

CANADA
DEPARTMENT OF MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

GEOLOGICAL SURVEY

PAPER 46-20

PLEISTOCENE DEPOSITS AND BEACHES OF
ORILLIA MAP-AREA,
SIMCOE AND ONTARIO COUNTIES,
ONTARIO

(REPORT, MAP, AND FIGURE)

BY

R. E. DEANE



OTTAWA

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PLEISTOCENE DEPOSITS AND BEACHES OF ORILLIA MAP-AREA,
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(Preliminary Account)

By
R. E. Deane

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PLEISTOCENE DEPOSITS AND BEACHES OF ORILLIA MAP-AREA, ONTARIO

INTRODUCTION

GENERAL STATEMENT

The object of this report is to present the results of an investigation of the Pleistocene deposits and beaches in Orillia map-area, Ontario. The direct economic importance of these deposits is limited to their use in the construction of roads, buildings, dams, tunnels, and drainage and irrigation canals, or in other engineering projects. Indirectly any Pleistocene deposits are of the utmost importance in agriculture, and in the supply of groundwater essential to both rural and urban settlement. Finally, it should, perhaps, not be forgotten that weathering and erosion begin in these deposits, and it is there that the study of sedimentation normally begins.

This report covers the work undertaken by the writer during the field season of 1945. Acknowledgment is hereby made of the valuable guidance and assistance so freely given by J. F. Caley of the Geological Survey, and to Messrs. Kostener and W.J.K. Dickson, who faithfully carried out their tasks as field assistants.

LOCATION AND AREA

Orillia map-area lies 85 miles north of Toronto between latitudes $44^{\circ}30'$ and $44^{\circ}45'$ and between longitudes $79^{\circ}15'$ and $79^{\circ}30'$. It includes those parts of Simcoe and Ontario counties that extend from Lake Simcoe to the north end of Lake Couchiching, and from Bass Lake to $3\frac{1}{4}$ miles east of Uptergrove station. The map-area comprises 215 square miles, of which approximately one-third is water.

PREVIOUS WORK

Mr. W. A. Johnston spent the summers from 1910 to 1914 for the Geological Survey in mapping the Pleistocene deposits of a district of which Orillia map-area forms a part. However, this work was not published, and no detailed accounts are available, although mention of some of the glacial features of the district has appeared in several more general reports.

OUTLINE OF FIELD WORK

Field work was concerned mainly with three problems: Pleistocene geology, groundwater survey, and beach elevations. In mapping the geology a few days were first spent in reviewing Johnston's work in order to take advantage of his wide experience. Later his maps were used for comparison with what had been re-mapped, and, in general, few discrepancies were found. Unfortunately his interpretation of some of the features could only be assumed as the notes were not available. The map accompanying this report shows the glacial material and topographical features. The material was classified mainly from natural and artificial exposures such as those of shore cliffs, ravines, road cuts, railway cuts, and wells, wherever these were available, but such excavations were not numerous, and most of the information was obtained from holes

dug to a depth of 3 or 4 feet.

A survey of abandoned shorelines was made with the hope that more light would be thrown on the history of glacial Lake Algonquin. These hopes were partly realized, but more detailed work in other areas will be necessary in order to solve this interesting and complicated problem. Work on groundwater supply was not completed, and published results await further field investigations.

PHYSICAL FEATURES

GENERAL ACCOUNT

The northern part of Orillia map-area lies at the southern margin of the Precambrian rocks of the Canadian Shield. During Pleistocene time glaciers scoured this granitic terrain, leaving numerous outcrops and, between them, depressions filled with glacial and lacustrine material. South of this border the area is largely underlain by Ordovician rocks or by glacial and lacustrine deposits of Pleistocene age. Near the border the Palaeozoic strata are exposed, or are thinly veneered with a till sheet, but the drift thickens rapidly to the south, particularly on the west side of Lake Couchiching.

Contrasting types of topography occur in this area. In the north are lowlands where bedrock outcrops are common and lacustrine or glacial deposits are thin. The only relief offered is by the innumerable roches moutonnées of the Precambrian and the limestone scarps of the Palaeozoic. This part of the area is quite unproductive. On the east side of Lake Couchiching are lowlands with drift of moderate thickness, where numerous drumlins break the otherwise monotonous flatness. Lacustrine deposits occur in the swales between the drumlins. On the west side of Lake Couchiching the land shows greater relief. Here the glacial deposits are thick, and the irregular nature of the country has been further emphasized by wave action of glacial Lake Algonquin. A few drumlins occur in the lower areas below the Lake Algonquin shoreline. A striking feature is the height of land, which in the higher stages of Lake Algonquin existed as an island. It is here called the Ardtrea Island, and is situated 6 miles north of Orillia.

