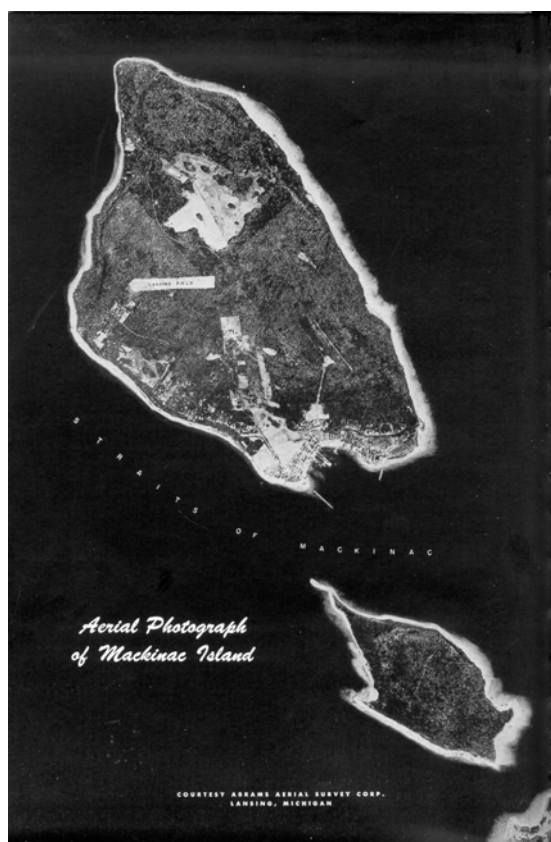




Frontispiece. Mackinac Island from the air, Courtesy Abrams Aerial Survey Corporation, Lansing, Michigan.

STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

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PRE-HISTORIC MACKINAC ISLAND

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FOREWORD

So historic a spot as Mackinac is a mecca for vacationists today, as it was for fur traders and explorers a century or two ago. Travellers and residents have been lured by the same natural advantages that are basic in its historic values. The imposing cliffs which were adopted for fortification, and all the scenic curiosities of the island spring from a geological story which began long before white men saw Mackinac or North America. Two and a half centuries of human history here are a mite compared to the long time of pre-history when the waves were washing the island and fashioning it into what we see today. Mackinac played a key part in the deciphering of the story of the Great Lakes and it is only proper that the story of Mackinac, the island, be available for those who find it of interest.

Because of the many queries regarding the origin of its scenic features and the evident desire of the public to know more about the geology of Mackinac Island, the Geological Survey Division in 1941 employed the writer to study the island and prepare the report.

Four weeks of the 1941 summer were spent in field work on the island. Spirit levels were run across the island in several directions. Most of the lines of levels were started from lake level but some took off from bench marks. Discrepancies at the closure or juncture of level lines were generally small. Observations on beaches were taken to the nearest tenth foot. Only a fraction of the total number of such observations have been plotted on the map and are there recorded to the nearest even foot. A few plotted elevations were determined by aneroid barometer or by use of hand level alone without a rod, and are accordingly not as reliable. They are as follows: seven elevations near the Nipissing bluff and within a quarter of a mile of Truscott Avenue, an elevation of 715, about 500 feet west of the pumping station, and two elevations on the Nipissing terrace, one of 625 near Radisson Point, one of 628 in Private Claim 331.

Surveying methods were not used to determine the mapped positions of any of the features. Where they were not evident from the aerial photographs or the topographic map, visual estimates were used. No effort was made to trace out on the ground all the individual beaches of the Upper Algonquin group or the post-Nipissing group. Doing this would have rendered the map more complete but it would have been a most time consuming activity in the dense woods and impossible of accomplishment during the time allowed for field work.

Moreover, it gave no promise of adding to the general story nor of yielding information needed in solution of some of the broader remaining problems. These series of beaches are plotted heavily on the map at several places where they were crossed and measured. Lighter lines of dots mark probable trends where unobserved.

Courtesies and accommodations from Mr. Walter Russell and Mr. W. F. Doyle of the Mackinac Island State Park Commission and of Mr. Robert Doud, Park Superintendent, are gratefully acknowledged. Mr. Arthur S. Hawley, student at the University of Michigan, gave fine assistance throughout the levelling work. A special tribute is paid to the late Frank B. Taylor who has contributed more than any one else to the deductions of Great Lakes history. He had intimate connections with Mackinac Island where he maintained a summer home, and where for nearly 50 years after 1885, he studied and wrote about the ancient and modern shores of the Island.

GEORGE M. STANLEY
Ann Arbor, 1944



Figure 1. Arch Rock -- Top of arch is 722.5 feet above sea level, about 142 feet above Lake Huron which is seen through the span.

THE PRELIMINARY GEOLOGICAL STORY

ANCIENT HISTORY of human civilization is somewhat like a distant view for it generally fades into obscurity at remote points. Seen from the present, it has a way of crowding together distant events and displaying modern foreground in broader perspective. Geological history likewise telescopes and jumbles antiquity in comparison with the recent. Geological like human history had its intervening "dark ages" -- blind spots in the past. The living processes of earth, wind, weather, running water, ice streams, made and then over and over eradicated the records of the geologic

past just as man has destroyed and obliterated many records of his past. A geologist has said that in the last volume of written geology: "the longest and most important chapter will be upon the latest and shortest of the geologic periods", -- The Ice Age, the Pleistocene -- and in only the final paragraph of this last chapter was the story of Mackinac Island as we know it today written. However, the story of the rocks upon which Mackinac Island is built goes back millions of years to pre-Cambrian time.

The pre-Cambrian was a vastly long time of earlier geological history. Life existed in the pre-Cambrian, at least toward its close, but only in lowly forms such as marine plants and worms. During that long time, the surface of the earth was built up by and covered with many different kinds of rocks. The oldest were formed by cooling of the magma (molten rock) of which the earth was made, forming a "crust" of igneous rock. Later agents of erosion broke down the igneous rocks and deposited the sediments to form sedimentary rocks. Widespread volcanic activity, and earth movements, changed (metamorphosed), both igneous and sedimentary rocks, to metamorphic rock. Types of all these rocks are visible today in many areas of North America. The oldest igneous rock and the first rock of the North American continent, is known as the "Canadian shield", a vast expanse of pre-Cambrian rock reaching from the St. Lawrence River to the Mackenzie and from Hudson Strait to Sault Ste. Marie. Most of this rock is hard and resistant, was formed deep down in the earth and has been revealed only as erosion removed the rocks deposited on top of it -- the overburden.

The agents of weathering broke up the overburden as well as the rocks of the "Shield" itself and carried them as sediments to the surrounding sea. Eventually the sediments solidified to rock, some of them were metamorphosed like the sediments that became the Iron Formations. Lava flows covered the "Shield" in other places but by the end of the pre-Cambrian time, the earth had settled down and the long processes of erosion began and started to build the bedded, layered or stratified rocks in a time known as Paleozoic, when life became important and plants and animals came on the earth in ever increasing numbers and variety.

The Paleozoic began with the Cambrian period. During Cambrian times, great seas fringed the Canadian shield and layers of coarse and fine sediments that later became sandstone, limestone and shale, were deposited on and near their shores. In following periods of the Paleozoic known as Ordovician, Silurian and Devonian, other muds and silts were deposited in layers above the sands. They became shales and limestones and are the basal rocks from which Mackinac Island was carved.

An especially interesting feature of these rocks are the breccias, which are rock formations composed of broken fragments of limestone, cemented into rock masses more solid and resistant than the limestones from which they were derived. They are found in a number of

localities, and seem to be isolated and unconnected masses although through careful study, they have been found to be connected from place to place. Also they are at different elevation levels and at any one spot the breccia may appear to have a greater extent vertically, up and down a cliff, than in a horizontal direction. A number of suggestions have been offered to explain and account for the origin of these breccias, but the most plausible theory now offered is that beds of salt deposited during the Silurian period were dissolved forming vast caverns into which the overlying limestone beds collapsed, breaking into small fragments in some places and into large fragments in others. The fragments were later cemented together and formed the breccias (pronounced *brechia*)¹. It is interesting that nearly every rock feature of interest on Mackinac Island, pinnacle, cave, arch, is a result of erosion around a mass of this resistant breccia.

Though a fairly complete section of Paleozoic rocks were deposited within Michigan, no rocks on Mackinac Island are like the rocks exposed in the Southern Peninsula that were made of sediments deposited during the later part of the Paleozoic -- later Devonian, Mississippian, and Pennsylvanian. Probably through all the millions of years the area of which the island is a part was above sea level and subjected to great erosion.

The last chapter of geological history brought to Michigan a series of ice invasions from the north. At four successive times, during perhaps a million years, glaciers spread southward from Canada covering our northern states as far south as the Ohio and Missouri rivers and melted away, leaving a vast quantity of rock debris, which they had scraped from the land they crossed and plastered over the land they invaded. The debris of stones, boulders, pebbles, clay, sand, is known as glacial drift. The ice of the last invasion, the Wisconsin glacial stage, almost obliterated the deposits left in Michigan by the earlier glaciers. The earlier glacial drift may be seen in Iowa, in southern Illinois, Indiana and Ohio, separated from the overlying Wisconsin drift by weathered drift material that contains plant remains and weathered soil.

The polished and grooved rock surfaces made by the erosive action of the ice as it scraped and rounded off the bed rock over which it moved, are marvellous sights throughout much of Ontario and in a few places in Michigan, but are curiously lacking from Mackinac Island. However, a few glacially smoothed and striated (scratched) stones have been found on the top of the island near Fort Holmes. The glacial drift may conceal some glacial grooving on the hard limestone rock but very likely the softer shales hold no clear record of glacial ice action. Any striations and groovings that glacial erosion left on the rock of the lower part of the island, have been worn away or concealed by later work of waves. The "erratic boulders" of pre-Cambrian rock on the summit of the island, brought there by the glacier from the Canadian shield, dispell any doubts that the ice covered Mackinac Island. Indeed at its maximum the ice

was very likely several thousand feet thick in this vicinity, since evidences of heavy glacial scour (wear) have been noted on the tops of much higher islands in the Great Lakes. One may well pause to consider the immense amount of material the continental glaciers of the Ice Age transported southward. In many places in southern Michigan the blanket of glacial drift made of the loose parent soil material scraped off Canada, is hundreds of feet thick, and it covers the bed rock nearly everywhere. Impressive too is the number of large boulders of pre-Cambrian rock, or "hard heads", one may see in the fields, or especially along some stretches of eroded lake shore. We have the boulders and the hills of glacial drift but the bare rock areas of Ontario may rightly regret the wholesale glacial robbery of precious soil dumped and piled to the south in hills so thick only a little of it can do good.

The final part of the last chapter in geological history is most legible, on Mackinac Island and elsewhere. The story is clear as written by the deposits left during the glacier's last recession and which are not yet mutilated. The indications are strong that the glacier did not capitulate at once to advancing climatic warmth but at times held ground so that retreat was a seesaw business, like the story of the frog climbing out of the well. At each halt the glacier dumped its accumulated rock debris in hills called moraines. At each advance the ice pushed the hills higher and on melting added more debris and so built hilly ridges that protected its front. Thus, a great succession of morainic ridges tell the story of the hesitating, oscillating retreat of the glacier. Each moraine marks the limits of one of the dwindling counter-advances, the place where the glacier was halted.

During the height of the Wisconsin glaciation, ice moved southwest across Michigan from a center near Labrador. But later a minor center of ice dispersion developed north of Lake Superior, from which ice again moved over Mackinac Island region in a southeasterly direction. This glacier carved out Les Cheneaux Islands and the long narrow hills in Presque Isle known as drumlins, all having the long direction from north-northwest to south-southeast.

As the ice border withdrew from the southern and southwestern ends of the Great Lakes basins, melt water from the ice remained ponded in the basins as lakes hemmed in by moraines that enlarged as the glacier melted away. These lakes were drained at first by large streams that flowed toward the Mississippi. However, as glacial retreat opened lower passages to the east or to the west, the outlets of the lakes shifted from one location to another and the water subsided to lower levels as each outlet determined. On occasion readvance of the ice obstructed the drainage channel and forced the lake to rise again and seek the next higher outlet. The story^{2,3} of these lakes is a sequence of generally downward stepping levels but now and then a rise, see-saw fashion again. It is a magnificent story, so far as history of a lake might be, and a credit to the observation and deduction, and familiarity with the

region of those who worked it out. The early part of the history of the Great Lakes, when much of Michigan was ice covered, does not touch on Mackinac Island. But as the glacier retreated and the lakes became larger, the most conspicuous beaches, bars, offshore islands, and other features of shorelines left by various stages of the lakes, were formed at the culmination of each rising level. This fact is very evident indeed at Mackinac Island. Its conspicuous scenic features were formed when the Great Lakes occupied much larger basins than they do now.

¹Landes, K. K., Ehlers, G. M., and Stanley, G. M., Geology of the Mackinac Straits Region: Michigan Geol. Surv., Pub. 44, G. S. 37, 1945.

²Leverett, Frank and Taylor, F. B., The Pleistocene of Michigan and Indiana: U. S. Geol. Survey, Mon. 53, 1915.

³They Need Not Vanish, Michigan Dept. Conservation, pp. 57-72, 1942.

HISTORY OF MACKINAC AS AN ISLAND

A MAN'S BIOGRAPHY naturally contains something of the developments of the time in which he lived. To give the history of an island we must tell the changes of the lake in which it stands. A lake may drain out at first one place and then at another; it may rise or it may fall. It might rise at one end and fall at the other if the land were tilting also, as it slowly is in the Lake Superior region today. For the sake of the island we must consider the lake and for the lake, we must concern ourselves with the crust of the earth which holds it.

