 miles N. of Fibre	Sand ridges
735	N½ 35, T.47N., R.3W.	4 miles NW of Brimley	" "
735	SW¼ 19, T.47N., R.3W.	Dollar Settlement	" " & cut cliff

The Fort Brady Beaches: - Fort Brady is located in the southwestern part of the city of Sault Ste. Marie. Here Leverett (see Mon. 55, p. 436) found a cut bench and cliff at an elevation of 699 feet, below anything that appeared to belong to the Battlefield levels, and distinctly above the Nipissing level. At other places, Taylor found a group of rather closely set, though light, beaches which seemed to constitute a group by themselves. On Mackinac Island he found beaches at five or more levels ranging from 653 (639?) to 691 feet which he includes with this group (Mon. 55, p. 437). At St. Ignace he finds five fairly strong ridges which belong to this group and states that the upper two are the strongest (662 & 678).

In Chippewa County there is considerable evidence in favor of setting off the lowest group of Algonquin water levels as a separate and distinct group. For, below the Battlefield level, shore features are missing throughout a considerable interval, at least 20 feet. Then there are a series of closely spaced beaches from about 690 down to 655. The best area for a study of these beaches is in the region

about Caribou Lake west of Detour. On the north road out of Detour (north line of section 33 etc.) a succession of beaches at different levels and at the same level may be found repeatedly. The elevation most commonly seen is 685, though others at 665, 675, 680 and 690 are common. The most remarkable spit seen in the county is the one which intersects the section line between 20 & 21, T.42N., R.4E. about 1/2 mile north of the southwest corner of 21. Its top lies at 690, but it was built out into deep water so that at its end it is fully 60 feet high. A small cut bench was made into it when the water stood at 670 and again at Nipissing level 635.

Raber Island: - During the existence of the Nipissing Great Lakes the water flowing through St. Mary's strait cut a small island out of the sand and clay deposited in Lake Algonquin. This island is located in section 17, T.43N., R.3E. and portions of the adjoining sections. This island was levelled off during Ft. Brady times and beach ridges at 675 and 680 were built upon it. They are gravel ridges five feet high and strongly developed. Farther north in St. Mary's strait it is hard to find any beaches of Ft. Brady age because the Nipissing waters undercut them and eliminated them. But to the west and north one or more of the beaches are occasionally present. At Taylor's Mill, for example, in section 20, T.43N., R.1E. there is a gravel spit at 695. Again at the Dollar Settlement there is a strongly developed cut cliff at 690. Farther west in the Taquamenon River region a strong bench at the same level is well developed.

Drummond Island: - On Drummond Island the Ft. Brady beaches are better displayed than any others. This is due to the fact that it is a low island with few places above 700, secondly, because there was so much rock material available for use in building beaches and other shore features and thirdly, because it lay in the direct current of the water surging through St. Mary's strait. Strong spits of gravel were seen at the four corners, two miles south of Drummond village, at 675 and 690. One mile east of the village is a strong beach ridge at 690. The drumlins seen along the road toward Johnswood have beaches on them or spits built out from them at Ft. Brady levels.

Altitudes of Ft. Brady Beaches in Chippewa County.

Elevation	Location	Description
675	NW¼ 31, T.42N., R.6E. Near Four Corners-Drummond	Gravel spit
685	NE¼ 31, T.42N., R.6E. " " " "	" "
690	NW¼ 31, T.42N., R.6E. " " " "	" "
665	S½ 31, T.42N., R.4E. 3 miles West of Detour	" ridge
685	SW¼ 28, T.42N., R.4E. 1 " " "	" "
690	SW¼ 21, T.42N., R.4E. 2 " " "	" spit
695	SE¼ 32, T.42N., R.4E. 1 " " "	Huge gravel ridge-trend N.50° W.
675	NW¼ 20, T.43N., R.3E. 3 " North of Raber	Gravel ridge
680	NW¼ 20, T.43N., R.3E. 3 miles N. of Raber	" "
695	NW¼ 20, T.43N., R.1E. Taylor's Mill	" spit
690	19, T.47N., R.3W. Dollar Settlement	Cut cliff & sand terrace
699	18, T.47N., R.1E. Ft. Brady in the Soo	Cut cliff & bench
685	NE¼ 24, T.45N., R.1E. 2 miles W. of Neebish Is.	Gravel ridge

Time and Rate of Tilting: - Now that we have differentiated the three groups of Algonquin beaches in Chippewa County and also have shown their correlatives from north to south or roughly along the axis of maximum tilting, it is possible to draw some general conclusions. The rate of tilting of the upper group of beaches is about 2.3 feet per mile. The rate for the Battlefield beach is almost exactly one foot per mile. For the Ft. Brady beaches the rate is about one foot in seven or five feet in 35 miles, which is less than .2 of a foot per mile.

It also appears from the data presented above that the time of tilting extended throughout Algonquin time. Tilting was going on rapidly at the beginning of Lake Algonquin time and became relatively less rapid as time went on. The amount of uplift between periods of stability varies from a small amount to as much as forty feet, the greatest figure being reached between Battlefield time and the eighth upper beach level. In the upper group of beaches 15 to 20 feet is the

usual amount of difference. In the Ft. Brady group 5 feet or less is the usual amount between beaches. For a discussion of the probable causes of this tilting of the beaches the reader is referred to Monograph 53 (25) page 503 and following pages.

Deposits in Lake Algonquin: - During the existence of Lake Algonquin from the time of the first water level to the end of the Battlefield stage great quantities of silt and clay were carried into the area which is now Chippewa County. The map (fig. No.) shows only the area which is now made up of clay deposits, but we must assume that a far larger area was originally covered by clay. Evidence of this is furnished by the streams which run through Lake and Kinross townships (44N. and 45N., R.3W. and 4W.). These streams have cut down through the sand deposits and reveal the clay in the lowest parts of their valleys. As Chippewa County was gradually tilted up during Algonquin time, the shoreline advanced over the areas in which clay was deposited at the beginning. Shore currents brought in great quantities of sand and distributed it in broad belts parallel to the shoreline. These belts of sand now obscure the clay.