RELIEF

The highest part of the map-area is in the southwest corner, where the irregular hills of kame deposits attain an elevation of 1,060 feet above sea-level. The lowest part is in the broad glacial valley west of Ardtrea Island, where the altitude is only 670 feet above sea-level. Lake Couchiching has an elevation of 718 feet. Most of the relief occurs in glacial deposits, and is the direct result of glacial action or of wave erosion. The shorelines of the different levels of Lake Algonquin are marked by features varying from gently sloping beaches to 80-foot bluffs. Those of the present lakes are low, nowhere rising more than 25 feet above water. Valleys of present streams are narrow, and downcutting has been excessive only in their higher reaches. On the east side of Lake Couchiching the general altitude of the flat lowlands is between 720 and 730 feet, but numerous drumlins rise 20 to 40 feet higher. The area underlain by Precambrian rocks is rough, but the relief is low and is broken only by the innumerable roches moutonnées, which rise from a few feet to 40 feet above the deposits of sand and till in the depressions. Palaeozoic outcrops are low and flat-lying, and exhibit no relief except where the ice has left scarps from 2 to 20 feet high.

DRAINAGE

Rivers are not numerous in Orillia map-area. Black River is the largest stream and flows between low rock banks through the Precambrian rocks to the north and east of Lake Couchiching. The river is still in a

youthful stage, as evidenced by the rapids and falls that occur between slow, sluggish stretches. The water is black in contrast with the green water of Severn River, which it joins above Washago. The second largest stream is North River, which forms the outlet of Bass Lake; several spring-fed tributaries drain the area northwest of Orillia, but exhibit only slight evidence of stream erosion. North River has the appearance of a youthful stream only in the upper 3 or 4 miles, where rapids, falls, and deep, narrow gullies mark its course; for most of its length in this area the stream appears mature, as it meanders between low banks in a broad, flat, glacial valley. Southwest of Orillia are three short streams originating in the bay regions of Lake Algonquin. Downcutting is excessive only where these streams have crossed the gravel bars at the bay mouths. The area east of Lake Couchiching is drained by intermittent streams only, and the nearly level swails between the drumlins are almost entirely untrenched. The lakes in the map-area, in order of size, are Simcoe, Couchiching, Bass, St. John, Mud, and St. George.

ORIGIN OF PHYSICAL FEATURES

The region around Orillia has stood above sea-level for a long period. The latest known marine sediments that outcrop in the area are the Black River limestones of mid-Ordovician age. If Silurian or Devonian seas invaded the region erosion has removed all traces of the sediments. Outcrops of the Palaeozoic rocks are flat-lying, and well records indicate that the bedrock shows very little irregularity beneath the drift. The Precambrian area may have been more rugged, for the ice removed some material in forming the roches moutonnées and filled in the depressions with debris. The topography of the Palaeozoic areas probably suffered very little change, as these areas are underlain by flat-lying rocks and hence could offer but little resistance to the movement of the ice. The scarps suggest that quarrying was the main method of erosion.

In the lowland areas outcrops are plentiful and the drift thin. Such areas were developed on a pre-glacial land surface, and owe their existence mainly to the lack of glacial deposition. In contrast, the highlands are formed of glacial deposits, and hence are of glacial origin, modified in places by water erosion and deposition. Approximately four-fifths of the land surface was covered by the waters of Lake Algonquin. As a result lacustrine deposits obscure some of the glacial features and wave action has modified others. All of the drumlins occur in low areas, and were below the level of Lake Algonquin. During the subsidence of the glacial lake the only modification was a steepening of the northwest side of some of the drumlins. During the high water stage of Lake Algonquin the waves eroded deeply into the morainic deposits west of Lakes Simcoe and Couchiching, leaving steep bluffs, cut terraces, and gravelly bars, spits, and ridges. Similar features occur at lower altitudes and are the result of temporary halts during the subsidence of the lake. Thus the abandoned shorelines are marked by beach deposits and erosional features. In places the waves of lower lake levels have removed the lacustrine deposits and exposed the underlying till. The areas below the shorelines are covered with varying thicknesses of lacustrine sands and clays. Those areas that rose above Lake Algonquin are composed of ground moraine or kame deposits. Whereas the drumlins are essentially deposits of the last advance or readvance of the Wisconsin glacier, it is questionable whether the total thickness of more than 150 feet of the morainic deposits west of Crillia is due only to this last ice advance. Although no outcrop evidence was found of interglacial deposits, well drillers reported running into a marl at 60 feet in one well, and a sand containing wood fragments at a depth of 145 feet in another well.