It is a fact that in the area of the northern Great Lakes, the ancient shorelines, where traced out and measured for elevation, show a rise of a few feet per mile northeastward, that is, toward the site of the central mass of the recent ice cap. Without any doubt the land there has been elevated many hundred feet since the glacier melted away. A very reasonable and generally accepted deduction is that the northern part of the continent was uplifted because the weight of the ice was removed. Conversely, thousands of years before as the glacier was gathering its growth, the land it covered must have been slowly depressed by weight of the ice. At both times the response of the earth's crust must have been twofold, an immediate response due to elasticity and compressability of the rock, trifling though this might be; and a so-called plastic response of more delayed action which involved the flow of material deep in the crust where rigidity of the rocks gives way in time to high pressures and high temperature. Such flow would gradually compensate large changes of load on the earth's surface to restore a balance called isostatic equilibrium. The rate of uplift increases northward from the hinge-line.

Postglacial tilting was an important factor in the later history of the Great Lakes. It took place north of the hinge-line which crosses the southern end of Lake Huron and is just south of Green Bay, Wisconsin. The Algonquin and Nipissing shorelines are perfectly

horizontal south of the hinge-line, but north from it they are sloping upward because the land has been tilted up.

LAKE ALGONQUIN

Glacial Lake Algonquin, one of the more recent ancestors of the Great Lakes, came into existence after melting of the glacier caused recession of the ice front northward away from the north facing escarpment near Niagara Falls and uncovered a lower outlet that allowed drainage from the Lake Huron basin to abandon its westward course toward the Mississippi in favor of an eastward channel to the Atlantic. The chronological order of the development of Lake Algonquin has been worked out by study of the records -- the beaches, deltas, bars, beach forms -- the lakes left.

1. THE FIRST PORT HURON STAGE. In the first stage the lake was a small body of water that occupied only the southern part of the Lake Huron basin and drained southward from Port Huron as Lake Huron does today. The north shore of the lake was ice -- the Huron lobe of the glacier. About the same time a larger body of water, Lake Chicago, in the southern part of the Michigan basin was discharging westward from Chicago down the Illinois River valley. As the lobes of ice in the Huron and Michigan basins retreated, the Mackinac Straits eventually were opened up and Lake Chicago (of the Lake Michigan basin) merged at the north with Lake Algonquin. This merger may have taken place before the eastern lake had formed an outlet north and east of Port Huron, or may have occurred before, the record is not quite clear. At any rate, disappearance of ice from the Straits allowed the first appearance of Mackinac as an island.

2. THE FENELON FALLS STAGE (OR KIRKFIELD STAGE). The second stage of Lake Algonquin has been variously named after the two Ontario towns 65-70 miles northeast of Toronto, near the site of its outlet. When the glacier had melted back to the north of Lake Simcoe in Ontario, the water of Lake Algonquin found a lower eastward passage from Fenelon Falls down the Trent River valley to the Lake Ontario basin near Trenton, Ontario. By this change in outlet, Lake Algonquin was lowered in level and the Port Huron outlet was temporarily abandoned. At this time the lake water probably stood about 200 feet higher on Mackinac Island than it does today. Evidence is not sufficient to warrant giving an exact figure because the lake set about consuming its own traces due to the uptilting of the land. (Nature has a habit of writing records and almost immediately beginning their erasure.) Mackinac Island and the whole Straits region were rising, but not as rapidly as the outlet at Fenelon Falls which was farther north of the hinge-line. Lake level rose just as rapidly as the outlet and the lake actually encroached on the land to the south. The lakes continued to rise until the water was again level with the Port Huron and Chicago outlets.

3. THE THREE-OUTLET STAGE. When Fenelon Falls had been uplifted to the same level as Port Huron, the lake

began to spill out to the south again. Both the Port Huron and Chicago outlets shared the drainage with Fenelon Falls for a time. But as a sill of hard limestone at the Chicago outlet prevented downcutting at that place, whereas in the Port Huron outlet the threshold was on soft material and erosion lowered it, all drainage gradually concentrated and overflowed southward from Port Huron. A significant point here is that Lake Algonquin at this stage had submerged and obliterated its shoreline of the Fenelon Falls stage nearly everywhere south of the Fenelon Falls outlet, Trent River. Only in one deep and protected embayment near Owen Sound on the western shore of Georgian Bay, Ontario, has that shoreline been observed. But the shoreline of the three-outlet stage marks the culmination of a rising level and is exceedingly well developed and conspicuous. It has been traced widely over the Great Lakes and is known simply as the "Algonquin beach." Absence of beaches of the earlier stages makes a more specific designation unnecessary. At the three-outlet stage of Lake Algonquin, the glacier had retreated so far that glacial ice occupied only the northeast coast of the lakes. Lake Algonquin was one vast body of water covering nearly all of lakes Huron, Michigan and Georgian Bay, most of Lake Superior and considerable areas of surrounding land. As uplift continued, the Fenelon Falls outlet went dry and the three-outlet stage ended.

4. LAST PORT HURON STAGE. Continuing uplift finally deprived the Fenelon Falls outlet of Lake Algonquin overflow, but lake level kept a stable position in conformity with the outlet at Port Huron which was below the hinge-line and unaffected by tilting. Thus as the ice retreated, the land north of the hinge-line, relieved of weight of the ice, was being gradually raised out of water and beaches were formed in close succession below the level of the Algonquin beach. These beaches are known as the "upper group of Algonquin beaches". The vertical range of the series increases with distance northward from the hinge-line, and at Mackinac is about 50 or 57 feet.

5. LOWER ALGONQUIN STAGES. Recession of the ice and opening of some newer outlet in the northeast, and to the south of North Bay, (near Callander, Ontario, about 175 miles north of Toronto) terminated the formation of the upper Algonquin beaches. The lake was rapidly drained to a lower level at which another shoreline was developed, then drained again to a still lower stage and another beach formed. This happened several times, and the beaches at the various stages have been called collectively the "lower Algonquin beaches". But unlike the upper Algonquin group which are in one continuous closely spaced series, the lower beaches are separated into stages by vertical intervals of 20 to 40 feet in which well developed beaches do not occur. Near Cape Rich, in southern Georgian Bay, the beaches of successive stages occur as given below:

<i>Stage</i>	<i>Elevation Feet Above Sea Level</i>	<i>Tilt Feet Per Mile</i>
Algonquin	801	3 $\frac{3}{8}$
Upper Algonquin group	801-762	
Lower Algonquin		
Wyebridge	718	?
Penetang	684	3
Cedar Point	663	2 $\frac{7}{8}$
Payette	624	2 $\frac{3}{4}$
<i>hiatus</i>		
Nipissing	640	$\frac{1}{2}$
Post Nipissing group	640-580	
Present Lake Huron	580	

At this locality four separate lower Algonquin stages are represented. The elevation of each shoreline is given in feet above sea level, and the approximate tilt or rate of rise toward the north-northeast in feet per mile. The uplift which was responsible for the spread of the beaches in the upper Algonquin group, was still slowly going on during formation of the lower Algonquin beaches, but as a factor in changes of level, it was not so important as the drops of the lake level to each new outlet that became available.

Lower Algonquin time was thus one of generally falling water levels down to the time the Payette beach was formed, and at that point the story passes into shadow for a time.

A LOST PERIOD OF LOW WATER

At the Payette stage, the water was more than 100 feet below present Lake Huron near its south end and its shoreline was almost 20 miles north from the site of Port Huron, on the present lake bottom. It seems rather certain that several still lower stages occurred of which little can yet be said. At one lower stage, the Minong, the lake had fallen so low that it probably lay bare almost the whole south end of Lake Huron below Pt. aux Barques, where the water today reaches 300 feet in depth. Since the beaches formed at these low levels are now submerged except along the northeastern-most coasts of the Great Lakes, their relations are not very evident. It is only in those rather wild spots that the perplexing problems can be explored.

Ultimately glacial ice receded beyond the province of the Great Lakes, and the lowest drainage way, the Mattawa valley, reaching from North Bay eastward to the Ottawa River, was opened. Perhaps the Mattawa-Ottawa outlet was functioning at the same time as the Minong stage but more likely came into use somewhat later. The period of the declining lake came to an end and a new regime took hold. Controlled by the rising North Bay (Mattawa) outlet, and keeping step with it the lake gradually climbed upward from its low level. At the

outlet, water level remained stationary with respect to the land, but everywhere to the south the lake was encroaching and most markedly near the south end. By all the evidence we have, uptilt took place very slowly, and changed very little within a man's life span. In order to raise the lake some hundreds of feet and return it near to its modern stand, this activity must have been in progress for several thousand years. Surely men must have lived along the shores of this lake for evidences of even earlier occupation have been found. Strange tales they must have had concerning inundation of their camp sites by the rising water. Possibly flood legends among the Chippewa Indians bear some relation to this phenomenon.

NIPISSING GREAT LAKES

The Nipissing stage of the Great Lakes was a direct outgrowth and culmination of the long interval of mounting lake level just described and began when the ice had completely disappeared from the lake region. When the water in southern Lake Huron basin topped the Port Huron pass, and found drainage southward through the St. Clair, Detroit and Niagara rivers, control of lake level passed from the North Bay, Ontario, outlet to the present Port Huron outlet. Further uplift as it continued only raised the northerly shore out of water and caused the North Bay outlet to run dry. Very likely during many centuries both outlets functioned together. This was the Nipissing (two-outlet) stage.

At the Nipissing stage, more than at any previous time, the lakes resembled the modern water bodies. The climate was more modern for the great ice sheet had entirely disappeared. In fact there are some reasons for believing climate to have been somewhat milder than at present. The Nipissing lake was a unified expanse over the Huron, Michigan, and Superior basins and conformed closely to the present coasts. At Mackinac Island the water stood about 50 feet higher than today. At Sault Ste. Marie the water was about 80 feet above present water at the foot of the locks, and almost 60 feet above Lake Superior. The site of the rapids and of the principal parts of the neighboring cities were submerged by a narrow strait that connected the great basins to north and south. The steep shore bluffs which bordered this strait are very conspicuous all about there today. Indeed high wave eroded cliffs generally characterize the Nipissing as well as the Algonquin shoreline. Erosion is abetted by high water and Lake Nipissing times were times of high water rising higher and higher until eventually all the overflow was to the south past the site of Port Huron.

TRANSITION TO PRESENT CONDITIONS

With the final establishment of Port Huron discharge, no new major drainage developments have occurred. Continued uplift gradually raised the North Bay-Mattawa outlet channel above lake level and also tilted up the Nipissing shore line. Storms continued to toss up gravel ridges on the sloping land below this shoreline. In many

embayments where waves are wont to accumulate sand or gravel in beaches, a considerable series of beach ridges is spread rather evenly between the Nipissing and the present shore. Some places have only five or six, others have over 20 of these crested beaches. But nearly everywhere they are distributed rather evenly over the slope below the Nipissing and bespeak the more or less gradual and even character of the movement which was taking place.

Based on the measured rate of recession of Niagara Falls within the last century of close to four feet per year, and on the relationships of post-Nipissing drainage to the Niagara gorge, it has been estimated that 4000 years have elapsed since the abandonment of the Nipissing beach and North Bay-Mattawa discharge and initiation of the present Great Lakes. During these 40 centuries the Nipissing shoreline has been tilted about one-half foot per mile.

Uplifting of the northern shores caused many rivers to cut down and trench the flats once occupied by the Nipissing lake. This process has been restrained in some places by hardness of the rock ledges over which the rivers run. For this reason many waterfalls and rapids exist not far from the mouths of streams entering northern Lake Superior and Georgian Bay.

Especially notable is the rapids of St. Mary's River. When uplift brought the sandstone sill at this rapids above the current lake level, the strait which had previously existed was converted to a more vigorously moving river -- probably only about 1300 years ago. Thereafter Lake Superior has been a separate lake and its level, in response to uplift, pivots on the outlet at the "Soo". Its northeastern coast continues to emerge but rising water has drowned and flooded the streams entering its southwest shore from Ontonagon to Duluth.

CONTINUED CHANGE IN RECENT TIME

Over 70 years ago, George R. Stuntz, a land surveyor, pointed out that Lake Superior had recently been flooding its southwestern shore and that many stumps in position of growth are below water level in St. Louis Bay near Duluth. Two or three decades later E. L. Moseley noted a similar condition at the west end of Lake Erie. At the same time G. K. Gilbert compared data from the water level gages and found they indicate that very gradual tilting was in progress over the Great Lakes area in exactly the same direction as the tilt of the ancient beach lines. More detailed knowledge of present times confirms these early deductions that the broad postglacial upwarping of our glaciated area is still active.

FUTURE CHANGES

Uptilting in the northeast has multifold effects on the Great Lakes. Levels of lakes Erie and Ontario which have outlets at their northeast ends are rising; Huron and Michigan which discharge at the south are shrinking away from their northern, rising shores. Lake Superior

combines both phenomena, for its outlet is midway along a southwest-northeast axis; and tilting is gradually submerging the Duluth shore while the northeast coast is emerging. The uptilting of the land has continued for thousands of years since glacial times, has been of measurable degree even during the last 50 years, and may be expected to continue. If the rate of uplift does not change, Mackinac Island should rise about three-quarters of a foot per century. Uplift will probably be twice as great at the northeast corner of Lake Superior (since the rate of uplift increases with distance north of the hinge-line). This small amount of continued change is quite overshadowed by the short term fluctuations of the lake due to season and weather.

SHORELINES OF MACKINAC ISLAND

DURING the long time the lakes stood at their several levels, waves were at work making cliffs and cutting promontories from the shores, cutting chimney rocks, building beaches, cutting terraces. As one approaches Mackinac Island by boat the island seems to rise in gigantic steps from the lake shore to Ft. Holmes at the summit, the treads are the terraces, the risers are the cliffs of the ancient shores. On this island the shore features made by the ancient lakes, now high and dry above the level of the modern lake, are the most striking features of the island.

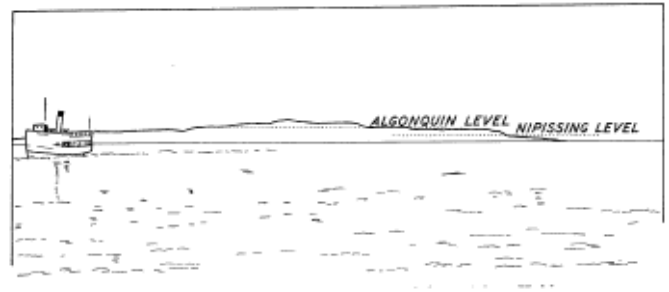


Figure 2. Mackinac Island from the lake. After Hobbs.