The largest area of clay at the present time is to be found south of Sault Ste. Marie. It covers parts of townships 47N., R.1E., 46N., R.1E., 1W. & 2W. The next largest area lies in the vicinity of Rudyard. It covers practically all of the townships 44N., R.2W. & 3W., with small portions of adjacent townships. This area connects up by a narrow strip a mile wide with the Pickford area. This is an irregularly shaped area extending ten miles toward the southeast past Stalwart, 5 or 6 miles southwest into Mackinac County and six miles northeast. All these areas were relatively distant from the shorelines of the upper beaches of Lake Algonquin, hence the streams flowing off the moraines in the county, which brought sand and clay into the lake, were not able to carry anything but the finest material out to them. During the Battlefield stage considerable portions of the same areas were still distant enough so that only fine material reached them. In the rather rapid drop of about 50 feet from the Battlefield stage to the highest Ft. Brady water level very little sand accumulated on the clay, for a large part of it lies between these water levels.

Depth of the Clay: - The depth of the clay can be determined from the records of the borings for artesian water in the county. In the well records only clay is reported for a considerable distance down to the water bearing layer. This clay may be in part till plain material but very likely the greater portion is lake clay. Assuming that it is all lake clay then we find a very deep deposit near Brimley (392 feet). In Rudyard and the near vicinity the depth ranges from about 150 feet to 403 feet. The greatest thickness observed on the outcrop is about 60 feet at Sault Ste. Marie in the southeast part of town where the Nipissing waters have cut a high cliff into it.

Nature of the Clay: - The clay laid down in Lake Algonquin has some striking characteristics. It is fairly uniform in texture and entirely free from pebbles differing in this way from clay laid down by a glacier. Another feature which impresses the observer immediately is the flat topography. One may stand on the small morainic patches near Dafter and look off for many miles over a surface which is apparently as level as the surface of the sea. The surface of the plain drops gradually from about 715 near the 'Soo' to 690 at Dafter and 666 at Brimley, thus showing an inclination toward the south and southwest. The Rudyard plain lies mostly between 670 and 700. It drops off toward Pickford to the Nipissing level. Nearly all the Pickford clay area lies below Nipissing level at elevations ranging from 615 to 635.

Finally, the color of the clay is also striking. It is mostly of a deep red color. The reason for this color is somewhat problematical. It may be due in part to the fact that the clay was derived from the iron bearing soils which lay to the northwest before the ice advanced over the region and part of it was derived from the soft red shales of the Cabot Head formation. These two sources hardly seem valid enough to account for the universal red color of the glacial till and the lake deposits over so wide an area as it is found to-day. Some climatic factor such as the lack of vegetation and consequent absence of reduction processes may be partly or wholly involved as the controlling factor.

Sand Deposits: - Near the shorelines of Lake Algonquin we should expect

sand to be laid down. The Bay-Chippewa moraine furnished an abundance of sand and in the later stages of the lake the Kinross, Donaldson and Gatesville moraines also contributed a great deal. At the highest water level only a small portion on the Bay-Chippewa moraine was above water. This portion lies in the north part of township 46 N., R.5W. The water appears to have stood at this level for a long time, for there is evidence that the waves cut back into the moraine for a distance of four miles (near Rexford) producing an offshore terrace 6 miles long and 4 miles wide. On the flat moraine 5 miles south of Strongs which occupies most of township 45 N., R.6W. (see map, fig.) the elevations range from 900 to 920. This is just about the level of the highest water plane of Lake Algonquin in this part of the county. Here we probably have a case of a moraine completely cut down and levelled by Algonquin waters. A great portion of it is a sandy plain which may be an offshore terrace.

The broad belt of sand which extends from Waiska Bay southwest through Kinross and Lake townships to Alexander and thence west past Trout Lake (see map, fig.) represents shore line deposits of various kinds and formed at different levels. Part of it is a beach deposit and part of it offshore terrace deposit. Some, no doubt, is also wind blown material piled up at some stage in the period when the upper set of beaches was made. In the discussion preceeding, the writer has described eight levels of Lake Algonquin as the upper beaches. This belt is about eight miles wide on the average. Hence we can imagine the water level of the lake dropping to successively lower levels and each time exposing roughly one mile. It is conceivable that wave action and undertow combined might cover such a width and spread a thin sheet of sand over it. If we add the amount blown by the wind we can see how this sand belt came into being. Another sand belt stretches west from Strongs to the edge of the county. This area reaches down to lower levels than the other one. Besides the sand accumulated at the eight levels of upper Lake Algonquin, there is also much sand that was accumulated when the lake stood at the Battlefield level. The area shown on the map as sand north of the Kinross moraine and also south, and for some distance west of that moraine, is no doubt a Battle field shore deposit, most of it being in the nature

of an offshore deposit made by the undertow. The only other considerable sand area of Algonquin time is the one in township 42N., R.2E. This also seems to be mainly a deposit made as an offshore terrace at the time of the Battlefield water level. An interesting remnant of an Algonquin sand plain destroyed by Nipissing waters is Raber Island. This island lies north of Raber about two miles and has remnants of Ft. Brady beaches on top.

Nipissing Great Lakes

The Nipissing Great Lakes were named by Taylor (25) in 1893 and were so named because the lakes were then, as now, practically separated from each other. Lakes Superior, Michigan, and Huron (including Georgian Bay) are the great lakes designated by the name Nipissing at a time in their history when the water flowed out past North Bay in northern Ontario and thence through the Ottawa River to the sea. This northern outlet had previously been blocked by a small ice barrier. With the melting of the ice or the removal of the barrier in some other way the water in Lake Algonquin dropped about ten feet and flowed across the col at North Bay. This event inaugurated a period of stability which lasted a long time. Nevertheless the upward movement of the land in Ontario and Quebec continued with the result that finally the outlet at North Bay became as high as the present outlet of Lake Huron at Port Huron. For a long time thereafter, both outlets were in operation. Finally, with continued uplift, the northern outlet was abandoned and all the water left the upper three lakes by way of the Port Huron outlet. This event marks the close of the Nipissing Great Lakes.

