ART. XXV.—*The Highest Old Shore Line on Mackinac Island*;* by F. B. TAYLOR.

EVIDENCE of post-glacial submergence has long been known to exist on Mackinac Island, which lies in the strait between Lake Huron and Lake Michigan. Its amount has been variously stated by different writers, some putting it at 250 feet, while others claim that evidences on the higher parts of the adjacent mainland indicate an amount of submergence that would rise far above the summit of the island which attains an altitude of about 300 feet above the present level of Lake Huron. The observations of which I give an account here were made during the autumns of 1890 and 1891.

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

The short target range crosses the beaches nearly at right angles and the width of the series is here a little less than a quarter of a mile. But on the southwestern side of the island

* An abstract of this paper was read before the Geological Section of the A. A. A. S., at Washington.

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

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

All of my measurements of altitude were made with an aneroid barometer and are subject to the inaccuracy of that instrument. But the 170 and 205 foot beach levels represent in each case the mean of more than a dozen independent observations taken under favorable conditions and are therefore

probably not far from true. But after determining the fact that the highest old shore line on Mackinac Island has an altitude of about 205 feet above Lake Huron, another broader and more difficult question arose. Did post-glacial submergence exceed this amount? Suppose that it did, as has been implied and suggested by those who point to shore lines at higher levels on the adjacent mainland. What evidence can be brought to bear upon this question?

A careful examination of the ancient little island of Mackinac, as described above, and of the surrounding mainland reveals among others, the following facts: The whole surface of the ancient island, except where the rocks were laid bare along the edges by the formation of cliffs, is covered with glacial drift. This drift is typical in its composition and topographical features. Its surface has that irregular rolling appearance which is characteristic of a drift-covered, broken country. Along the edges near the cliffs the drift has been notched by the little rain rills which carry away the surface water. Otherwise, the surface shows no evidence of post-glacial modification.

The composition of the drift is well shown in the excavations of old Fort Holmes on the highest point of the island. The parapet of the fort was built of material dug partly out of the interior of the enclosure and partly out of an outer ditch. This ditch is five or six feet deep and seems to have been excavated entirely out of boulder clay, which is well exposed in several foot paths which cross the earthworks. The clay is very tough and of a reddish color, and when wet is quite slippery under foot. But when it is dried in the sun, it forms a very hard surface. It contains a fair sprinkling of boulders of moderate size, but appears at the fort to include comparatively little sand and gravel. The clay and coarser constituents form a heterogeneous mixture in characteristic drift fashion, and a fair proportion of the boulders show striæ. Although the composition of the drift varies somewhat in different places, it everywhere presents such characters as clearly preclude the supposition that it has been washed or worked over by the action of waves since its deposition by the ice sheet.

The whole surface of the ancient island is well sprinkled with boulders and a large number of them are erratics of northern origin. With hardly an exception their exposed surfaces are strongly weathered. I found only two small surface boulders with striæ still preserved, and both looked so fresh that they probably came from some of the excavations near by. I examined hundreds of boulders below the 205 foot level, but found none with glacial scratches. Exposures in

road-cuts and gravel-pits are common on all parts of the island, but I found not a single striated pebble in any of those below the 205 foot level. Below this level the loose material of the island generally appears to be rounded and water-worn. The sharp angular fragments which are intermingled in small quantities are of the country rock and were probably freshly derived from the cliffs. I found nothing resembling bowlder clay below the 205 foot level, though it probably occurs in protected places.

During the last season a pit was dug at the target on the short range which is against the foot of Fort Holmes hill, and an excavation was also made at a higher level to obtain material for filling in behind a log backstop. The pit is in the trough behind the 205 foot beach, and the backstop is about ten feet higher on the side of the hill. A number of beautifully striated pebbles were found which had been thrown out of the pit. Almost the whole mass of material excavated for the backstop consisted of Paleolithic flint chips originally derived, apparently, from the chert nodules of the limestone of the upper cliffs. This excavation was about four feet deep.

Altogether, the appearance of the surface of Mackinac Island seems to show that all parts of its surface, up to the level of 205 feet, has been modified by wave action since the deposition of the glacial drift; but that above that level no such modification has taken place.

An examination of the mainland north and south of the island shows that they, too, have been post-glacially submerged up to certain levels. Within a radius of 20 miles no land reaches an altitude of more than 160 to 170 feet. McGulpin's Point on the south side of the strait, with an altitude of about 110 feet, was completely submerged. So also was the high ground on the north side near Pointe La Barbe, altitude about 140 feet, and at Gros Cap farther west and a little higher. On the shores of Little Traverse Bay, about 40 miles southwest, a heavy shore line is found near Petoskey at an altitude of about 100 feet above the lake, and a little higher at Harbor Springs on the north side of the bay. At the latter place the shore line appears as a great terrace, and from the head of the bay it is developed westward and northward continuously for a distance of more than 20 miles to a point northeast of Cross Village. At a very early day this terrace was largely cleared by the red men and is said to have been almost one continuous village for its whole length.