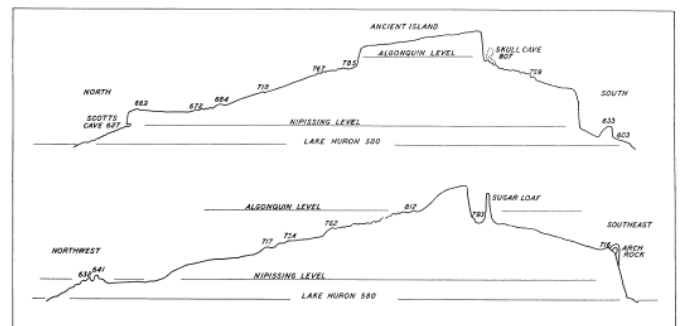


Figure 3. Profiles across Mackinac Island to show former shore levels. Upper profile north to south, from St. Clair Point to Scott's Cave, across east edge of Early Farm, to north end of Ancient Island to Fort Holmes, across short rifle range to west edge of Fort Mackinac grounds, to Hank's Pond to harbor; Skull Cave stack in dotted line. Lower profile northwest to southeast along British Landing Road to Beechwood Trail, to Point Lookout, to Sugarloaf, to Arch Rock.

HIGHEST ALGONQUIN

The high hill on Mackinac which stood as an island in the three-outlet stage of Lake Algonquin has been referred to occasionally as "the Ancient Island".⁴ It is little more than half a mile long and almost a quarter of a mile wide. It is highest at the southeast end, the strategic eminence of Fort Holmes. In fact the highest natural point (elevation 891 feet) is at the very tip of the Ancient Island which drops away abruptly in a wave cut precipice. The top of the island near the north end is 60 feet lower. Algonquin sea cliffs skirt the Ancient Island almost completely, and the long northeast face is one continuous cliff for over half a mile. The south side also is cliff, as well as the southwest side as far as Fort Holmes Road. The north tip is surrounded by cliffs which reach south for one-quarter mile along the west side. Only in the vicinity of Beech wood trail are the cliffs absent. Here obviously, deposition predominated over wave erosion and the eroded materials were sifted into gravel ridges.

For this very natural reason the very highest shoreline is only in this stretch. In the back part of the Protestant Cemetery, the shore line is a gravelly bench at 813 feet, extending north-northwest across Fort Holmes Road. Changing to a gravel ridge, it swings to almost due north near Beechwood trail and crosses a small valley which drains down the west slope of the Ancient Island where it stands six feet above the bottom of the valley. Followed by Cliff View trail the shore continues at elevation 811 to 812 feet about one-quarter mile to the north tip of the Ancient Island where it is at 810 feet. Toward the north end limestone cliffs are back of the gravel ridge and also a low cliff is in front of it where wave action at a subsequent lower level eroded out a bench. This bench, at an elevation of 785 feet, swings around the north tip of the Ancient Island and so truncates the highest gravel ridge. From here all along the east and south sides of the Ancient Island the highest shoreline has been similarly destroyed by later erosion at lower levels. The 812-foot contour of the highest shore on the west follows the face of cliffs on the east and south. The highest shore marks of the east side are indistinct benches at about 793 feet at the base of the cliffs. At the southeast corner of the Ancient Island a strong gravel ridge takes off from the cliff and runs west at an elevation of about 800 feet. Its point of attachment at the tip was nearly eroded away from the east by the 793-foot bench development. All along the south side a marked swale five to seven feet lower is between the ridge and the cliffs. A path follows this swale from the south tip of the Ancient Island west to Skull Cave.

The cliffs along the south side of the Ancient Island make a salient behind Skull Cave and swing sharply to the northwest. From this salient a gravel ridge takes off to the northwest, it is crossed by the bridle trail just northwest of Skull Cave and is followed by Garrison Road most of the distance from Skull Cave to the cemeteries and Fort Holmes Road. The Post Cemetery east of Garrison Road lies in the deep swale between

this ridge and the cliffs of the Ancient Island. The north, wedge shaped end of the Catholic Cemetery, between Garrison Road and Custer Road, is on the crest of the ridge. From the cemetery the crest continues northwest, parallel to and just west of the road to about 500 feet beyond Fort Holmes Road. North of Fort Holmes Road and on the east side of British Landing Road, are pits from which gravel was taken out some years ago. Beyond the pits the ridge swings north across British Landing Road and trends toward the north tip of the Ancient Island. This ridge is considerably more bulky and longer than the highest beach and is only about two feet lower. From near Skull Cave to the Custer Road, the ridge has an elevation of about 806 feet but reaches 810 feet near Fort Holmes Road and 809 feet to the north of British Landing Road. Evidently this ridge is what Taylor referred to as the highest shoreline, indicated on previous maps; but the ridge to the east is higher and is a well formed beach.⁵



Figure 4. Sugarloaf Rock -- Viewed from Point Lookout with Lake Huron in distance. This mass of breccia is a stack along the Lake Algonquin shoreline. It rises about 75 feet above the surrounding flat and reaches an elevation of 856 at the summit.

Two stacks associated with the Algonquin shoreline have interesting implications. A stack or "chimney rock", is a small rocky island separated from the coastal cliffs by wave erosion. Along the shores of the ancient lakes, many stacks are high above the reach of waves of the modern lakes, but their tops were once off-shore islands of the ancestral lakes, made dry land as the lakes lowered. Sugarloaf, about 300 feet east of the Ancient Island, below Point Lookout, is the most conspicuous stack on the island (fig. 4). This rock stands about 75 feet above the surrounding ground and its summit (elevation, 856 feet) must have been 40 or 50 feet above water at the highest stage of Lake Algonquin. It is a magnificent display of limestone breccia. One may see by close inspection, fragments of bedded limestone of various sizes from very small fragments to blocks several feet long, tilted in random directions, and all cemented into a solid mass. Obviously these breccias are more firm and resistant than the surrounding beds, and the survival of the Sugarloaf in Lake Algonquin is due to resistance of the breccia to wave action. A small cave in the sheer north face of the Sugarloaf is near the

level of the highest shoreline, it was carved by wave erosion in a softer part of the breccia.

It seems a fair assumption that the Sugarloaf in its present form could not have withstood the erosive powers of the great masses of ice which ground over and past it long before the Algonquin beach was formed. The present pinnacle must have been a much stouter mass of rock at the time it was ice covered to have escaped destruction by the glacier. In all likelihood it was a part of the parent rock mass to the west, the Ancient Island, until it was cut off as the cliffs of the Ancient Island were gradually driven back by wave erosion of Lake Algonquin. The existence of these high cliffs bespeaks considerable wave erosion and it is well known that Lake Algonquin was very productive of such precipices along its highest shoreline. Recognition of the fact that Sugarloaf has been isolated 300 feet from the cliffs of Ancient Island gives us a visual impression of the amount, or at least the minimum amount, of erosion at this place. It seems likely that much of the erosion that cut off the stack, occurred during the rising of the water which culminated in the highest stage of the lake. Undoubtedly the highest part of the Mackinac Island mass was eroded away and removed by the time the Algonquin beach was built. At the present summit, the southeast tip of the Ancient Island, the surface is sloping gently upward toward the top of the wave cut bluff.

The Skull Cave stack is not as conspicuous as the Sugarloaf but its relationships are much the same. It also is composed of the limestone breccia; its summit is at 831 feet; it was 15 to 25 feet above the highest lake level and it is separated by about 50 feet from the nearby cliffs of the Ancient Island. Plainly, the salient of the former coast here was caused by it. Between the stack and the cliffs, one can make out three indistinct flattish little rubbly beaches, all less than 100 feet in length which tie the stack to the Ancient Island; two of the beaches, at elevations 804 and 800 feet, trend northeast from the stack; the other beach -- its elevation is 804 feet -- runs northwest to the cliffs. Skull Cave itself in the west side of the stack is a sea-cave produced by wave action (fig. 5). The floor at the entrance to the cave is at an elevation of 806.5 feet and the roof overhead is about 3 feet higher. The entrance was perhaps awash or was slightly submerged at the time of highest lake level. The interior of the small cave is somewhat pocketed due to erosion in the softer parts of the breccia, but the rounding and smoothing of surfaces, which characterizes wear by the waves, is not very evident. Only in one or two of the upper pockets is such wear to be seen and in one of these pockets the writer found a wave rounded limestone pebble. Time and weather have apparently erased or concealed the abraded water worn surfaces elsewhere.

The story of Skull Cave and its naming is worth repeating here. Alexander Henry, famed early fur trader and voyageur, having survived the massacre of Pontiac's conspiracy at Mackinaw City on June 4, 1763, was at Mackinac Island a few days later in the

protection, as a friend and adopted brother, of a Chippewa Indian, Wawatam. Some trading canoes had just arrived from Montreal and their English goods, had been confiscated by the Indians. Here are Henry's own words describing what happened:

"In the Indian canoes was a large proportion of liquor, a dangerous acquisition, and which threatened disturbance among the Indians, even to the loss of their dearest friends. Wawatam, always watchful of my safety, no sooner heard the noise of drunkenness, which, in the evening did not fail to begin, than he represented to me the danger of remaining in the village and owned that he could not himself resist the temptation of joining his comrades in the debauch. That I might escape all mischief, he therefore requested that I would accompany him to the mountain, where I was to remain hidden, till the liquor should be drunk.

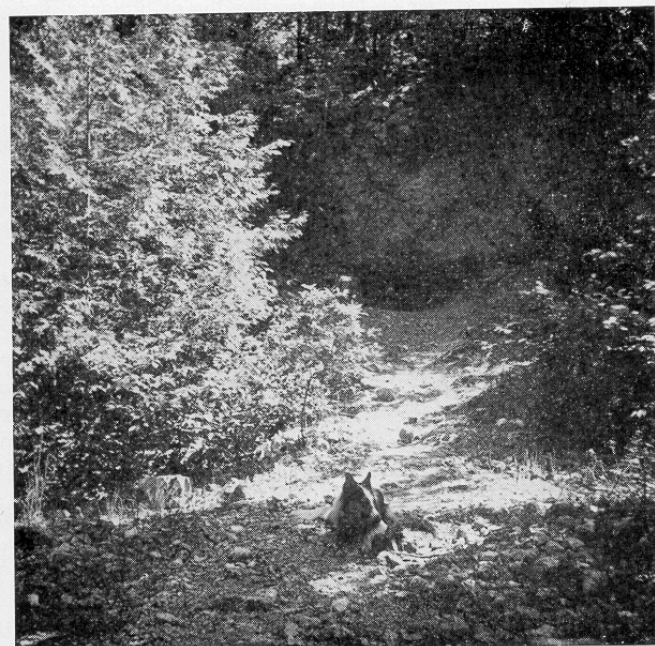


Figure 5. Skull Cave -- a sea cave (elevation 806-809) at the Algonquin shoreline, eroded into a stack of breccia.

"We ascended the mountain accordingly. It is this mountain which constitutes that high land in the middle of the island of which I have spoken before, as of a figure considered as resembling a turtle, and therefore called Michilimackinac. It is thickly covered with wood and very rocky toward the top. After walking more than half a mile, we came to a large rock at the base of which was an opening, dark within, and appearing to be the entrance of a cave.

"Here Wawatam recommended that I should take up my lodging and by all means remain till he returned.

"On going into the cave of which the entrance was nearly ten feet wide, I found the further end to be rounded in its shape, like that of an oven, but with a further aperture too small, however, to be explored.

"After thus looking around me, I broke small branches from the trees and spread them for a bed; then wrapped myself in my blanket and slept till daybreak.

"On awakening, I felt myself incommoded by some object upon which I lay; and removing it found it to be a bone. This I supposed to be that of a deer or some other animal and what might very naturally be looked for in the place in which I was; but when daylight visited my chamber, I discovered, with some feelings of horror, that I was lying on nothing less than a heap of human bones and skulls which covered the floor!

"The day passed without the return of Wawatam, and without food. As night approached I found myself unable to meet its darkness in the charnel-house which, nevertheless, I had viewed free from uneasiness during the day. I chose, therefore, an adjacent bush for this night's lodging and slept under it as before; but in the morning, I awoke hungry and dispirited and almost envying the dry bones, to the view of which I returned. At length, the sound of a foot reached me and my Indian friend appeared making many apologies for his long absence, the cause of which was an unfortunate excess in the enjoyment of his liquor.

"This point being explained, I mentioned the extraordinary sight that had presented itself in the cave to which he had commended my slumbers. He had never heard of its existence before; and upon examining the cave together, we saw the reason to believe that it had been anciently filled with human bodies.

"On returning to the lodge, I experienced a cordial reception from the family which consisted of the wife of my friend, his two sons, of whom the eldest was married, and whose wife, and daughter, of thirteen years of age, completed the list.

"Wawatam related to the other Indians the adventure of the bones. All of them expressed surprise at hearing it and declared that they had never been aware of the contents of this cave before. After visiting it, which they immediately did, almost every one offered a different opinion as to its history.

"Some advanced that at a period when the waters overflowed the land (an event which makes a distinguished figure in the history of their world) the inhabitants of this island had fled into the cave and been there drowned; others, that those same inhabitants, when the Hurons made war upon them (as tradition says they did) hid themselves in the cave and being discovered, were there massacred. For myself, I am disposed to believe that this cave was an ancient receptacle of the bones of prisoners, sacrificed and devoured at war-feasts. I have always observed that the Indians pay particular attention to the bones of sacrifices, preserving them unbroken and depositing them in some place kept exclusively for that purpose."

It may be noted that the skulls which were in the cave, being unknown to the Indian residents at the time, appear to have been then of some antiquity. Whether

they could have dated back to a very ancient time when the Algonquin shoreline was little above water level would seem very unlikely since the exposed bone material could scarcely last so many thousands of years. Moreover, the island was separated from the mainland by a greater stretch of water than it is now and its smaller size would have held little attraction for primitive man. But good evidence⁶ has now come to light that ancient people were inhabiting the Great Lakes shores at a time not so long after the Algonquin beach was formed and while ice still remained along the north shore of the glacial lakes.