Shorelines of Nipissing Great Lakes: - The shoreline of the Nipissing Great Lakes now lies about 15 feet above the level of the present Great Lakes in the area where it has remained undisturbed. North of the hinge line which is the same as the one described above for Lake Algonquin, there are three definite levels at which the water stood. When the water escaped through the North Bay outlet a beach was formed which may now be found only north of the isobase of North Bay. For, south of this line the water was gradually rising as the land was being tilted upward toward the northeast. A line drawn through North Bay and connecting all points which have been elevated the same amount has been called a nodal line or isobase. Acoording to Taylor (25, p. 449(this isobase runs westnorthwest and only a little of Lake Superior

lies north of it. For our purpose, therefore, it will be unnecessary to say more about the earliest shoreline of the Nipissing Great Lakes.

Nipissing Beach: - The shoreline formed during the time when there were two outlets should be strongly developed near the isobase of the northern outlet, for along this line the water plane stood continuously at the same level and the waves worked for a long time. South of the isobase it should become weaker since the water plane was rising and had to rise higher and higher progressively toward the south. A rising water plane doubtless assisted the waves in the work of cutting back the headlands so that cut cliffs are to be expected where the topography was marked by steep slopes. Where the shoreline was sloping and wave deposition was more predominant, we should expect high and strong beach ridges to be formed. Also we should expect to find many broad, wave cut terraces strewn with sand. An examination of the portions of Chippewa County which lie close to Lake Superior and St. Mary's River reveals abundant evidence of a beach showing such strength and individuality. This beach although it was made at the two outlet stage of the Nipissing Great Lakes, is usually called the Nipissing beach, and this use will be followed in this paper.

In Chippewa County the Nipissing beach is almost always a prominent cut cliff with a terrace in front of it. This terrace was originally a terrace due partly to wave cutting and partly to deposition by the undertow. The original terrace is commonly obscured by sand which was brought in by shore currents and worked over by waves and undertow. Other shore features such as spits, bars, beach ridges and barriers are exceptional.

Beginning at the Taquamenon River (see map, fig. No.) the Nipissing level is marked by a cliff of varying height as far as Pendell's Bay. In this stretch the waters have cut into the moraine. In the protected bays, such as the one just west of Neomekong Point, the wave cut terrace is preserved, because the waves cut into Lake Algonquin clay. (see map, fig. No.). Half way across Pendell's Bay the waves cut into Lake Algonquin sand deposits. Here the shore currents from Nodaway Point built a bar toward the southwest of small pebbles and sand. This bar now holds in a small lake known as Pendell's Lake. On the other side of Nodaway Point bars and barriers have similarly hemmed in Spectacle and Monacle Lakes. Wave action on the

northeast side of Nodaway Point seems to have been particularly violent, for here (Mission Hill) we have the highest cut cliff in the county. The terrace at the top of the cliff lies at an elevation of 815 feet making a cliff 175 feet high. In the distance from the Taquamenon River to Nodaway Point the cut cliff lies at 640 feet above sea level (40 feet above Lake Superior).

Continuing east, we find that the cut cliff continues into Waiska Bay, cutting into sand deposits of Lake Algonquin. At Brimley it was cut into the clay deposits of the former lake. Here again, we find a small gravel spit, between the village and the bay. Thence eastward the cut cliff continues as far as Sault Ste. Marie. In the southeastern part of the town the cliff is 50 feet high. The cut cliff now turns and trends south as far as the Donaldson moraine and is cut back into the clay of Lake Algonquin. In this stretch it still maintains its elevation of 640. One peculiarity noted in this distance is the presence of boulder walls evidently due to ice. A good place to see these is in section 15 (southwest corner) of T.46N., R.1E. Here the boulders consist of crystallines and Lake Superior sandstone pieces some of which reach a size of two feet in diameter. One mile west the cut cliff fades out and its place is taken by an ice rampart consisting almost entirely of cobbles and boulders with but little cementing material. In the southwest quarter of section 15 are two small islands cut out of the Algonquin Lake plain by Nipissing waters. Two similar tiny islands were seen farther north, one in the southeast quarter of section 27, T.47N., R.1E., and the other in the northeast quarter of section 34 adjoining on the south.

South of McCarron the Nipissing cut cliff trends southeast around the end of the Donaldson moraine, then bends back sharply to the west toward the Meridian road which it crosses in section 25, T.45N., R.1W. It now continues almost south cutting a cliff into the easternmost portion of the Kinross moraine. It crosses the meridian again in section 19, T.44N., R.1E. From there on to the south and west it is difficult to follow because the cliff is very low and ill defined. It leaves the county in the southwest quarter of section 34, 3 miles west of Pickford and then runs parallel to a small esker due west three miles, where it reenters Chippewa County. From there it can be followed to the southeast through township 43N.,

R.1W., to section 24 where it crosses the meridian and enters Chippewa County once more. From here east as far as Stalwart, where it turns sharply north, it is poorly defined. Thence northwest toward Pickford around the west side of the Gatesville moraine it becomes more prominent again and is represented by a three foot cliff on the section line road 2½ miles east of Pickford. It now skirts the north end of the moraine as a plainly defined cliff gradually gaining in height, turns east in section 26 and south in section 27.

On the east side of the Gatesville moraine the Nipissing water level has cut a very prominent cliff which averages about 35 feet in height. The cliff is very distinct to section 26, T.43N., R.2E. It becomes prominent again near Raber and from there it can be followed parallel to the coast and within a mile of it down to Maud Bay. In Detour and southwest of this town there are quite a few gravel spits and bars at Nipissing level.

Raber Island: - An interesting topographic feature is an island about 2 miles in area which was carved out by Nipissing waves. This island lies in section 17, two miles north of Raber and in portions of adjoining sections. This island is bounded on all sides by a cliff as high as 45 feet in places.

Neebish Island: - Practically all of Neebish Island is too low for any beach higher than the Nipissing. There are four tiny morainic knobs in the southeastern part of the island which reach somewhat higher. In the northcentral part of the island is an area of about four square miles which was above Nipissing level. It is bounded by a cut cliff at an elevation of 635.

Drummond Island: - Drummond Island rises to somewhat greater elevations than Neebish. The portions which were above Nipissing level take in about half of the area of the island (see map, fig. No.). Cut cliffs may be seen at a number of points, but they are not nearly so prominent as on the mainland. This is due to the fact that Drummond Island consists chiefly of rock outcrops, whereas the mainland areas attacked by Nipissing waters consist largely of unconsolidated deposits such as lake clay. The waves could make rapid headway in the latter, but did not have enough time to modify rocks to any extent.