At the time of the great post-glacial submergence the high tract north of Little Traverse Bay and west of the G. R. and I. Ry. was a large island, nearly round and about 15 miles in diameter. On the south side of the bay the shore line ex-

tends inland eastward from Petoskey at least 20 miles, and passes south of Crooked, Pickerel, Burt and Mullet Lakes. Beyond this its place is not yet determined. Southwest from Petoskey the old shore line is quite irregular but continuous, at least as far as Traverse City, a distance of about 50 miles, at which point the old delta of the Boardman River shows the water level to have been at an altitude of about 80 feet.

The identity of this great deserted shore line with that found on the shores of Lake Huron and Georgian Bay, called by Professor J. W. Spencer, the Algonquin beach, and described by him in recent numbers of this Journal, seems almost certain. The upper beaches of Mackinac Island are without doubt only an isolated part of the same great shore line.

It is well known that almost the whole of the northern peninsula of Michigan has been submerged since the glacial epoch. This area of submergence is continuous with that which I have described on the south side of Mackinac Strait, and includes a large part of the south shore of Lake Superior. Some years ago I saw deserted shore lines near Au Train, at Marquette and at the west end of Lake Superior which probably belong to some stage of the same epoch of submergence.

The old shore line between Traverse City and Mackinac Island shows the same northward rise as has been found in post-glacial shore lines elsewhere. From Petoskey to Mackinac Island the northward component of distance is about 33 miles and the Mackinac beach is about 100 feet higher than that at Petoskey. The northward component of differential elevation between these points is, therefore, three feet per mile. From Traverse City to Petoskey the northward component of distance is about 41 miles, and the difference of elevation of the beaches is approximately 20 feet, making the northward factor of differential elevation six inches per mile. Two isolated observations near Levering and Pellston 15 miles north of Petoskey on the G. R. and I. Ry. seem to show an elevation for the shore lines at those places of not less than 150 or 160 feet. This is somewhat higher than the plane directly connecting Petoskey and Mackinac Island. But the local variation of differential elevation which seems to be suggested by these two observations needs further verification.

Near Harbor Springs and Wequetonsing on the north side of Little Traverse Bay, and at Petoskey and Traverse City, the evidence that post-glacial submergence has not extended above the level of the observed old shore line is fully as plain as on the island of Mackinac. This statement applies to the surface forms and the composition of the drift, and also to the presence of striated boulders in the drift above the line and their absence below it. Back of Petoskey the hills rise 300

feet or more above the lake. They have been cleared for cultivation and they show those peculiarities of surface formation which characterize only an unmodified drift topography. They are heavily drifted and their surfaces have those long, graceful curves with upward convexities which are unerringly attributed to the constructive action of the ice sheet, and which are plainly not a product of any known destructive or eroding agent. In case of greater submergence they would be exposed, as the shore below is to-day, to the full force of the west and northwest winds, and they could hardly escape the eroding action of the waves. The modified course of Bear Creek proves that during the formation of the Algonquin beach at this point, and during the entire subsequent recession of the waters down to their present level, the waves of the west winds have played a strongly predominant part in the modification of the shore. Below the Standard Oil Co.'s station south of Petoskey, Bear Creek runs towards the northwest and once entered the lake in that direction through a narrow gorge. But its present course turns abruptly from northwest to northeast where its banks are about 90 to 100 feet above the lake. From this point it flows about half a mile to its mouth in a course nearly parallel with the present shore, and descends quite rapidly. There are good exposures in the banks at the bend and they show deep sections of characteristic beach material—rounded pebbles, gravel and sand—up to about 90 feet elevation. The position of this material shows that at the time of the Algonquin submergence the eastward littoral transportation was so great that it forced the stream to turn aside in the direction of the movement, and the continuation of the stream in the same modified course ever since shows that the same disturbing element has acted continuously at lower levels. The shortness of the rock gorge below the bend indicates a comparatively recent date for the change. Many lakes along this shore have been partly formed by littoral dams of Algonquin or later age.

But in respect to exposure to wave action, Mackinac Island seems to me to be a test case. For its geographical position is such that in the event of a general submergence of that region to or beyond the depth indicated by the Algonquin beach, it would stand alone in a wide expanse of water. The nearest mainland would then be about 30 miles to the south and the nearest islands about 20 miles to the north and southwest. In all other directions open water would stretch away 100 to 200 miles. From Traverse City to Mackinac Island and at least 25 miles farther north, the plane of wave erosion appears to have acted at every horizon up to the level of the Algonquin beach. But above that plane there is no evidence of such action ; at

least up to a level of 100 feet above the Algonquin beach as seen on Mackinac Island, and 200 feet above it as seen at Petoskey.

It might be supposed that the small area of Mackinac Island was submerged and re-elevated by movements so sudden that the waves had no time for effective action at any horizon between 205 and 300 feet. But the difficulties in the way of such a supposition are many and great, and when it becomes necessary to extend the application of it to an area 100 miles long and even to the whole area of the three upper Great Lakes, the difficulties become insuperable.