Just how high the former water level reached cannot be stated precisely, except that it stood within a very few feet of the highest gravel ridge at 812 feet. Was it two or three feet over this ridge, say at 816 feet, or three or four feet below it, perhaps at 810 feet? In some places, beach ridges give evidence of having been formed above water level, in other places ridges are formed below water level. But instead of trying to answer the question of the water, a related question may be put. Where does the water of the modern lakes stand with reference to their beaches? Records prove that in the last few decades, the modern lake levels have varied up and down as much as six feet. Such a range in level is not at all improbable for the ancient lakes.

Mackinac Island today is sheltered from the west and from the prevailing winds by the peninsula at St. Ignace. But this peninsula was entirely submerged in highest Algonquin time. Much evidence suggests that the dominant storms at that time were from the east since extensive beach gravels were deposited only on the west side of the Ancient Island. And at immediately lower stages, while more gravel ridges were being built along the west shore, the east side was retreating under a continued heavy pounding by the waves. The ice front lay only some 100 miles to the northeast of Mackinac at this time and perhaps the outflow of violent winds from the ice cap, as from Greenland and the Antarctica today,⁷ brought about a control of Mackinac's shore problem by easterly storms.

The geography of the region surrounding the Ancient Island was quite different from the geography of the Mackinac Straits region today. The nearest mainland was about 30 miles to the south, 10 miles south of Cheboygan. The northern part of the Southern Peninsula was then an archipelago. Open water reached for at least 15 miles in all directions and covered most of the eastern part of Michigan's northern peninsula. A few islands were north of Hessel, Mackinac County, and between Cheboygan, Cheboygan County and Petoskey, Emmet County. The sites of Beaver Island to the west and Cockburn Island to the east, were marked by small islands, and a few high hills on Manitoulin were islands in Lake Algonquin. But Bois Blanc and Drummond Islands, and most of the Beaver Island group, as well as St. Martin's Islands and Round Island, were under water. Lake Algonquin had a reach

of 700 miles and was one of the most expansive fresh water lakes of which we have any knowledge.

⁴Taylor, F. B., The Highest old shore line on Mackinac Island: Amer. Jour., Sci., vol. 43, pp. 210-218, 1892.

⁵Op. cit., p. 420, footnote (e).

⁶Greenman, E. F., and Stanley, G. M., Archaeology and Geology of Two Early Sites near Killarney, Ontario: Michigan Acad. Sci. Papers, vol. 28, pp. 505-530, 1942.

⁷Hobbs, W. H., The Glacial Anticyclone and The Continental Glaciers of North America: Am. Phil. Soc. Proc., vol. 86, No. 3, 1943.

UPPER ALGONQUIN GROUP

The shorelines of the Upper Algonquin group of beaches are found closely spaced on the lakeward slopes for a vertical interval of 40 or 50 feet below the Algonquin beach. The series is typically displayed on the Short Rifle Range behind Fort Mackinac where 11 ridges are between elevations of 799 and 759 feet. Custer Road crosses 14 ridges of the series between 806 and 764 feet. British Landing Road passes in rolling undulations over 15 ridges between 810 and 762 feet. All three of these successions drop abruptly from the crest of the lowest ridge down to flatter ground in front. The Short Rifle range group drops 15 feet, the Custer Road group 16 feet and the British Landing group 23 feet. The number of ridges in the group is obviously dependent on local conditions -- the gentleness of the slope, the amount of materials drifted longshore by wave action, etcetera. In the north part of Private Claim 110, 12 successive ridges are between elevations 795 and 774 feet, and farther northwest, seven additional ridges are between 772 and 763 feet. And to these 19, several more above 795 feet must be added to the total number in the series.

The vertical interval covered by the series seems to be of more than local significance. And inasmuch as this range is not precisely known, particular attention was paid to the elevation of the lowest beach of the Upper Algonquin group. The 763-foot beach northwest of Harrisonville and near Annex Road is a very strong gravel ridge, as pronounced as the ridges at 759 feet (Rifle Range), 764 feet (Custer Road) and 762 feet (British Landing Road). But into its fore slope a bench cut at 754 feet represents a still lower level. About three-eighths of a mile to the south, in the northeast part of Private Claim 4, a long hair-pin shaped shoal was built out to the west-southwest from the south part of Harrisonville. The gravel ridges have summit levels of 793 feet east of Indian Road, 787 feet a few hundred feet to the west near the dump, and 775 feet near the west end from which the ground abruptly drops away. Delicate ridges line the flanks of this shoal near its end. On the south side eight ridges were counted from the summit upper ridge down to the lowest, which is a small sharp crested gravel ridge at 756 feet, associated with a bench at 754 feet eroded into the terminus of the hair-pin shoal. Though well wooded, this locality gives a nice display of the lower part of the upper group of Algonquin beaches. The effects of wave activity at the 754-756-

foot level (and at 759 feet at the foot of the Short Rifle Range) are considerably less than at the 762-763-foot level in many other places.

About one-eighth of a mile north of the shoal locality and due west of Harrisonville, the strong north-south beach at 763 feet is succeeded by a few very minor ridges down to 752 feet. At a slightly lower level, a long conspicuous shore ridge extends westward across Annex Road to end at the Hert home in Private Claim 3. It is over half a mile in length. Its elevation drops from 749 feet at the east end, to 747 feet at Annex Road, 738 feet in Private Claim 331 and finally to 731 feet at the west end. It seems quite possible that this ridge was constructed principally under water and as a submerged feature that extended westward from the island while the waves were forming the 763-foot beach. If so it was formed in from 15 to 30 feet of water, a fact which provokes doubts concerning its origin. Small minor ridges at lower levels border its course, but the principal ridge, in its bulk and height and trend away from the shore and especially in its vertical position is unique among Mackinac Island shore features. At other places on the island only a few weak beaches (northwest of Hert's residence; at State Road near British Landing Road) are between the upper Algonquin beaches and the Battlefield beach and no features that might have been formed by wide spread surf activity are in this interval.

The upper group beaches, like the Algonquin beach show that during their formation gravel accumulation and beach extension were continuing extensively only on the west side of the Ancient Island. Few gravel beaches of the upper group are on the east side -- two have been traced just northwest of the Sugarloaf at 780 and 779 feet.

LOWER ALGONQUIN

Below the upper Algonquin group of beaches is a zone or interval where no beaches were formed because the lake fell with comparative rapidity due to drainage at new outlets, which is in contrast to the zone of well worked gravel ridges of the upper group, formed with the gradual emergence of land (or gradual drop of lake level). On Mackinac Island well marked beaches are generally absent between the 763-762 level and the Battlefield beach at 718 feet. (See map). However, a few beaches 10 or 15 feet above the Battlefield may be seen in several places close to the southeast boundary of Private Claim 1. They are very weak and indistinct gravelly ridges. In the south part of Private Claim 2 between elevations 715 and 730 feet, several ridges are more distinct but they are short and not strongly developed.

Battlefield Beach

The type Battlefield beach extends across the south part of Private Claim 1, and was named by Taylor after the Battlefield of August 4, 1814. It takes off from a cut bluff runs westward in a broad curve across British Landing

Road and across the golf course, and splits up into minor ridges which die out in the woods to the west. It is a conspicuous ridge in the open land east and west of British Landing Road and stands six feet above the swale. Its elevation in this stretch varies between 718 and 716 feet but is nearly everywhere 717 feet. Wave cut bluffs border the north side of the hill east of the beach and from the hill another ridge at similar elevation continues to the northeast. The beach is weakly developed at a few spots along the most northerly part of Leslie Avenue. Bordering the front of the beach on the golf course are a few weak shoreline marks at lower levels. A sandy ridge just east of the club house, a foot or so below the principal Battlefield ridge, marks the landward edge of a little lagoon closed off by it.⁸

Since the Battlefield stage of the lake was but a temporary halt in the decline of lake level as ice barriers were giving way, its mark on the land is less imposing than the records made during the highest Algonquin or Nipissing stages. The Battlefield shoreline cannot be completely traced as it is not continuous. However, a number of fragments of it may be identified where gravelly ridges are found at accordant altitudes.

To understand the method of correlating shorelines by elevations, it must be remembered that all but the most recent shorelines have been tilted up to the north-northeast, along what is called the "tilt-line". The tilt is a fact well established by detailed measurements over the whole lakes region, but the phenomenon cannot be demonstrated on Mackinac Island alone since the island is so small its extent along the direction of the tilt-line is not great. Therefore, comparison of shore line elevations must be made with ancient shorelines farther south and farther north. When we compare the elevation of the highest Algonquin shoreline at the nearest point to the south which is two miles north of Levering, Emmet County, (elevation 763 feet), with its elevations at Mackinac Island (812 feet), and at Hessel (863 feet), a distance of 30 miles, we note the rise of 100 feet in 30 miles along the tilt-line, or 3.3 feet per mile. The lower Algonquin shorelines are tilted almost as much as the highest Algonquin but the Nipissing shores are tilted only about one-sixth as much, that is half a foot per mile.

Considering the tilt therefore, the Battlefield beach should be about three feet lower in the southern part of Mackinac Island than at the type locality farther north. Measurements of the elevations at northern and southern parts of the island indicate this. A well formed gravel beach curves northeast from the intersection of Tranquil Lane and Indian Road, its elevation ranges from 716 to 713 feet. One of the weak, lower ridges associated with the Battlefield shoreline, is a short distance southeast of this intersection, at elevation 702 feet. A weak Battlefield beach, elevation 716 feet, is within the road loop at Arch Rock, another with elevation about 715 feet is west of Leslie Avenue near the pumping station. A strong gravel ridge also trends northward across roadways in the north part of Private

Claim 2, and a short beach is in the western part of Private Claim 331 where the garage behind a lonely cottage is situated on its crest. Near the southwest line of Private Claim 1, State Road cuts through a very short beach of large, rounded rubble, elevation 717 feet.

⁸Taylor considered that the Battlefield beach everywhere has an uncommonly coarse, bouldery composition and suggested that it has somewhat of the character of an ice rampart. The writer is inclined to discount the implication that such characteristics are widely typical of the Battlefield beach. In this connection a considerable difference of opinion exists between the views expressed by Taylor and more recently by the writer, as to what beaches elsewhere correlate with the type Battlefield beach on Mackinac Island, (See Taylor, 1915, p. 433). The coarse composition of the type Battlefield beach can not be doubted. In addition, the writer observed a striking abundance of scattered boulders, largely pre-Cambrian glacial erratics from Canada, on the slopes a short way behind the Battlefield beach in the woods on Mackinac.

Other Lower Algonquin Shorelines

A considerable number of beach lines are on the island at elevations intermediate between the Battlefield and the Nipissing beaches. They are a miscellaneous lot and no special names are used for them.⁹ No well defined beaches were developed for about 33 feet below the Battlefield beach. The next well developed shoreline is at about 683 feet above sea level. A good gravel ridge at this elevation is in the east part of Private Claim 1. It extends southwest from a wooded knoll and crosses open fields for about a quarter mile, then it swings northwestward and ties to another knoll in tombolo fashion. A roadway runs along the ridge for some distance. Short Cut Trail and Bluff View Trail cross gravelly correlatives of this beach at 684 feet, a little farther northeast. One of these beaches is truncated (cut off) obliquely by the high bluff as a result of later cliff recession at the Nipissing lake stage. This beach at 684 feet elevation seems to have been built from the east as a recurved spit around the high ground to the south of the remaining part of the beach. More spit beaches are at 676, 673, 672 feet, all similarly cut off by the Nipissing bluff. About 600 feet to the southwest a nicely formed little sandy hooked spit at 675 feet elevation was built southwestward across the roadway and into the basin of the swamp. A gravel ridge at 669 feet runs parallel along the top of the Nipissing bluff near the cut and road ramp down to Scott's Cave Road. It is a lower successor of the truncated spit beach at 672 feet nearby, and was developed similarly as a spit from the southeast but was not recurved.

The series of beaches just described cover a vertical range of about 15 feet at this locality. The highest beaches were most strongly developed. A few weak beaches are in the same general range elsewhere on the island: at 683 feet at the first cottage northwest of the Grand Hotel, at 684 feet at the top of the Nipissing bluff overlooking the breakwater east of the harbor, and near State Road at the Mackinac Straits trail.

In the high wood northeast of British Landing a fine array of spit beaches is around the northwest side of the plateau-like high ground. The highest beach of this set is a ridge at 676 feet near the north end of the plateau.

Just north of it are much stronger beach ridges at 670 and 666 feet which are sharply separated from one another by a swale 10 feet deep. The 666 foot ridge, where it ties to a higher rock knoll at the very north tip of the plateau, was almost removed by cliff recession at the Nipissing stage. The plateau is in fact circled on three sides by the Nipissing cliffs. That a number of lower beaches were removed by Nipissing erosion is quite evident as one follows the top of the bluff around to the southwest and south. Five more ridges successively appear, three strong ridges at 663, 660, 657 feet and two weaker ones at about 657 feet. All are sliced off at acute angles by the Nipissing cliff and their headward, northerly portions are gone. Toward the southern ends, all the spits are recurved to the east and terminate at the entry to a wide, deep water bay of Lake Algonquin which opened toward British Landing and is now the low swampy area of Private Claim 1. The highest spit (667 feet) drops off abruptly 15 or 20 feet from its outer tip, and even where obscured by the forest growth in the dense woods it constitutes a rather spectacular example of this type of shore feature. The entire group is an excellent illustration of the principles of erosion and deposition along shorelines and relationships to topography.