Altitudes of Nipissing Beach: - It is not advisable to give a list of the altitudes of the Nipissing beach at a number of places in Chippewa County because the difference is slight. In the southern part of the county the beach lies at an elevation of 634 to 635 and in the region of the 'Soo' at 640 to 642. Two miles northwest of Shelldrake the Nipissing lies at 642 which is about as high as it was observed at any point. This is a difference of 8 feet in about 40 miles, or at the rate of one foot in five miles. At Mackinac Island it lies at 631.

Deposits in Nipissing Great Lakes: - During the existence of the Nipissing Great Lakes deposits of sand and clay were made in Chippewa County. These deposits occupy a belt of varying width along the shores of Lake Superior, St. Mary's River, and Lake Huron. At Whitefish Point some 15 square miles are covered with sands and gravels of Nipissing age. From there south the belt averages a mile in width as far as the Taquamenon River. At the mouth of this majestic river an area of 25 square miles was built up by deposits in Lake Nipissing. From there to Neomekong Point the deposits consist of clay, chiefly. From Neomekong Point to Nodaway Point, and beyond as far as Sault Ste. Marie, there is a narrow strip of sand which rarely attains a greater width than two miles most of which has been accumulated as offshore terrace deposits. From Sault Ste. Marie southward the sandy Nipissing belt is somewhat wider and reaches to the River. South of this river only clay was laid down as far south as section 18, T.45N., R.2E. On the north side of Munuscong Bay the Nipissing deposits cover 20 miles or more and consist of sand on the north side of the Munuscong River. South of that stream there is a large clay area which reaches to Pickford and beyond, making a deep cul de sac embayment which reaches to section 6, T.43N., R.1W., nearly to Rockview on the south, and within a half mile of Stalwart on the east. This old Pickford embayment was sheltered behind a peninsula 8 miles long that had been carved out of the Gatesville moraine by Nipissing waters. It was a heritage from Lake Algonquin and it is probable that only a thin veneer of Nipissing clay was laid down upon the Algonquin clay.

On the northeast side of the peninsula where shore currents were more active a broad sheet of sand was laid down which covers an area of nearly 40 square miles between Munuscong Bay and Raber. In this area a small remnant of clay has remained

uncovered. It lies just west of Raber Island. From Raber to Detour only a narrow ribbon of sand marks the site of Lake Nipissing. Similarly from Detour west along the shore of Lake Huron there is mostly sand. An interesting modification of the shoreline in this stretch is the Albany Island tombolo. Shore currents drifting sand along the shore have tied the former island known as Albany Island to the mainland by means of a sand bar.

At many points the Nipissing sand forms only a thin surface cover over clay which was laid down at an earlier date. For instance on the west side of Hay Lake a number of artesian well records indicate that it is only 10 to 15 feet deep near the river and gradually thins out toward the west. The soil map brings out the areas in which the sand is thinner than three feet. Again in the Whitefish Bay area well records at Emerson indicate the sand is only 17 feet thick at Emerson (see part III of this report).

The Algoma Beach: - The Nipissing Great Lakes came to an end when all the water was discharged by way of Port Huron or in other words when the outlet at North Bay was definitely abandoned. This event therefore, marks the beginning of the history of the present Great Lakes. During the existence of these lakes their outflow waters have cut down the outlet about 12 feet, which has lowered the plane of the shoreline that amount. In addition, the tilting which was so prominent in previous periods, seems to have continued. For, the evidence of a prolonged stand of the waters is clearly indicated in the Algoma beach.

The Algoma beach was first observed and named by Taylor (53, p. 464). He noted it at Algoma Mills on the north channel of Lake Huron in 1893, where it was found to lie about 50 feet above Lake Huron (630 A.T.). Since then he found the same strong beach at a number of other places farther south. Leverett and Hobbs have also reported the beach. In Chippewa County the writer was impressed by the strength of a shoreline about half way between Nipissing level and the present one, and noted it at many places. It is particularly well displayed on Neebish Island and Drummond Island. On the mainland it is best developed in the vicinity of Raber Island. Practically everywhere this beach lies at an elevation of 615 feet (or 25 feet above Lake Huron).

On the shores of Whitefish Bay this water level is indicated usually by a cut cliff, as for example at the Dollar Settlement. In some parts of this stretch it is represented by sandy beaches which have been obscured or built higher by wind drifting. It is in St. Mary's Strait that we find the best evidence of this shoreline. There it is displayed as remarkably strong gravel and cobble ridges. These are doubtless due in large part to the work of shore ice rather than of waves. Such a boulder beach may be seen in the southeast part of section 22, T.47N., R.1E. The boulders are mostly of large size, ranging from a fraction of a foot to several feet in diameter. The boulders consist of granite, diorite, quartzite and Lake Superior sandstone. Some sand and small pebbles are present. A very fine gravel spit at Algoma level was seen in the southeast quarter of section 35, T.45N., R.1E.

Neebish Island: - For anyone who is interested in ice ramparts and boulder beaches Neebish Island is indeed a choice spot. Nowhere else has the writer ever seen such a marvelous display of these shore features. The north central part of the island was a small island (see fig. No.) in the Nipissing Great Lakes and is surrounded by a cut cliff. On the terrace below this cliff there is a great profusion of boulder beaches in all directions. These are most accessible in the southern and southeastern part of the island. The main travelled road of the 'Encampment' or O-Non-E-Gwud Inn, crosses these ridges at a number of places. In the southeast corner of section 23, is a ridge about five feet high. One mile south is another, even better ridge. It is a spit built out from a morainic fragment lying to the east, which consists of almost nothing but large boulders. One and a half miles west of this point are some lower beach ridges, more gravelly and sandy with quite a few boulders. In the middle of the section is a high morainic knob which has furnished material for the building of more ridges. The top of the knob lies at 680, or 65 feet above the Algoma level, yet it covers but a few acres in area. Enormous blocks of Trenton limestone were observed here. Next in abundance are boulders of quartzite and two jasper conglomerates were also noted. The Nipissing level is also present here and marked by a boulder beach. On the west side of the island near Oakridge, there are many scattered boulders which gives one the impression at first of a till plain. They are evidently ice carried boulders.