The most impressive feature of the old shore line which I have described is the great strength of its development. The time during which the water level stood at or within 35 feet of its highest stage must have been of very long duration, for by far the strongest development is within this limit. The appearance is just such as would be produced if the water had risen slowly at a steadily decreasing rate, stood long at its highest level, and then had fallen away again as slowly and at a steadily increasing rate. The Iroquois beach of the Ontario basin, described by Dr. G. K. Gilbert and Professor J. W. Spencer, has the same strong development, except where lack of drift gave little loose material for the waves to work upon.

If the rise of the Algonquin beach on the east side of the Georgian Bay continues northward, it must extend far above the pass at Lake Nipissing. The Iroquois beach has the same northward rise, and if its approximate mean plane, not counting the exceptional high grade northeast of Watertown, N. Y., be produced northward, it too strikes much higher than the Nipissing pass. The two planes come as near together at Nipissing as could be expected in view of the considerable extent of irregular, local earth-warping. Considering this fact and the general similarity of the two beaches, it seems probable that the Iroquois and Algonquin beaches are in reality one continuous line. Terraces have been noted on the hills at Nipissing, at an altitude of several hundred feet above the pass and they are in all probability a part of the connecting link.

The generally accepted explanation of the origin of all the old shore lines of the basins of the Great Lakes is that they were made by bodies of water held as lakes in front of the ice sheet as it retreated northward. But this theory does not seem applicable to the Algonquin and Iroquois beaches. The long duration of wave action at one horizon, as attested by the strong development of these lines, is hardly reconcilable with the idea of an ice dam, which must have been formed by an

ice sheet which we know to have retreated with a halting, fluctuating movement.

But there is positive evidence of marine post-glacial submergence in the St. Lawrence valley. On the mountain at Montreal marine shell beds occur at an altitude of 520 feet above the sea, and in the Pleistocene deposits of Vermont near Lake Champlain the skeleton of a whale was found. In the depths of Lake Superior a marine or brackish water organism is found living to-day. These facts are all well known and their *prima facie* significance is unmistakable. Yet many geologists put them aside for the ice-dam theory which seems more complete. The idea of the ice dam accounts for the submergence which made the shore lines. But the facts proving marine submergence do not explain the cause of that submergence. There is no proof that the waves which washed the Iroquois beach were of fresh water. They may have been salt, but more probably were brackish. If there were no evidence of marine post-glacial submergence in the St. Lawrence valley, then, on purely negative evidence, we might remain in reasonable doubt. But the marine shells at Montreal and the Champlain whale are positive evidence of marine submergence of those localities, and they are not more than 150 miles from the Iroquois beach at Watertown, N. Y., and 100 miles from its position at Fine. No adequate reason can be given why we may not make the almost obvious inference that these marine beds are in the same area of post-glacial submergence as the Iroquois beach. We know that salt water stood more than 520 feet deep at Montreal, and we do *not* know that the Iroquois waves were of fresh water. It seems more pertinent, therefore, to ask what barrier could have held the salt water out of the Ontario basin, than what could have held a supposable body of fresh water in.

Higher shore lines exist in the Ontario and Erie basins, but they are generally comparatively weak in development and many of them are known to be of a distinctly fragmentary character, suggesting isolated areas of submergence and less duration of time in their formation. All those which have been thoroughly identified as shore lines are in hydrographic basins so situated with respect to the several lobes of the retreating ice sheet and certain old disused river beds as to strongly suggest the operation of ice dams. The longest beaches yet found at the higher levels are those of the Erie basin. The Maumee beach, which is the highest, extends eastward from Fort Wayne and ends at Cleveland, and Dr. Gilbert found the termini of others of the same series in western New York. All these termini are in comparatively open

country where the lines could easily be followed farther if they existed. No such end has ever been found for the Algonquin or Iroquois beaches. They have merely been lost in the bush, or rocky, scantily drifted regions, and await more careful and energetic exploration.

If shore lines are found in the highlands 50 to 70 miles south of Mackinac Island, as has been reported, they must have been formed by ice-dammed lakes which were drained off and had disappeared before the summit of the island itself emerged from the ice. The higher beaches of the Ontario basin and all those of the Erie basin were probably made by ice-dammed lakes. But the heavily developed and apparently continuous Algonquin and Iroquois beaches, including the 170-205 foot beaches of Mackinac Island,—probably all one line,—were made by waters which had open connection through a broad strait at Nipissing with the Gulf of St. Lawrence, and the Atlantic Ocean. The facts suggest a provisional classification of the deserted beaches of the Great Lakes into two divisions, produced by entirely different causes, and probably at widely separated times, namely: the higher level, fragmentary and comparatively weak beaches, probably produced by ice-dammed lakes, and the lower, strongly developed, continuous beaches of marine origin, formed, probably, long after the ice sheet had disappeared from eastern North America.

Fort Wayne, Ind., Nov. 18, 1891.