The lowest beach of the lower Algonquin group is a little to the south of the beaches just described and in the vicinity of State Road. It is divided into two parts by the rocky hill which rises abruptly on the east side of State Road about one quarter of a mile southeast of British Landing. The smaller part of the group begins from a cut bench (636 feet) at Mackinac Straits Trail where it is rather faint and curves from east to northeast across State Road and ties to the hill. Its elevation varies around 638-639 feet and the swale back of it (to the east) is eight feet lower in places. Its gravel is moderately rounded. A wave formed beach at 635 is developed in the west slope of the rocky knoll overlooking State Road. From the north side of the knoll, the longer section of this shoreline runs north-northwest as a broad high bar which closed in the broad bay to the east (the swampy area of Private Claim 1) and converted it from an open bay to a land held lake or lagoon. The gravels in the bar -- predominately limestone, are rounded to a considerable extent but not so much as the gravels in the Nipissing bar to the west. Dense woods with impassible wind falls hindered measurements along the northern part of the ridge and prevented any view of the entire feature, or of its benched rear slope or the hollow immediately back of it, yet the general relationships are unmistakable. British Landing Road reaches a summit (about 641 feet elevation) in crossing the north end of the bar and cuts through it, three feet below the crest of the ridge. The end of the feature is a curiously short wedge-shaped fragment on the north side of the road beside the flight of steps up to a cottage at the top of the bluff. The wedge is due to Nipissing erosion which cut off a small slice of the bar at almost the precise point where it was attached to the bluff and terrace with which it was originally

associated. Except for this tiny infringement, the bar survived Nipissing erosion throughout its length in contrast to the cutting of the higher beaches farther north. The position of the bar in the bay gave it some protection and the Nipissing bar later developed to the west prevented its destruction by the waters of Lake Nipissing. Undoubtedly more of its north end would have been lost at Nipissing times, had it not been for the resistant salient in the Nipissing bluff about 300 feet north of British Landing Road. Yet material was lost to Nipissing waves along the bar's cut front slope as will be described later.

Perhaps a correlative of this beach is a low ridge at 640 which extends a couple of hundred feet eastward from Cadotte Avenue into the golf links, just east of Grand Hotel. However, the evidence proving that this feature is of lower Algonquin age rather than Nipissing is much less clear or convincing than the evidence proving the beaches near British Landing are of lower Algonquin age.

⁹Taylor called these the "Fort Brady" beaches in the belief that they correlated with a shoreline at Sault Ste. Marie. But reasons have been presented for rejecting this correlation and the use of the term. (See Stanley, G. M., Lower Algonquin beach of Penetanguishene Peninsula; and Lower Algonquin beaches of Cape Kich, Georgian Bay; Geol. Soc. Amer. Vol. 48, 1936, pp. 1933-1960; vol. 49, 1937, pp. 1665-1686). Theoretically the beaches in this group must correlate with some of the lower Algonquin strandlines described in Georgian Bay (Penetang, Cedar Point, Payette), but any attempt to draw such connections with present data would have to be done more or less arbitrarily, since on Mackinac Island these beaches are not manifestly separated into different stages. It seems best for the present, therefore, to suspend judgment on correlation of individual beaches in this group with those on Georgian Bay.

MACKINAC DURING THE LOST PERIOD OF LOW WATER

The relationship between the Nipissing shoreline and the lower Algonquin beaches immediately above it is peculiar. It is a relationship of discontinuity and abrupt transition of discordant trends and separation by high cliffs.

The successive beaches of the upper Algonquin and post-Nipissing groups and the successively lower hooked spits near British Landing show that they were developed as the lake level gradually lowered. But at no place do the lower Algonquin beaches grade into the Nipissing to show that a similar gradual lowering to Nipissing level occurred. Surely a considerable hiatus separated the Nipissing shoreline from the lower Algonquin beaches. Mackinac Island has less proof of this fact than other areas in the Great Lakes region where detailed studies of more phenomenal examples of the discordance have been made and which confirmed the matter by the equally unconformable tilts of the respective water-planes. Mackinac Island bears good illustrative evidence of this break even though the kernels of proof lie elsewhere.

It is now believed that after the lowest of the lower Algonquin beaches (at 639-641 feet elevations southeast of British Landing) was abandoned by the

lake, the water continued to fall to lower levels, very likely by stages and periodic declines to lower outlets. How low the lake level declined and in how many stages, are questions for which answers must be sought. Certainly it was far below present lake level at Mackinac Island.

One of the various evidences which point toward a level below the present lake level is the Minong beach of Lake Superior. The Minong beach has been traced in detail along the east coast of Lake Superior between Montreal River and Goulais Bay (an eastern arm of Whitefish Bay, northwest of Sault Ste. Marie and almost straight north of Mackinac Island) where it slopes southward about 3¾ feet per mile. If the slope of the beach be projected southward at the rate of 3¾ feet per mile from Goulais Bay where its elevation is 700 feet, to Mackinac Island, the beach would be about 120 feet below present water level at the Island. And below the Minong beach are others which indicate that the water was even lower.¹⁰ Trenching the floor of Mackinac Straits at depths of 150 feet and more is a remarkable river valley which once drained water from the Lake Michigan basin eastward to the basin of Lake Huron at a time when the water was much lower than now. It seems rather certain that a river was flowing through the straits during the low water period between lower Algonquin and Nipissing times. The valley courses eastward midway between St. Ignace and Mackinaw City, turns northward to make a great loop about the west, north and east sides of Mackinac Island, then almost touches the western tip of Bois Blanc Island as it opens out into deeper water in Lake Huron (see fig. 6).

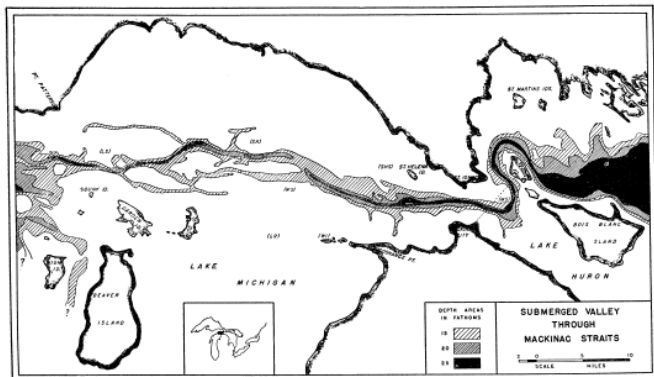


Figure 6. Submerged Mackinac Valley.

Soundings of the Mackinac Straits recorded on the hydrographic sheets of the United States Lake Survey, indicate that at such a low water stage, historic Mackinac, the lonely island of the Algonquin lake, had ceased entirely to be an island. It was, instead, a lofty headland at the end of a peninsula that extended southeast through Round and Bois Blanc Islands and was connected to the mainland near Cheboygan. The shrinking waters by lowering lake level exposed large areas of bottom land and the present busy steamer lane that separates Mackinac and Round Islands was then dry land.

¹⁰The reader must always bear in mind that upcanting or tilting of the land to the north raised low beaches to a high level and preserved them.

NIPISSING

The return of the lake level from its extreme low position to the Nipissing shoreline 50 feet above present water at Mackinac has been explained as a result of land tilting. By all inferences this movement taking place through several thousand years was a slow and leisurely process by which lake level was rescued from the 200 foot depth of its depression. Naturally erosion was extensive, with so much time available, and especially owing to the fact that it was always "high water" along the rising lake's shores.

However interesting it would be to know, it is impossible to trace around the Mackinac Island mass, the shore line of this low level stage before the Nipissing stage, that is to trace the contour which corresponds in elevation to the Nipissing shore. Such a contour would follow the outline of the land before lake Nipissing was actively cutting or with all Nipissing erosion and deposition restored. Doubtless it would be far more irregular than the actual Nipissing shoreline that can be followed about most of the island today. The oblique transection by the Nipissing bluffs of lower Algonquin beaches all around the island tell plainly enough how wave erosion endeavored to straighten the coast by cutting off the headlands and peninsulas. The mute cliffs are an eloquent testimony to the attempt.

The results of deposition in smoothing the Nipissing shore are evident in several places. The beach developed at 641-foot elevation southeast of British Landing shut a deep interior bay off from the lake during lower Algonquin time. Dissatisfied with this arrangement, the currents of Nipissing time effected a further straightening. They spanned the mouth of the semi-circular bay as it then existed with a great gravel bar which is over a quarter mile long and probably one of the most impressive shore features on the island. Its elevation ranges from 628 to 632 feet above sea level. The high bluffs north and south of this were beaten back somewhat by erosion at the same time.

Contrarily, on the south shore, Nipissing deposition built a pointed lowland out into the lake (a cusped foreland) between the Grand Hotel and Fort Mackinac. The land was built by the union of two gravel bars, one built for a quarter mile southwestward from the cliffs at the foot of Fort Mackinac, the other built at the same time southeastward from the bluffs which front the Grand Hotel. It is plain that the storms and currents from the easterly quarter were more effective for they built faster and higher than the currents from the west, they built the bulk of the foreland and at the same time were the more active agents in erosion of the adjacent cliffs. The well worn gravels are well shown behind the old Astor House at the cliff in the front slope of the easterly bar. The bar ranges in elevation from 630 to 635 feet and reaches its maximum height midway of its extent rather than near

the point of attachment to the cliffs. Hank's Pond occupies a sharp hollow 25 feet below the crest of the bar which closed it off (fig. 7). The bar on the west side of the salient seems to have been constructed as an underwater feature for it is 10 feet lower than the easterly bar in elevation, yet both bars tie cliffs of the same elevation.

In the triangular area enclosed by these bars are three very curious beach forms -- very gentle and subdued ridges which were built northeastward toward Hank's Pond. The ridges appear to have been formed before the 624-622 foot bar along the southwest side of the triangle since the bar truncates all the ridges and is generally higher. It almost seems that the terrain to the southeast of these ridges and within the point of the triangle may have been in existence previous to Nipissing time and that its presence attracted the currents and caused construction of the bars; and that the weak beaches at 622, 620 feet were perhaps formed along the gentle northwest slope of this terrain in lower Algonquin time. The very inconspicuous nature of these beaches would fit in with such an explanation, for the beaches would naturally have been washed over, lowered and weakened at the Nipissing stage. That this interpretation is correct may well be doubted since the field relationships at this spot are far from convincing. Nevertheless, as excellent evidences of such a condition are at several places in Georgian Bay, the possibility of such a relationship on Mackinac seems worth mentioning.



Figure 7. Nipissing bar (elevation 630-635) and lagoon hollow on the golf links behind the village. Eastward view from near Cadotte Avenue. The bar extends across the right half of the picture from the large church house in the center. The steep back slope dropping off to Hank's Pond is visible. The roadway leading across the golf links toward Fort Mackinac is shown on map in pocket.

The Nipissing shore cannot be traced in a complete circuit about the island. Along several stretches the abruptness of the slopes, combined with exposure to storm waves, allowed erosion to continue even after culmination of the rising level was reached and on into the period of post-Nipissing emergence. In some places the distinction between the true Nipissing shore and the

shore of a slightly later stage is subtle, depending on a difference in level of five or eight feet. The shores are so nearly at the same level that complete discrimination seemed scarcely worth the effort in field work. It would have involved a level traverse entirely around the base of the high cliffs, with many obstinate tangles of windfalls and impassable fences to contend with. A few examples will suffice to illustrate. The true Nipissing terrace has an elevation of about 629-632 feet at the base of bluffs, the crests of gravel beaches are about 629-635 feet. Where terraces beside cliffs have a somewhat lower elevation, say below 625 feet, they must have been a result of later shore action at lower levels. The terraces below the South Sally Port of Fort Mackinac (figs. 8, 9, 10), at the promontory between Chimney Rock and Heriot Point, and along the bluffs near Scott's Cave are at such lower levels. With allowance for the slight tilt of the Nipissing water-plane, (see Glossary), the shoreline should be about a foot higher near the north end of the Island than at the south. Inherent small disparities in beach height are enough to totally eclipse this amount of tilting over the small area on Mackinac Island. Bearing in mind the existence of subtleties in correlation pointed out in the discussion of the Algonquin shoreline we may go on and for convenience of discussion use the term Nipissing with the same latitude which has been customary and not differentiate between the two levels or give a name to the lake at the slightly lower level.

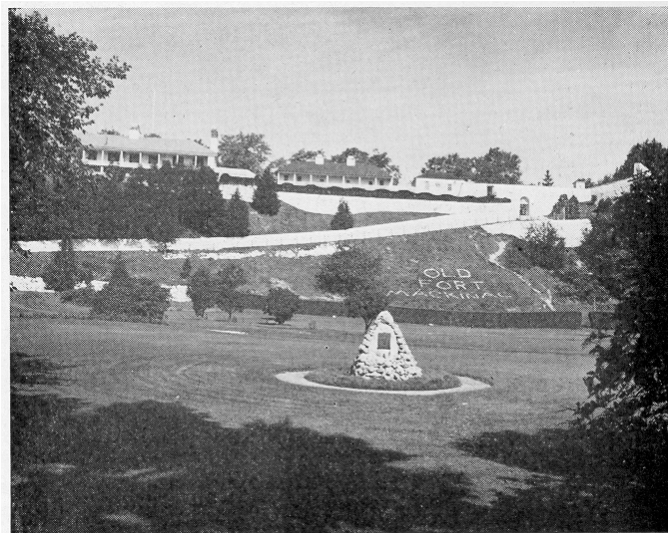


Figure 8. South Sally Port of Fort Mackinac and entrance ramp from the yacht basin dock. The Fort is built on the brow of the Nipissing sea-cliff, and the west blockhouse overlooks the end of the Nipissing bar.

From the beginning of the great bar at the foot of the stairs and ramp to Fort Mackinac, the Nipissing shore extends as a terrace backed by high cliffs eastward almost to Robinson's Folly where it has been cut away, and in this stretch a minor gravel bar runs east from Truscott Avenue to the Mission House (fig. 11). North of Robinson's Folly the Nipissing shore has been consumed by more recent erosion for a half mile. The terrace abutting the high cliffs for a half mile is only six or eight feet above the water and has probably been in

existence only a few centuries. A fragment of the Nipissing terrace, a distance of a hundred yards long, is at Hennepin Point and a much longer fragment can be traced behind and northward from the pumping station where it makes a landing for the stairway. A rubble beach ridge is on this fragment just north of the stairway. At both ends this remnant of Nipissing terrace tapers out gradually against the cliffs and has been destroyed for over a quarter mile farther north. From the point where it appears again it is continuous all above the north end of the island to British Landing. It was almost removed, however, just south of Carver Pond where a mass of resistant breccia makes a salient in the cliffs and diminishes the width of the terrace.