Mainland: - On the mainland of Chippewa County south of Neebish Island, the records of the Algoma level were noted at a number of places. One locality is particularly striking and should be visited by everyone interested in shore features. Three tenths of a mile northwest of Thorice, a summer resort in the southern part of section 33, T.45N., R.2E., is a ridge composed of clay and gravel with a few boulders. It is 15 feet high and 300 feet wide and trends WNW to ESE. Evidently it is a spit built out from the higher land in section 32, but this could not be proved as it was overgrown with a dense scrubby tree growth. One and one half miles north of this feature is another cobble and boulder ridge. It crosses the road in a nearly east to west direction.

Raber Island: - In the vicinity of Raber Island (two miles north of the village of Raber) the Algoma level is well shown in a number of ways. The road leading north from Raber first encounters the Nipissing cliff with its characteristic boulder strewn terrace. Later between section 19 and 20 another cut cliff appears at 615. It is only 6 feet high but nevertheless a well defined feature. North of Raber Island in the northwest part of section 8 this cut cliff intersects the road once more. The same cliff with low sandy barriers in front of it at places may be seen along the shore south of Raber.

Drummond Island: - On Drummond Island the Algoma beaches are also well shown. Perhaps the best place to see them is in the vicinity of the mouth of the Potagannissing River. The road in section 15, T.42N., R.6E. crosses over a high ridge fully 10 feet high. Again just beyond the point where the road turns sharply to the north is another similar ridge with numerous boulders and little matrix. Lower and perhaps more normal gravel beaches and spits were seen in section 15, T.41N., R.6E. near the south shore of the island and again in the eastern part of the island in sections 32, 31, and 5, 6, T.41N., R.5E.

Conclusion: - Since the Algoma beach was made there has been relatively little change in the configuration of Chippewa County. The beach has been elevated 15 feet during the existence of the present Great Lakes and the fact that there are no other well marked water levels below the Algoma down to the present beach seems to indicate that the uplift proceeded at an even pace. The time since the

Nipissing Great Lakes existed or the period of duration of the present Great Lakes has been placed at 3000 to 3500 years (25, p.467). This estimate has been based on the amount of cutting which the Niagara River accomplished since all the water of the Great Lakes has been going over the falls.

The data set forth in the foregoing pages will give the reader a general picture of the events which constitute the history of Chippewa County since the advent of the great ice sheet. The maps show the types of glacial and lake deposits made in the county during that time. Many interesting problems have been left untouched. The rising of the land has caused the deflection of streams, as for example, the Waiska River, which now has a most peculiar course. Its original course and the stages in its deflection would make an attractive study. Similarly the sand dunes associated with the ancient shorelines and their modification since they were formed would be fascinating to work out. Also the sand dunes of the present should be studied to see what changes have taken place and particularly whether they have migrated or not. These few problems occur to the writer. There are no doubt others of a similar nature, all of which means, that more geological work still remains to be done.

GEOLOGY OF CHIPPEWA COUNTY MICHIGAN.

Part III. Economic Geology.

Chippewa County does not rank with some of the other counties of the upper peninsula as a great producer of iron ore or copper, yet it has considerable wealth stored up for future generations in its geological materials. Foremost among its natural resources of this kind should be mentioned the limestone deposits. Next in rank, but at present of more immediate importance are the great deposits of clay. In third place we would mention the very widespread deposits of gravel. The sand, sorted out by lake waters, covers extensive areas and is of value for a variety of purposes. Finally there are scattered deposits of peat and marl.

Limestone: - The limestones and calcareous rocks of Chippewa County cover wide range chemically and geologically. They vary from high calcium rock which shows 95% calcium carbonate to dolomitic limestones and pure dolomites having over 40% of magnesian carbonate. In age they vary from middle Ordovician to the top of the Niagaran. The places where these limestones may be found on the outcrop were described

in part I of this report. It only remains, therefore, to discuss each with reference to their special uses.

Uses of Limestone: - The uses of limestone are numerous. R. A. Smith (24, p.123) lists over 40 uses of limestone in its raw or burned condition. Among these the most important ones are as follows. For building stone the composition is not particularly important as long as the stone resists weathering well, is hard and uniform in texture. Hence the dolomitic limestones such as the Hendricks would be suitable. After crushing, limestone may be used for road material, for railroad ballast and in concrete. For these uses the limestone should be hard and fairly resistant to weathering. The Engadine dolomite would be very good stone for this purpose. Limestone is also one source of the oxide of calcium commonly referred to simply as 'lime'. This substance is of inestimable importance in the chemical industries and in the building trades, inasmuch as it is the most readily obtainable of the strongly basic oxides. It is produced by heating limestone to a temperature high enough to drive off the carbon dioxide. In this case the chemical composition of the limestone is very important. Smith divides them as follows according to their calcium and magnesium carbonate ratio: -

High calcium lime (0-30% MgO) = High calcium limestone (93% or over of $CaCO_3$)

Low calcium lime (5-30% MgO) = Low magnesian limestone (7-30% $MgCO_3$)

High magnesian or dolomitic lime (30% or over MgO) = High magnesian limestone 30-40% $MgCO_3$) and dolomite (over 40% $MgCO_3$)

The high calcium limes combine quickly with water to form slaked lime, but the magnesian limes combine very slowly. Impurities in the limestone are also disadvantageous in this connection and should make up not more than 5% of the lime. Besides the uses of lime in building operations, it is also used in agriculture as a soil amendment, and in the chemical industries for a great variety of purposes. In making lime mortar, high calcium lime is in general preferred for all rough or heavy work and high magnesian lime for finishing. Both have certain advantages and certain disadvantages so that mixtures of the two are very commonly used.

On the soil lime exerts some very favorable influences. It may serve as a nutrient to the plants grown. More often however, it is used to offset acidity or in other words to eliminate the 'sour' condition of the soil. Furthermore, it has the ability of improving the texture of the soil. In clay for example it produces a 'crumb' structure which promoted water and air circulation. In sand, on the other hand, where water and air circulation are too rapid it tends to work in the opposite direction. The value of ground limestone or of lime in agriculture can hardly be overstated. The composition of the limestone that may be used for this purpose is of some import. It used to be thought that a high calcium lime was necessary. Now, recent investigations seem to indicate that magnesian limes are equally desirable on certain types of soils.