Figure 9. West blockhouse of Fort Mackinac, looking east.

Similar promontories of breccia are at Eagles Crest and Scott's Cave and between Friendship's Altar and British Landing Road. The breccia too is responsible for the little islet of Friendship Altar which is an excellent example of a stack, though it is much smaller than the Sugarloaf. The Altar is about eight feet wide and 13 feet high and is separated from the Nipissing bluff by a 10 foot gap. The terrace at the base of the bluff nearby is at 629 feet and a little narrow bench at the same elevation circles the outer side of the Altar (fig. 12). The top of the altar must have been regularly deluged with spray from Nipissing storm waves. About 500 feet northwest of Scott's Cave a similar but smaller remnant of rock stands 40 feet out from the bluff.

Scott's Cave is an excellent example of Nipissing wave erosion within the breccia (fig. 13). It is about 15 feet long and eight to ten feet wide with a nine foot ceiling which has a rough and weathered surface. The elevation of the floor of the cave is generally within a half

foot of 625 feet though it is a couple of feet higher at the entrance. Both the floor and the lower wall surfaces show heavy wave scour and rounding.

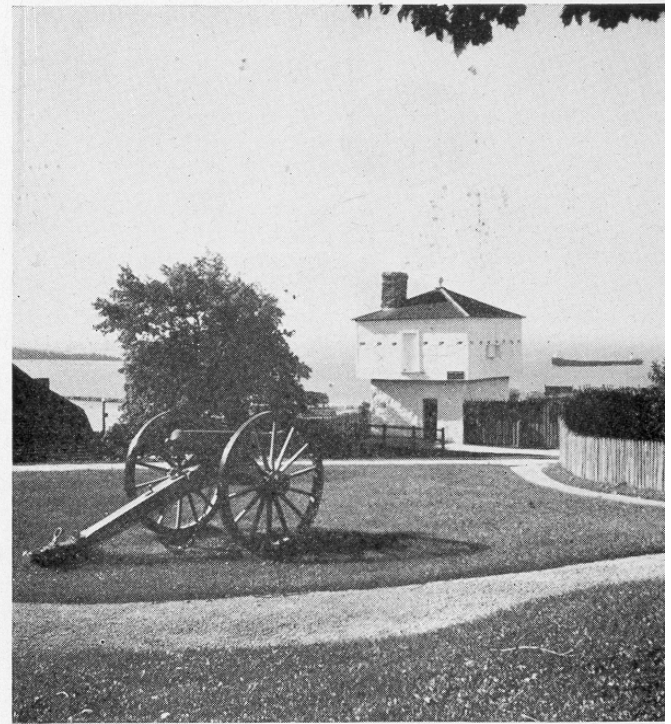


Figure 10. West blockhouse, Fort Mackinac. Round Island in left distance; freighter at right, east-bound through the Straits.



Figure 11. Nipissing terrace and wave cut bluff, lined with cedar trees in the background, behind old Mission Church. Covered with small thornapple trees, a Nipissing bar parallels the bluff and the Mission House at the right is situated on it. View east-northeast across Truscott Avenue.

At the north tip of the Nipissing Island and near the driveway to a cottage east of Point aux Pins, Scott's Cave Road follows a gravelly bar which closes off behind it a large hollow two or three hundred feet long and about 18 feet deep. The relationships of the bar and the lagoon hollow are evidently very similar to the relationships of bar and lagoon at the Nipissing bar southeast of British Landing, yet with a point of decided

contrast. The bar southeast of British Landing fronts the mouth of an embayment, the bar of the Scott's Cave Road loops around a bold headland where the littoral (shore) drifting currents from the southeast rebelled at the sharpness of the turn and carried gravel beyond, northwest of the cliff shore. Both features contributed to a smoother shore contour than existed previously. The embayment southeast of British Landing is discussed in more detail later on.



Figure 12. Friendship's Altar. A stack of the Nipissing shoreline, northeast of British Landing.

The Nipissing shore cliffs run southwest from Mackinac Straits Trail to a breccia protected salient behind Radisson Point, continue south through Private Claim 2, swing west to another salient near Heriot Point and again turn south to Chimney Rock which is another stack of breccia. The terrace narrows and pinches out near the boundary of Private Claim 2 and Private Claim 3 and very bold cliffs take its place for about a thousand feet. In the west part of Private Claim 331, the terrace reappears and continues southeastward to Lovers' Leap in Private Claim 4. The terrace is nearly everywhere from 25 to 60 feet wide but increases to 120 feet in width in the southwestern part of Private Claim 331, and narrows in one or two places at promontories in the associated cliff. A strong ridge of rubble runs along it through part of Private Claim 331 and the terrace has a peculiar back slope toward the cliffs. For one-quarter mile southeast of Lovers' Leap the terrace has been destroyed and replaced by lofty cliffs but it is continuous for the next quarter mile to the Grand Hotel. It is generally narrower in this stretch than in Private Claim 331 but otherwise, is quite similar. Below the west protico of the hotel the bluff reaches another salient where it turns sharply to the east and is bordered by a much broader terrace. Eastward in front of the Grand

Hotel the bluff loses height, disappears at Cadotte Avenue and gives way to the depositional bar already referred to.



Figure 13. Scott's Cave. A sea cave of the Nipissing shoreline. Its floor, (elevation 625) is conspicuously rounded by Nipissing wave action.

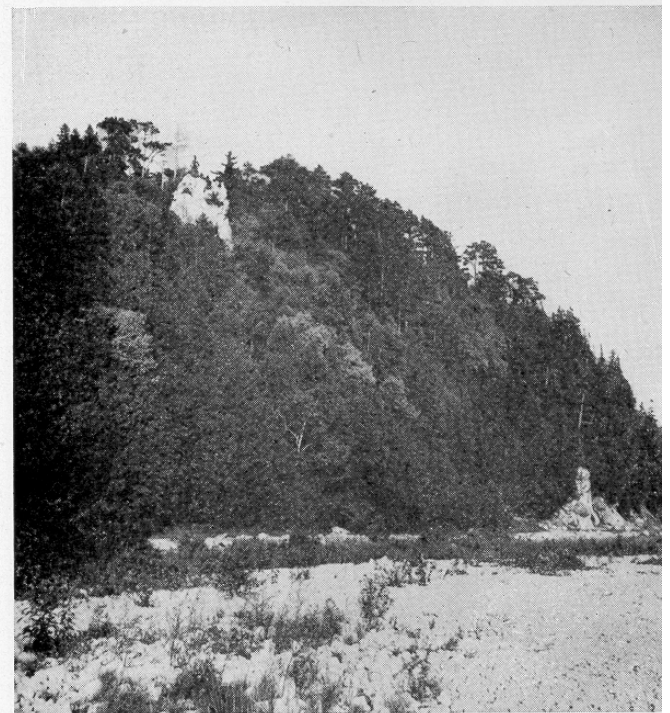


Figure 14. Lovers' Leap. A rocky pinnacle of brecciated limestone along southwest shore. Wave erosion during and since the Nipissing stage has worn away surrounding softer material.



Figure 15. Arch Rock -- as seen from the lake shore.

Lovers' Leap (fig. 14) and Sunset Rock are peculiar features and not true stacks as they first appear. During the Nipissing stage of the lake they were not islands at all but were chimney-like promontories along cliffs from which they were detached only at a considerable height above water level. The gap between Lovers' Leap and the cliff was about 60 feet above Nipissing level, now at 690 feet above sea level. Nevertheless, Lovers' Leap and Sunset Rock are probably just as much creations of Nipissing wave erosion as is Friendship's Altar. Their hard breccia masses merely stood up in increasing solitude as the softer cliffs were worn back around them. A great many smaller, partially detached promontories, elsewhere along the Nipissing cliffs, have identical relationships. The mass of breccia near the South Sally Port gives the same suggestion though it is less outstanding.

Arch Rock seems to be of somewhat similar origin (fig. 15). At first the writer was inclined to interpret it as a sea arch of the Battlefield stage of the lake. The top has an elevation of 722.5 feet, and the arch is eight or 10 feet thick with a yawning hollow for a distance below it (figs. 16, 17, 18). Though the arch is at about the proper level to correspond to the strong Battlefield beach its proximity to the eroded cliffs of Nipissing and later time advises a different interpretation. It probably was produced by wave erosion at fully 80 to 120 feet below the Arch itself where water action was able to undermine and remove softer materials and leave some of the firm breccia as a bridge.

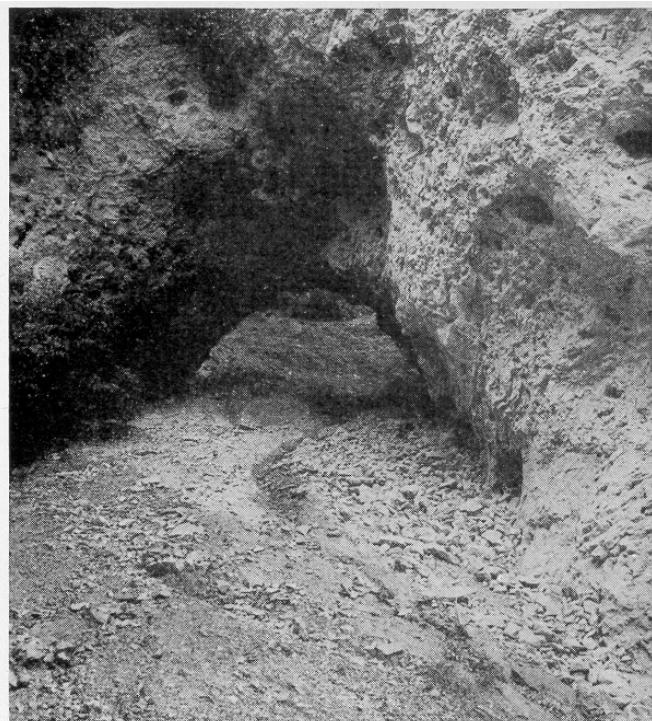


Figure 16. Sanilac Arch. A small arch near the east base of Arch Rock. Looking up the slope of alluvium collected from disintegration of the cliffs around and beyond the tunnel-like arch.



Figure 17. Gitchie Manitou -- also known as Michabou's Rock. A huge block of breccia which has evidently fallen from the high pinnacle at the left, at the south edge of Arch Rock. The rock at the top of the pinnacle resembles the fallen mass, and softer beds underlie it.

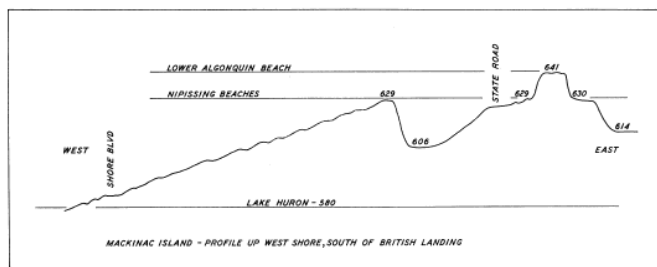


Figure 18. Profile across post-Nipissing, Nipissing and lower Algonquin beaches, extending east from west shore at a point about 1000 feet south of British Landing. The relation of the Nipissing bar to its lagoon hollow is well shown; also the Nipissing terrace at the back of the lagoon, cut into a lower Algonquin bar; the Nipissing bench along the east side of bar was formed by a small land enclosed pond in Nipissing time.

The low swampy area of the northern interior of the island was the floor of a wide deep-water bay of Lake Algonquin which opened toward the west. During Algonquin time, a bar was built across the mouth of the bay forming an enclosed lagoon, which continued to exist as a pond during Nipissing time. A little gravel beach is just north of the culvert on the east side of British Landing road where it crosses the big swamp. The beach extends southward from high ground to the swamp at elevation 628-625 feet. A very conspicuous bench at elevation 630 feet borders the east side of the high 641-foot bar southeast of British Landing. Marl has been deposited in somewhat lower situations nearby. The pond was separated from the open Nipissing lake to the west only by the narrow lower Algonquin gravel bar which stood about 12 feet above Lake Nipissing level. As the pond waters could easily percolate through the loose gravels of the bar, the pond drained readily and maintained a level, very close to the level of the main lake. The Nipissing developments on the western side of this gravel bar remain to be described.

A magnificent Nipissing gravel bar (elevation 628 to 632 feet) runs north-northeast from the cliffs at the southwest line of Private Claim 1, crosses Mackinac Straits Trail, curves north across State Road and joins the cliffs just north of British Landing Road. It makes a gentle arc concave to the west and is three-eighths mile long. Where the beach lies on the flattish gravel terrace north of its mid-point, its crest stands from three to seven feet above the ground to the rear (east) but where it closes in two depressions farther south, it stands 22 or 23 feet above them with pronounced ridge characteristics -- it appears much like a railroad embankment and is actually taken advantage of for a minor roadway. Considerable marl and numerous Nipissing shells can be seen in the bottom and slopes of the larger hollow.

The two contrasting slopes of this bar are characteristic of Nipissing bars in similar situations elsewhere and offer a good illustration of geological processes. The rear slope of the bar falls abruptly off into the deep hollow near the south end. (Elevation 606 feet.) The front slopes gradually off toward the lake in step-like series of lower ridges. (See fig. 18.) During the stage of rising

water the waves and currents continually swept gravels north and south from the cliffs and deposited them across the mouth of the bay. Gradually the deposited gravel ridges met and the bar was formed; waves continued to sweep gravel into the bar, building it higher; also waves threw materials eastward over the crest, so that the gravels slid down the back slope and created the "angle of repose"¹¹ slope there. Rising water also aided the waves in gradually heaping the bar to greater height. When the highest level of lake Nipissing had been reached and the bar emerged permanently above water, the waves continued to build, but built successively lower and lower ridges on the front slope.



Figure 19. Bank of limestone rubble cast up by storms of recent years. It is invading a grassy flat, vegetated during previous years of lower water. Southwest shore; Grand Hotel on top of bluff in left distance.