In the chemical industries limestone is needed for the manufacture of soda ash where it is needed to recover the ammonia from the ammonium chloride. Only high calcium limes are used in this process. For bleaching powder high calcium lime is also desirable. In the manufacture of calcium carbide a finely ground mixture of lime and coke are heated in an electric furnace. Here again calcium oxide in a nearly pure state is necessary.

In the manufacture of cyanimide and calcium nitrate, lime is also needed. The former is produced by heating finely powdered calcium carbide (or lime) and coke in an electric furance and treating the mixture with nitrogen. Only calcium oxide is used in this process. In making calcium nitrate, milk of lime is used, through which nitric oxide is passed, which is taken from the air by passing it through an electric arc. In this process either calcium or magnesian oxides can be used. Both substances, the cyanimide and the nitrate of calcium, are important because they furnish nitrogen to the soil and therefore to plants. Nitrogen is the most important nutrient element in the soil and the importance of producing cheap compounds containing nitrogen cannot be overestimated.

In the manufacture of sugar only calcium oxide is used as magnesium causes mechanical difficulties. Similarly, silica is also an objectional impurity, hence the limestone destined for sugar purification purposes should be below one percent silica. The lime is needed to neutralize the organic acids, break up organic compounds, and to

coagulate the albumen and mucus.

High calcium lime is also needed in the manufacture of sandlime brick. The mixture of sand and lime is pressed into form and heated in steam under pressure, by reason of which the lime combines with a portion of the sand forming calcium silicate which acts as a cement. Other impurities such as clay or silica are not harmful, but rather helpful on account of their fluxing properties.

In most of the above uses of limestone only the oxide of lime is desirable, hence magnesian limestone and dolomites such as constitute the bulk of the limestone resources of Chippewa County, seem to have little value. There is, however, one use in which dolomite and high magnesian limestones are more desirable than high calcium rocks. That is for lining open hearth furnaces. The reason for this is because calcined dolomite slakes very slowly upon exposure to the air and is much less likely to crack on account of temperature changes.

Finally, one of the most important uses of limestone is for fluxing iron ores. Impurities that occur with the iron in nature such as alumina and silica are acid and not readily fusible, hence some strong basic oxide is needed to convert them into fusible compounds. For this purpose high calcium limestones are usually preferred, however, magnesian limestones and dolomites can be used.

Cement and Hydraulic Lime: - Portland cement is made by burning a mixture containing three parts of calcium carbonate and one part of silica, alumina and iron oxide. It was formerly thought that the limestone used for the first member of the above mixture should not contain more than four percent magnesia (MgO), but later investigations indicate that as much as 7.5% may be used without sacrificing any advantages. For the second member of the mixture clay or shale may be used. Natural or Roman cement is made from limestone which contains more than 10% of certain impurities chiefly clay and silica.

Hydraulic lime is made from limestone that contains from 5 to 10% of sand and clayey material. This lime will slake without further treatment, but if the limestone contains more than 10% of the impurities mentioned then it becomes necessary to grind the mixture into a fine powder in order to produce slaking. Either high calcium or magnesian limestone may be used. The Black River limestone formation

in Chippewa County seems to have the required composition for making hydraulic lime.

Black River and Trenton: - The oldest limestones in Chippewa County are the Black River and Trenton limestones. No analyses of these rocks from samples taken in the county have been made so far as the writer is aware, except the analysis of C. Rominger listed by Smith (24 p.284). This analysis was made from a hand specimen collected at Neebish rapids (probably Black River limestone) and shows 52% calcium carbonate and 40% magnesium carbonate. According to this analysis this rock would be chiefly of value for basic hearth furnace linings. It has other properties, however, which widen its use considerably. It breaks up into rectangular blocks of homogeneous stone of great hardness. Thus it makes an ideal stone for buildings, walls, piers, breakwaters, etc.

The Trenton limestone crops out in Chippewa County on the east side of Neebish Island and in the Waiska River. Samples of this rock from the county have not been analysed to the writers knowledge, but analyses from other counties indicate that it is similar in chemical composition to the Black River linestone. Hence its possible uses should be the same.

Richmond Limestone: - The Richmond limestone of Cincinnatian age does not crop out on the mainland of Chippewa County. On Drummond Island it forms a belt along the north shore two miles wide and probably 100 feet thick. It is an argillaceous limestone and would therefore be of very little use at the present time.

Manitoulin Limestone: - The Manitoulin limestone crops out only on Drummond Island. Analyses of this rock have been made from samples collected from Manitoulin Island (21, p.110). These all show the rock to be strongly magnesian. The lime runs from 26% to 30% and the magnesia from 18% to 20% with the chief impurity silica averaging close to 5%. On Drummond Island a large part of this formation is coral reef rock which should run higher in calcium carbonate. However, on account of its thinness and its location the rock is not of great importance at the present time. This part of the formation deserves careful testing and if it proves to be high calcium stone further examination of its thickness and areal distribution would be in order.

Hendricks: - The Hendricks formation consists of thin bedded dolomites which do not appear to have great value at present for chemical purposes. As a building stone they have proved to be quite desirable. Large quantities were taken from the Drummond quarry for local buildings and for the older locks at Sault Ste. Marie and for similar operations on the shores of the Great Lakes. Many years ago layers from the Hendricks were quarried and burned for lime at the Limekiln quarry on Drummond Island. (See p. of this report). The accessibility of this formation in high cliffs near water makes it seem worth while to look into their possible utilization more fully.

Fiborn: - The Fiborn rock is unquestionably the most valuable limestone in Chippewa County. It crops out in the western part of the county in section 17 and 18, T.44N., R.6W. Analyses made of this rock at Fiborn quarry which lies three miles west of this locality show that it is a high calcium stone and therefore of great value (24, p.296). No more outcrops are to be seen in Chippewa County until Drummond Island is reached. There it seems to be represented by about 22 feet of rock above the Hendricks. In this interval are some layers which have the texture of the typical Fiborn, but about half of the interval is occupied by buff limestones which may be magnesian. Some analyses of these layers were made by Rominger from samples collected at Marblehead. These are given by Smith (24, p.284) and show certain layers to run as high as 95% of calcium carbonate. More analyses of samples collected at other points are necessary to prove the value of this deposit. Quarrying conditions are rather favorable, for the formation crops out in a fairly high cliff almost across the whole island and a number of places and quite near water.

Manistique: - The Manistique formation has been divided by the writer into three parts (see page). The upper part of the formation is well known in Scott quarry where much rock was taken out before quarrying operations were abandoned. No analysis of this rock is available to the writer, but it appears to be highly magnesian rock and therefore unsuited for most purposes. The stone taken from the Scott quarry was used for crushed stone on roads and railroads. When the need arises for more stone of this kind it may be found at the places enumerated in part I of this report.

The middle Manistique consists of two massive dolomite layers with some thin

bedded white lithographic limestones between them. These thin layers appear to be high calcium limestones, but no analysis has been made as yet to corroborate this statement. If it should be found to be of a favorable composition, the fact that there are only 8 feet of this type of rock may prevent its utilization for the present. It crops out at many places on Drummond Island and is readily accessible.

The lower Manistique consists of buff, hard and even bedded layers of dolomite which probably run rather high in magnesium. They would therefore be of use only for the purposes that high magnesian limestones are used for, such as basic hearth furnace linings, sulphite paper manufacture and possibly for fluxing iron ores.

Engadine: - Next to the Fiborn the Engadine will probably turn out to be the most valuable limestone in Chippewa County. It is a very massive, hard magnesian limestone having a thickness of 55 feet and of very uniform texture and composition. It crops out 4 miles east of Trout Lake over a considerable area under very favorable quarrying conditions. It also appears again northeast of Rockview over an area of several square miles. The lack of railroad facilities would probably offer an obstacle to its exploitation at that place. Near Detour the Engadine crops out widely and it would seem that the transportation facilities offered by the proximity of the St. Mary's River would be an inducement to its exploitation. Again, on Drummond Island there are a number of places where it could be quarried and moved cheaply. On this island the tonnage available is enormous.

The Engadine has been quarried near Ozark in Mackinac County for use as flux. On Manitoulin Island (21, p.98) the Engadine has been quarried by the Lake Superior Corporation at Quarry Point, about 7 miles south of Meldrum Bay, for the stone work of the Sault Ste. Marie canal, on the Canadian side. According to the analyses given by Smith (24, p.286) the Engadine contains about 55-56% of calcium carbonate and 42-44% of magnesium carbonate with the impurities less than 1% in some cases and rarely over 2%. This would indicate that the stone should be considered favorably for the linings of basic hearth furnaces and the manufacture of paper.

Clay Deposits: - The distribution of clay in Chippewa County was given fully in part II of this report (see page). An examination of the map (fig. No.) shows that a large area of Chippewa County is underlain by clay. The physical

characteristics of this clay and its probably uses were studied by Brown (28). He describes four samples taken at fairly well separated points in the county on page 400 and 401. One of these is a sample taken from Thornton's brickyard in Rudyard, another is from a point near Brimley, the third from a place about two and one half miles south of Sault Ste. Marie, and the fourth from section 7, T.44N., R.1E. All these samples vitrify at a relatively low temperature (1100-1200). In general they seem best adapted to the manufacture of common brick, building tile, drain tile, and possibly face brick. No chemical analyses are given except the one which had been previously reported by Russell. This shows a percentage of 5.62% of lime and 2.82% of magnesia. Lime shortens the vitrification range of clay so that it becomes viscous at a temperature near that at which it is hard burned. This defect is partly offset by the presence of magnesia. Lime by uniting with the iron in the clay at higher temperatures has a tendency to bleach the product. If the lime is present in lumps or small masses it will swell by slaking and cause 'lime-pops'. Magnesia is not so objectionable as lime and may be present up to 7 or 8% in brick clays. It is reasonable to presume that the Chippewa County clays run higher in magnesia than most clays as they were largely derived from the Silurian dolomites.

At the time of the writer's visit to Rudyard, the Thornton brickyard mentioned by Brown (28, p.400) had been taken over by Olsson and Odaffer. The new owners intend to expand the plant considerably and install new machinery. There is an excellent local market for the products that this clay is suited for and considering that the clay has a thickness of over 350 feet, as shown by artesian wells nearby, success seems assured for the new venture.

Gravel: - Gravel is widely distributed over Chippewa County. It occurs chiefly in old lake shore features as spits, bars, and storm beach ridges. Near such places as Scott quarry where the waves of Lake Algonquin had abundant supplies of limestone fragments to work upon because of the crumbling of the Manistique dolomite cliffs, we find many spits and similar ridges made up of gravel. Just west of this cliff there are four parallel ridges 5 to 8 feet high and 30 feet wide which are long spits built out from the cliff at the time of the second Algonquin level (865 and 870). North of the cliffs about one mile is a long gravel ridge which may

be a barrier. It has an elevation of 830 and thus corresponds to the fifth Algonquin water level. This gravel ridge can be traced a distance of over three miles. Such a length is exceptional, however, there are a number of others in the county whose length closely approaches this one. In the region south of Modaway Point there are quite a number of gravel ridges over a mile long. The best developed ones belong to the fifth Algonquin water level (865). Some of the best gravel ridges were seen about a mile and a quarter south of Strongs and again 2 and 3 miles northwest of the same village.

At Rockview are three very prominent ridges of gravel at 850, 855, and 860 feet (third Algonquin level). These ridges have been drawn upon very extensively for road building purposes, but still contain much material. On the Gatesville moraine there are several very prominent ridges. One of these crosses the corner just one mile west of Gatesville at 775 (seventh Algonquin level). It is perhaps the most remarkable gravel ridge in the county both for length, width, and composition. It can be traced four miles to the northwest and to the southeast. Four miles west of Gatesville is another long and prominent gravel ridge. South of Gatesville (two miles) is the beginning of a gravel ridge which is rather low at that point but becomes higher and crosses the main highway one mile farther south as a fifteen foot embankment and again one mile farther south as a similarly high feature. In the region about Caribou Lake and especially west of Detour there are very many gravel ridges formed at Ft. Brady levels (650-700). On Drummond Island also there are many gravel ridges at approximately the same levels. On account of their number it is not advisable to list all the gravel ridges in the county, but they may be found by consulting map (fig. No.) which accompanies this report.

The eskers of the county offer another source of gravel which was being exploited at the time of the writer's visit. The esker along M-25 two miles south of Sault Ste. Marie is 3 miles long and 20 feet high in places. The esker 5 miles west of Pickford is not so high but nearly as long.