Figure 20. Abrupt drop of one to two feet along landward edge of rubble bank. Such rubble banks are currently common along the southwest side of the island, and illustrate the resurgence of the lake which formed the Nipissing bars.

Several diminutive analogies may be seen today along the present west shore. Here the low water of low Lake Huron level uncovered broad flats which are somewhat vegetated. The rising lake of the last few years has

been strewing banks of bare, coarse, limestone rubble along the edges of these flats (figs. 20, 21). On the landward side each bank of rubble drops at the same repose angle as the Nipissing bar, a foot or two down to the flat; on the lakeward side of the flat in many places are two or three lower ridges that were formed in less violent storms or at seasonably lower water. The analogy of these present day examples with the Nipissing bars is perfect in both form and principal. The difference is only in magnitudes.

Levels were run throughout the entire length of the Nipissing bar and 33 observations were taken on its crest. The elevations vary from 632.1 feet at the extreme north end, just north of British Landing Road, to 629.3 feet opposite the northern hollow, to 627.3 feet, the lowest point, about 300 feet from the south end, to 630.3 feet at the extreme south end. The northern three-fourths of its length stands above 628.5 feet.

The front slope of the 641 foot lower Algonquin bar has been sharply cut away by Nipissing wave action to a 10-foot bluff and two to three little gravel ridges are strung along the back (landward edge) of the terrace which meets the base of this bluff, east of State Road. Altogether the back of the terrace and the crests of these ridges fall within a half foot more or less elevation than the minimum elevation (628.5 feet) of the Nipissing bar to the west, and the highest of these Nipissing features east of State Road are perhaps a few tenths of a foot below the mean summit of the bar on the west. Similarity of elevations suggest that the Nipissing beaches east of State Road were made before the great bar was heaped to its full present height.

The gravel in the lower Algonquin bar at 641 feet and in the bluff along its front contains more coarse pebbles than in the gravels in the Nipissing beaches at its base. Gravel in the Nipissing beach runs in places to a very uniform gravel of hickory nut size, which indicates considerable reworking by the Nipissing waves of the gravels that were eroded away from the lower Algonquin bar. However, in one or two places the Nipissing gravels seemed to be much less weathered and to have a fresher appearance which is reasonable enough, but the observation lacks sufficient verification. It is generally true that in beaches of similar situation and exposure to storms, Nipissing gravels are much better worked than are the gravels of lower Algonquin age. It is of considerable interest that these two sets of gravel of identical origin, separated vertically by as little as a foot or two, are separated in times of deposition by thousands of years, during which the lake dropped 200 feet more or less below the level of the 641-foot beach and then during Nipissing times rose again to within a few feet of the former level. (See figs. 18, 31.)

¹¹The steepest slope on which rock fragments rest.

POST-NIPISSING GROUP

The beaches developed after Lake Nipissing time are best displayed in the northern part of the island where

they generally fill the entire interval between the Nipissing shore and the present strand. East of Scott's Cave a connecting road (not shown on the map) runs up the slope from the Shore Boulevard to Scott's Cave Road and crosses 13 well formed beaches ranging in elevation from 586 to 621 feet. The base of the cliffs is only a couple of feet higher than the innermost beach and the true Nipissing beach is absent at this place.

The woods back of the British Landing dock contain 27 ridges which seem to cover the complete vertical interval of about 45 feet between the Nipissing and the modern storm beach at 583 feet. This series of beaches vividly indicates the gradual character of the change from Nipissing time to the present. The successive ridges average less than two feet apart vertically, and 40 or 50 feet horizontally. Probably several times as many gravel beach ridges were actually formed along this shore since Nipissing times. Many were formed at seasonal or recurring cyclical low water stages and subsequent great storms at high water destroyed one or two but heaped all their combined rubble together and thus replaced them by a slightly higher and more massive beach. Undoubtedly the serried beaches are just such high storm beaches which remain today, left high and dry by the subsiding lake.

In the field near Cannon Ball Inn at British Landing, 15 beaches, some of them faint, are between elevations of 588 and 612 feet. More beaches at higher levels can be found in the very thick woods. On the lowest beach, (588 feet), beside British Landing Road, 12-inch cedar trees are growing which proves that the beach has existed for over half a century.

Where erosion rather than deposition of gravel was predominant, the post-Nipissing beaches are only partially developed or are absent. Even on some gentle slopes, because of the nature of the shore and insufficient littoral drifting of the materials, they were not strongly enough developed to be conspicuous today. South of the Grand Hotel and back of the east breakwater scattered beaches partially illustrate the group.

A particularly strong beach about halfway between the Nipissing and present lake level has been recognized in a number of localities, especially over northern Lake Michigan in the proximity of Mackinac Straits. It has been termed the Algoma beach, but it cannot be well interpreted since it has not been continuously traced over the region; its slope is unknown and its elevation and presence are doubtful at many places. The writer has observed its fine development on the Fox Islands off Charlevoix in Lake Michigan, at an elevation of 600 feet, about 18 or 20 feet lower than the Nipissing beach (618-620 feet). A few beaches on Mackinac Island may represent the Algoma shoreline since they outrival development of other higher and lower post-Nipissing beaches. The beaches at 607 and 612 feet east of Cannon Ball Inn, and at 608 and 604 feet east of Scott's Cave may be of Algoma age. More striking shore forms are found near the village: A terrace (603 feet) and

wave cut cliff behind the Astor House; another (603-605 feet) trending west-northwest from the corner of Cadotte Avenue and Mahoney Street, one-quarter mile southeast of the Grand Hotel; and a narrow little bench (604 feet) of but two or three yards width which runs for some distance along the steep slope below the Nipissing bench west of the Grand Hotel.

The Shore Boulevard at Mission Point follows a terrace with bluff, at an elevation of 590 feet which was probably abandoned by the lake within a very few centuries. At somewhat the same level or lower, the boulevard follows the base of wave cut cliffs from Robinson's Folly almost to Carver Pond and from the Grand Hotel to Chimney Rock. Bordered by extensive flats close to lake level this relatively modern shoreline is of great strength compared to most other shore forms in the post-Nipissing group.



Figure 21. Storm gravel beaches on north side of dock near British Landing. The dog is in swale back of highest beach which has an elevation of 584 or about 4 feet above water level.

MODERN CONDITIONS

Conspicuous storm beaches of gravel are being built along the modern shore north of British Landing and around Point aux Pins (figs. 21 to 26). Three to five ridges are between the water and Shore Boulevard. At the British Landing dock the gravel crests are at 583.5 feet, or about four feet above 1943 water levels. The ridges are younger than the dock since they curve outward in attachment to the cribbing (figs. 24, 26). At the time of the writer's visit (1941) a marked line of recent flotsam, sticks, reeds, cans and other floated objects were piled along this stretch of shore at about 582 feet. They were cast up by storm waters, probably by the great windstorm of November 11, 1940, which entangled Mackinac's woods with so many prostrated balsam trees (fig. 28). Two very recent beaches are still lower at 581.8 and 580.2 feet. These beaches are composed of fresh, unweathered, white limestone pebbles. The gravel in the beaches at 583.5 feet, which post-date the dock, is slightly darkened by a growth of

tiny lichen. Along the outer edge of the shore road, a gravel ridge at 587-588 feet is more or less grown up with 10-inch cedar trees and pines.



Figure 22. Storm gravel beaches near Point aux Pins. They have been built by easterly storms with consequent littoral drifting to the northwest. Tiny lagoons may be seen in the distance.



Figure 23. British Landing.

Southward from Pointe aux Pins along the east side of the island, the wide Nipissing terrace and the series of post-Nipissing beaches, narrow, diminish, and disappear southeast of Carver Pond. It is evident that the littoral drift of material was dominantly northward along the east shore in harmony with the greatest fetch of storm waves and that much of the gravel deposited in the north was derived from cliffs farther south. Carver Pond is closed off by a gravelly bar that indicates northward construction. Later storms threatened to cut the bar away after the Shore Boulevard was laid along it, and log revetments were emplaced to protect the road. Even

so considerable gravel was carried off northward to form newer beaches. Thus the island is being continually built northward. Along the shore near the pumping station one may find many bricks rounded off by wave action. They are relics from the steam boiler plant in use before the modern plant was put into operation. The distribution of the worn bricks along the shore illustrates the dominant direction of drifting by wave action. A few bricks are found for about 75 feet to the south of the plant, but most of them are distributed along the beach for 400 feet to the north.



Figure 24. Storm beaches and dock near British Landing. View south.

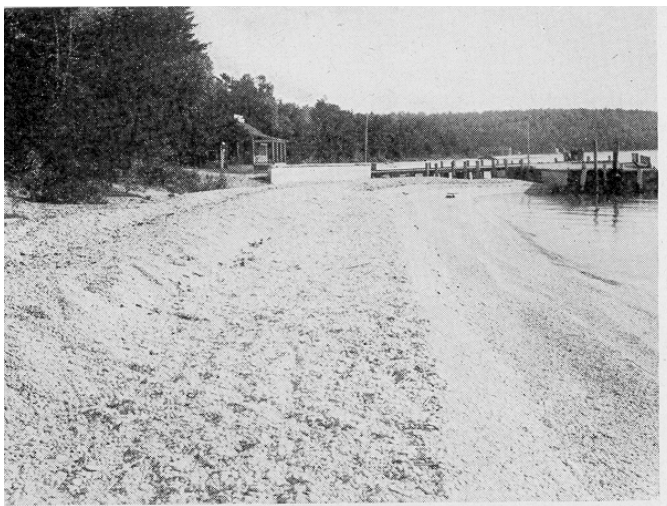


Figure 25. Storm beaches and dock near British Landing. View north. Note how the beaches, constructed subsequently to the dock, have turned outward from shore to tie to the ribbing. The shelter of the dock has broken the force of wave action and interrupted the course of littoral drifting by affording a protection for deposition behind it.

Fluctuations in lake level are a matter of concern to navigation, to commerce, and to shore communities, especially when changes of lake level are abnormal. Changes in modern lake level are due to various causes. Occasionally temporary changes of a few feet occur within an hour, due to seiches or oscillations of the lake caused by passing changes in air pressure or barometric

waves. Ordinarily seiche pulsations do not cause much change in lake level but fluctuations of five to nine feet have been noted. Protracted wind also may cause water to pile up at one end of a lake. On Lake Erie, differences of about 12 feet have been noted at Toledo and Buffalo during storms from east or west. Apparently the moon exerts a pull on the lakes as lunar tides of a couple of inches are reported. Lake Huron regularly reaches its seasonal high level peak in midsummer, about one or one and a half feet above the minimum level of mid-winter. Over periods of years its level sometimes varies more than one and one-half feet.

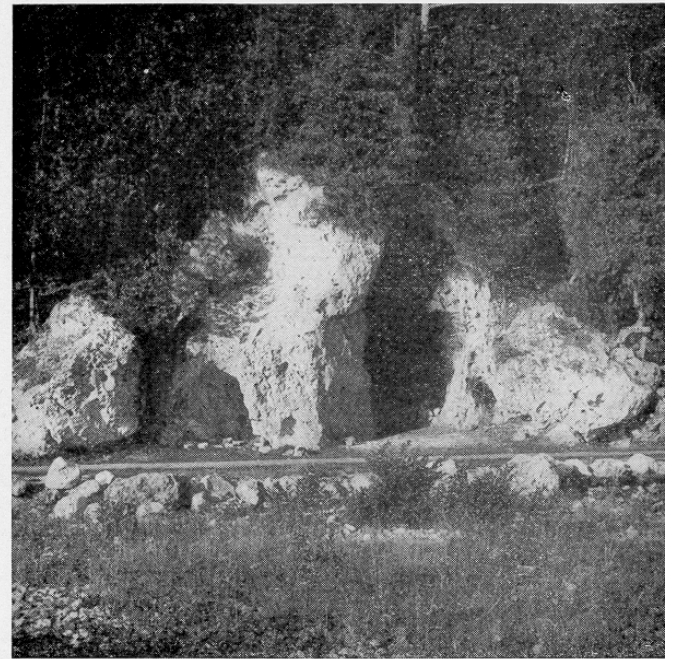


Figure 26. Devil's Kitchen. Sea caves associated along the shoreline of the last few centuries, eroded in breccia. Ground elevation along base of rocks is 584-585.

Mean level of Lake Huron from 1860 to 1932 was 580.87 feet. Highest recorded level was 584.69 feet in 1838. Lake Huron level reached 583.7 feet again in 1876 and 1886. In 1925-1926 the lake was below 578.5 feet; in 1929 it rose to 582.3 feet, and in 1934, remained below 578.0 feet. These secular variations are related to rainfall and weather conditions. From a low of 577.4 in March 1935, the lake level rose to 581.52 in August 1943. High level in 1944 was 580.83 feet in July, followed by a low of 579.6 in February 1945.

The writer was informed by Mr. James Doud and Mr. John Bogan that the water around Mackinac Island was up to the cave at Devil's Kitchen about 1875 and prevented walking past the cliffs at this spot. The rocks are undercut, pockety and smoothed by wave action. The ground along the base of these rocks today has a minimum elevation of 584 feet. The ground has about the same elevation between Biddle Point and Water Street where according to Mr. Patrick Doud, the water in the 1870's almost reached the position of the present street. As Mackinac Island has been uplifted six inches

during the last 65 years, these facts agree well with the high water record (583.7 feet) of Lake Huron, 1876.



Figure 27. Undercut and rounded rock surfaces at Devil's Kitchen. The big rock mass at left is the same as at left in Figure 26.



Figure 28. Wind felled balsams, along Scott's Cave Road north of Friendship's Altar; from the storm of November 11, 1940.

Although the lakes will undoubtedly repeat cycles shown in the past and fluctuate to higher levels and lower levels (figs. 29, 30), it seems inevitable that the permanent

effect of crustal tilting will more and more make itself felt at Mackinac Island and elsewhere on the northern shores of the surrounding lake. The peak of high water of every century that passes will tend to fall short of the mark reached previously. But the change is a slow one that reveals itself only to very careful scrutiny and systematic measurement.

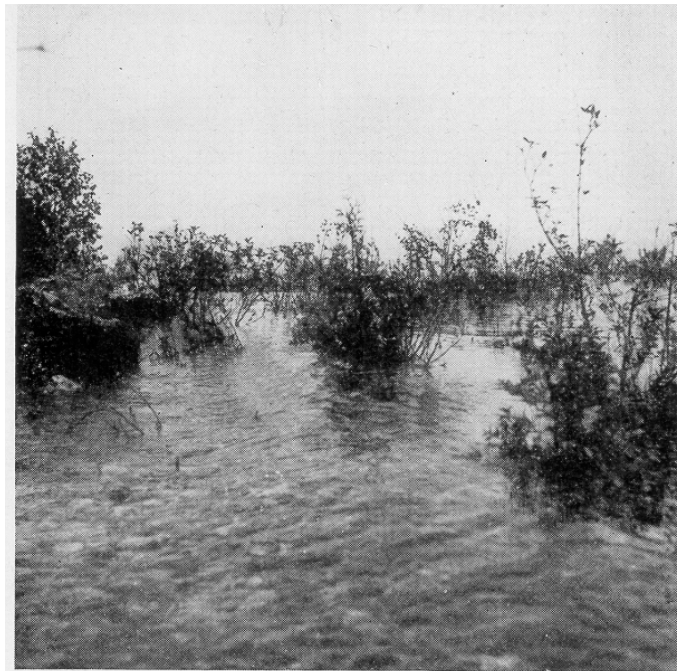


Figure 29. Shore of Mackinac Island northeast of Robinson's Folly. Showing return of high water, June 1943.

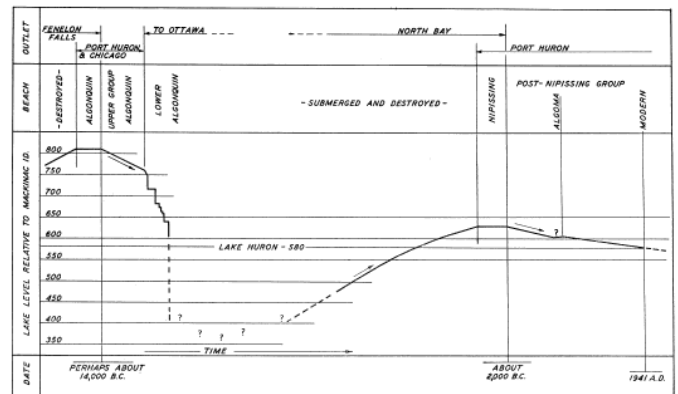


Figure 30. Pre-historic fluctuations of lake with relation to the level of Mackinac Island. Chronology follows recent estimates of Antevs. The diagram is intended to convey an idea of the changed, not to represent precise knowledge as to dates, etc.

EFFECTS OF SOLUTION ACTIVITY IN THE LIMESTONE

On Mackinac Island, as in other limestone regions, water at the surface and underground has been active in dissolving limestone and forming cavities in the rock. No well developed sink holes are on Mackinac Island similar to the sink holes of Presque Isle and Alpena counties, but numerous small depressions are obviously solution

sink holes. The most marked sink is on the east side of State Road just within the edge of the woods lining the golf course, and about on a prolongation of the common boundary between Private Claims 2 and 3.

Immediately east of State Road and about one-quarter mile southeast of British Landing, a Nipissing beach is interrupted by a little depression which appears to be a sink hole. The beach runs north from a limestone knoll for a couple of hundred feet at an elevation of 629, is missing at the depression for over 50 feet, and sets in at the same elevation for a considerable distance beyond. The depression extends about eight feet below the beach level. Moreover, it makes a scalloped gap in the bluff to the east, which was eroded into the 641-foot lower Algonquin beach during the Nipissing stage. Some doubt may be entertained that this depression is a sink hole but that it is a man made gravel pit, but if it is a gravel pit made by man, it must be very ancient for a number of good sized trees grow in its bottom and the vegetative ground cover extends unbroken into it, unlike in any of the other abandoned sand or gravel pits which the writer has seen on Mackinac. Moreover, this was a very isolated spot before the recent construction of State Road. It seems more probable that the depression is a small sink hole caved into an underground drainage channel leading from the swamp to the east. If so, the work of solution has been accomplished in post-Nipissing time. It is barely possible that the deeper hollow across State Road to the west is also a sink along the same line of seepage though it seems more likely to be an original lagoon hollow behind the Nipissing bar. Certain peculiarities of the lagoon hollows behind Nipissing bars at the north tip of the Nipissing Island and at Hank's Pond suggest they may have been deepened by solution agencies, but the evidence is not at all conclusive.

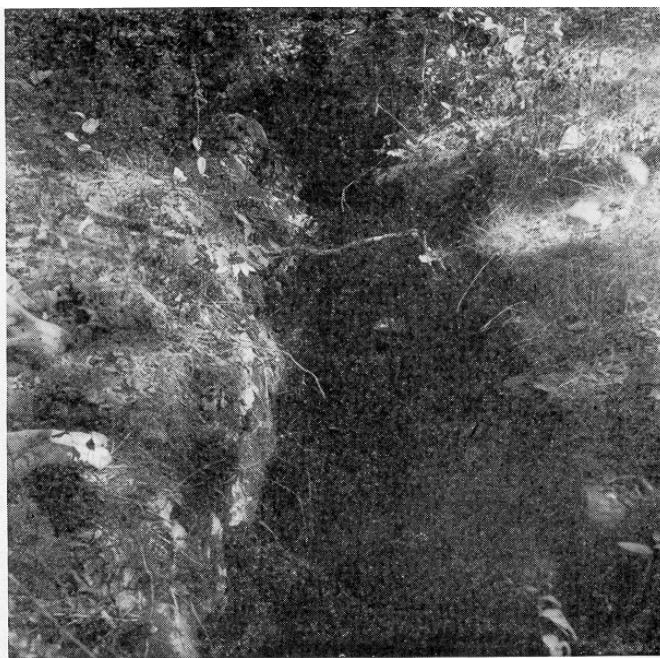


Figure 31. Crack-in-the-Island near the Cave of the Woods north of airport.

Long fissures in the limestone are common in many places over Mackinac Island and the largest has long been known as the "Crack in the Island". Many people have thought that these fissures are caused by earthquakes; but they are as readily explained as a result of solution along fractures in the limestone. The best example of fissures is the Crack-in-the-Island which runs across Reese Road to the north of the air field (fig. 31). Several other fissures are shown on the map. Northeast of the pumping station a crack cuts one of the Battlefield beaches in such a way as to show that the crack was developed later than the beach. A half mile farther north one of the cracks comes out on the north slope of a little ravine, and blocks of limestone along the edge of the crack seem almost to have broken the ground surface, seeming to furnish suggestive evidence that the crack may have resulted from earth movement. Although this evidence is very indefinite, the general appearances of the Crack-in-the-Island warrants some credit being given to the theory of its origin from a local earth rifting movement. One might expect to find such effects in this uplifted region. On the other hand, in several spots along Bluff View trail, one may hear his foot steps resound as though cavities are underground, especially near the well developed cracks. These cavities are the result of solution work in the limestone. Infalling of the roofs of the caves might cause the rocks above the cavities to open in wide cracks. The history of the brecciated rocks of the Mackinac region show that cracks produced by collapse of the rocks are not uncommon. If the collapse should be sudden, slight local earth tremors would result.

GLOSSARY OF TERMS AS USED IN REPORT

Bar -- A ridge of sand or gravel built by wave action, littoral drifting and deposition across an embayment, that closes off an area of water or joins an island to shore. A bar with the island it ties to the shore is sometimes called "tombolo".

Bench -- A narrow terrace resulting from wave wash against a steep slope and deposition of sediments.

Breccia -- Rock composed of fractured and disorganized fragments of a parent rock mass, cemented again into solid material.

Drift -- or glacial drift refers to miscellaneous deposits of a glacier, regardless of form or materials.

Drumlin -- A glacier formed hill composed of till, shaped like a cigar or inverted canoe; usually half a mile or more in length.

Erratic -- A glacially transported boulder, recognized as a foreign rock type not native to the region.

Facet -- A flattish surface or face ground on to a stone by glacial abrasion.

Hook -- A hooked spit, or recurved spit, curved at the outer end.

Hinge-line -- The southern limit of a postglacial uplifting movement, the pivot-line on which the land is tilted or canted up; an isobase of zero.

Isobase -- A contour of the tilting movement, a line on a map connecting points which have been uplifted an equal amount, as connecting correlative beaches of equal elevation in the tilted region, and naturally parallel to the hinge-line; with no relation at all to present topography.

Lagoon -- A pond which has been isolated from the main body of water by construction of a bar.

Littoral drift -- Long-shore current, the effect of waves striking the shore obliquely and gradually moving materials parallel to and along the beach.

Moraine -- Glacial deposits, essentially of till, piled up into hills and ridges at the margin of the ice, the terminus of glacially transported materials.

Pre-Cambrian -- A very ancient period in geological history and the rocks then formed; nearly all of northern Ontario is of such rock.

Sink hole -- A depression caused by under mining and sinking of rock due to underground solution action of water on certain rocks, typically in limestone.

Spit -- A ridge of gravel or sand built out from shore by wave action and littoral drifting of material, and terminating in water; when tied to land at the distal end it becomes a bar; Round Island light house, opposite the village at Mackinac, is located on a splendid example of a spit. A spit curved at the outer end is a hook.

Swale -- A hollow shut in behind a wave formed beach ridge or bar.

Terrace -- Flattish or very gently sloping ground due to erosion cutting into steep slopes and to deposition of materials farther out; a wave formed terrace is associated with wave cut bluffs or cliffs along its back. A bench is a narrow terrace.

Till -- A glacial deposit of clay, sand, stones and boulders, unmodified by the sorting action of water.

Tilt-line -- A line following the direction of land tilting, or at right angles to the hinge-line and isobases.

Tombola -- A land tied island and bar.

Water-Plane -- An imaginary plane or surface of a former water level, connecting beaches formed by it.

six inches. A few elevations determined in previous surveys, and acknowledged below, have been included.

Road Elevations

745.0	Annex Road at summit of knoll by Hert's Road (Crown of road)
739.3	Annex Road at Reese Road (Crown of road)
762.2	British Landing Road at Annex Road, Crooked Tree Road (Crown of road)
732.6	British Landing Road and State Road, Leslie Avenue (Center of triangle in road intersection)
713.7	Cadotte Avenue and Tranquil Lane
765.5	Crooked Tree Road at Eileen Trail (Crown of road)
710.2	Custer Road and Tranquil Land (Center of triangle at road intersection)
804.9	Custer Road and Garrison Road (top of hydrant in triangle)
807.2	Garrison Road and Fort Holmes Road (Center of triangle at road intersection)
791.0	Harrisonville Road at summit south of Harrisonville, near dump (Crown of road)
725.4	Herb's Road at southeast entrance gate (Crown of road)
716.5	Leslie Avenue and Short Cut Trail to north (Center of triangle at road intersection)
715	Leslie Avenue at Short Cut Trail to south (Crown of road)
621.2	Scott Cave Road opposite Scott's Cave (Crown of road)
669.1	State Road at Mackinac Straits Trail (Crown of road)
Miscellaneous	
722.46	Top of Arch Rock (From notebook of Morgan W. Wright 1913 at Fort Mackinac)
830.85	Top of Skull Cave rock mass
855.81	Top of Sugarloaf rock mass (Notebook of Morgan W. Wright)
615.60	Southwest corner of sun dial plate in Marquette Park (Notebook of Morgan W. Wright)
904.1	Top of pipe east embankment of Fort Holmes
900.5	Top of pipe southwest embankment of Fort Holmes Bench Marks
596.60	Corner of Marquette Park opposite Chippewa Hotel (From notebook of Morgan W. Wright)
736.30	Upper gun platform, Fort Mackinac (From notebook of Morgan W. Wright)

ELEVATION REFERENCES

Since a considerable amount of levelling work was done by the writer on Mackinac Island in connection with the field study, some elevations are given here for any use they may serve in the future. Errors are not more than

777.30 Sugarloaf Rock, 50 feet northwest of Chippewa Hotel (From notebook of Morgan W. Wright)

873.93 Point Lookout, overlooking Sugarloaf (From notebook of Morgan W. Wright)

BIBLIOGRAPHY

Andrews, Roger: Old Fort Mackinac on the hill of history. Herald-Leader Press, Menominee, Mich., 1938.

Antev, Ernst: Late Quaternary upwarps of northeastern North America. Jour. Geol., v. 46, p. 707-720, 1939.

Gilbert, G. K.: Recent earth movements in the Great Lakes region. U. S. Geol. Surv., 18th An. Rep., pt. II, p. 601-647, 1898.

Greenman, E. F. and Stanley, G. M.: Archaeology and geology of two early sites near Killarney, Ontario. Mich. Acad. Sci., v. 28, p. 505-530, 1942.

Gutenberg, Beno: Changes in sea level, postglacial uplift, and mobility of the earth's interior. Geol. Soc. Amer., Bull. 52, p. 721-772, 1941.

Moseley, E. L.: Formation of Sandusky Bay and Cedar Point. Ohio Acad. Sci., 13th An. Rep., p. 179-238, 1904.

Stanley, G. M.: Lower Algonquin beaches of Cape Rich, Georgian Bay. Geol. Soc. Amer., Bull. 48, p. 1665-1686, 1937.
The submerged valley through Mackinac Straits. Jour. Geol., v. 46, p. 966-974, 1938.

Stuntz, G. R.: On some recent geological changes in northeastern Wisconsin. Am. Assoc. Adv. Sci., Proc., v. 18, p. 206-207, 1870.

Taylor, Frank B.: The highest old shoreline on Mackinac Island. Amer. Jour. Sci., 3rd ser., v. 43, p. 210-218, 1892.
The history of the Great Lakes. U. S. Geol. Surv., Mon. 53, p. 316-523, 1915.

Williams, M. C.: Early Mackinac. Buschard Bros., St. Louis, Mo., 1901.

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