The moraines also have yielded much gravel for roads in the county. There is a large patch of gravel in section 18, T.45N., R.3W. six miles west of Kinross. Another is located in section 34, T.46N., R.1W. on a morainic fragment near Dafter.

On the Kinross moraine in the southwest quarter of section 29, T.44N., R.1W. there is a large area of gravel which seems to be uniform in texture and quite deep.

Artesian Water: - One of the most valuable natural resources of Chippewa County is a copious supply of excellent artesian water. The phrase 'artesian water' is used in a number of different senses. Myron Fuller (29, p.14) defines artesian water as "that portion of the underground water which is under artesian pressure and will rise if encountered by a well or other passage affording an outlet." He defines an artesian well as "any well in which the water rises under artesian pressure when encountered." These definitions were decided upon after he had consulted many geologists in regard to the matter.

Water under pressure is obtained in Chippewa County from a coarse sand or gravel bed which is overlain by clay. The perviousness of the sand and gravel allow rapid movement of the water, whereas the imperviousness of the clay stops its movement completely. The rain water enters the relatively loose soil in the moraines, (see map, fig.) percolates downward, and gets under the clays deposited in lakes Algonquin and Nipissing. Here it is confined until tapped by a deep boring.

The areas where we may expect artesian water are therefore practically the same as those shown on the map as lake clay. But, as was pointed out,previously, this lake clay is in places covered by a thin sheet of later sand as, for example, in the strip west of Hay Lake where the sand is only 9 to 12 feet thick, or at Emerson where it is 17 feet thick.

Pickford Area: - In the Pickford clay area, over 30 wells have been drilled. These range from 67 feet to 151 feet in depth, but most of them are from 122 to 140 feet deep. They show red clay practically to the bottom, where gravel is struck. The water has a temperature of 43 degrees to 45 degrees F. and contains only a moderate amount of lime.

Rudyard District: - The clay area which centers around Rudyard covers about 90 square miles without counting the clay which is under a thin sand cover in Kinross and Lake townships. In this area there are probably more than 70 wells of an artesian character. The deepest one is the Germain well in section 12, T.44N., R.3W. This well is 403 feet deep. In section 1, north of the former well, another

deep well was drilled on the Thornton estate. It is 367 feet deep. The Anderson well in Rudyard is 285 feet deep and the well at the Fountain House 278 feet. In the last mentioned well the head is 22 feet which is nearly a maximum for the district. The log of this well shows a thickness of 240 feet of red clay, below which there is 40 feet of 'slush' and 5 feet of gravel at the bottom. We may consider this a typical record, the 'slush' being evidently a fine sand or silt which does not permit rapid flow of the water and hence is not used, although it is water bearing. Most of the wells in this district have a flow of about one to two gallons per minute, though there are some in which the flow reaches ten gallons or more on account of favorable porosity conditions in the water bearing layer. The temperature of the water is about 45 degrees F. and the composition of the water excellent, though it is somewhat hard and contains a small amount of iron.

North of the town of Rudyard, the depth of artesian water becomes rapidly less, being 148 feet on the Hellenick farm (NE¼ of 31, T.45N., R.2W.) and 35 feet on the Birch Farm. West of Rudyard and near Dryburg, the wells run close to 150 feet in depth. The J. T. Joyal well is 158 feet deep and shows 110 feet of red and blue clay with sand and clay alternating to the bottom where gravel, as usual, furnishes the flow of water. At Fiber the wells are 110 feet deep. Two miles west of Fiber the well of Ross and Bros. is 115 feet deep. This well begins in sand but penetrates mostly red clay.

Sault-Dafter District: - The clay area which extends from Brimley eastward past Dafter to McCarron and Neebish Island, and reaches to Sault Ste. Marie on the north, has many artesian wells on it. Most of these wells are from 35 to 100 feet deep, but there are a few which show exceptional depth. One such well is the creamery well at Brimley which is 392 feet deep all of which is clay except the gravel at the bottom. This well is used by practically all the village people, as the water from shallow wells is not considered desirable. The McKee well in section 19, T.46N., R.1E. is 211 feet deep, flows 6 gallons per minute and, according to the owner, was drilled through red clay to the bottom gravel.

Eckerman District: - In the stream valley which runs from Strongs past Eckerman and Hulburt and Algonquin lake clay lies under a cover of sand of varying

thickness. At Strongs, for example, one well is 203 feet deep and shows 7 feet of sand, 168 feet of clay which is red for some distance and then is grey to the bottom, below which there is 10 feet of gravelly hardpan and 6 feet of quicksand. At Eckerman there are three wells 35 to 47 feet deep which show 15 feet of sand above the clay.

Whitefish Bay District: - Deep wells were drilled at Emerson and Shelldrake. At the former place there are 9 wells ranging from 116 to 130 feet in depth. In these the drill found 17 feet of sand above the clay. The wells had a head of 5 to 6 feet in 1905 (see 29, p.39). The temperature of these wells was about 45 degrees F. when tested in the same year. Leverett also reports that the Culhane well at Shelldrake was drilled to a depth of 250 feet without striking rock, passing through clay and thin beds of sand. Several wells there are 75 to 80 feet deep.

Ordinary Wells: - Water at the level of the water table is not under pressure. In Chippewa County such water can usually be obtained at shallow depths of 20 to 30 feet. On the hilly tracts especially where the soil is sandy or gravelly the depth to the water table is greater. For instance on the Kinross moraine water is found at 55 to 75 feet, at Rexford on the outwash plain at 45 feet. One deep well was drilled near Wellsburg to a depth of 280 feet. This was an artesian well and the water rose to within 45 feet of the top.

Conclusion: - Chippewa County ranks first in the upper peninsula in the amount and excellence of its artesian waters. It also has very large supplies of limestone which are merely waiting for a larger demand before they are quarried on an extensive scale. The road building era which is just beginning to get under way, has raised gravel to the position of one of the most valuable geological resources. In this respect the county is fortunate, because it has large quantities of gravel well suited for road building purposes. It is especially fortunate because of the fact that the gravel deposits are well distributed over the whole county. The very large clay deposits have scarcely been touched. At Rudyard some attempts have been made to develop them, but, because of their thickness and wide distribution it would seem that the clays deserve to be worked on a larger scale.

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