Insufficient information is known about Lakes Simcoe and Couchiching to unfold their history. Lake Simcoe is the deeper of the two lakes, and no rock outcrops on its shores in this area. Bedrock outcrops in many places along the east shore of Lake Couchiching, and as the lake is shallow it is doubtful if its existence as a lake pre-dates Pleistocene time. Glacial debris separates the two lakes, and the narrow channel connecting the two is only

8 to 10 feet deep. Prior to the last few feet of uplift the connecting channel was much wider. Rock outcrops in numerous places around the shores of Lake St. John, which is probably a true rock-basin lake of glacial origin formed at the contact of the Precambrian and Palaeozoic rocks. St. George, Mud, and Bass Lakes are entirely enclosed by glacial and lacustrine deposits, and occur in depressions of glacial origin.

GENERAL GEOLOGY

GENERAL ACCOUNT

The superficial deposits that cover most of Orillia map-area differ from the bedrock that underlies them in that they are unconsolidated; are glacial, glacio-fluvial, or lacustrine in origin; and are vastly younger in age. They belong to the latest of the geological periods, the Quaternary, which is subdivided into Pleistocene and Recent epochs. The glaciers of Pleistocene time removed almost all surface covering that existed prior to their advance, so that the soils of the area have almost all formed on these young, unconsolidated deposits.

During the Pleistocene or Glacial epoch the continental glaciers advanced from their gathering grounds far to the north. All records of repeated ice advances, so remarkably shown in the Toronto region at Scarborough and the Don Valley, are lacking in this area, though it is probable that deeper exposures would uncover such information. All evidence in this area indicates that the latest, or Wisconsin, glacier advanced through the region from Labrador Peninsula far to the northeast. During the advance of the ice much of the loose material lying in its path was transported over varying distances, either being pushed ahead or incorporated in the lower part of the glacier. The ice also eroded the underlying bedrock by plucking out masses of the rock or grinding down the solid material over which it passed. As the ice retreated it left the land surface covered with accumulations of transported material in the form of ground moraine. During periods of temporary halts or readvances recessional moraines or kame deposits were left to mark the position of the ice front. Drumlins and eskers formed under the glacier survived the retreat of the ice to show the direction of its last advance.

The weight of the ice had depressed the land relative to sea-level. When the ice had withdrawn from southwestern Ontario an extensive lake, known as Lake Algonquin, formed in the basins now occupied by Lakes Superior, Michigan, and Huron, and spread over much of the surrounding country. Uplift of the land followed the retreat of the ice. The initial uplift was rapid and local, and confined to the area immediately south of the ice front. Regional uplift followed the close of Pleistocene time until the land had regained the altitude above sea-level at which it is today. It is probable that the withdrawal of the ice front north of Orillia was slow, and during this time the ice formed the northern shore of Lake Algonquin. A temporary halt or readvance of the glacier in this area is marked by a small water-laid recessional moraine east of Lake St. John. A slow withdrawal of the ice is necessary to account for the long period of time required to develop the strong shore cliffs of the highest level of Lake Algonquin. In the earliest stages of Lake Algonquin, prior to the retreat of the ice to the Orillia district, the outlet was to the south by way of Port Huron and, possibly, Chicago. Later, at the Fenelon Falls stage, the glacier had retreated enough to open Trent Valley and had allowed the lake to drain eastward into Lake Iroquois. At this time the lake was lowered sufficiently to close the Port Huron outlet. A subsequent "two-outlet" stage began when uptilting in the north had elevated Trent Valley until discharge again began at Port Huron (and, possibly, Chicago). It was during this stage of drainage at both Port Huron and Fenelon Falls that the highest Algonquin beach was formed. A fourth stage was instituted when the Fenelon Falls outlet was closed as a result of continued uplift in the north and successive lowering of the lake level, leaving Port Huron as the sole outlet. A fifth stage commenced with the closing of the Port Huron outlet, due to repeated lowering of the lake as outlets in the north were uncovered by

the retreating ice. The waters of the lake reached their lowest level during this stage. Lake Algonquin ceased to exist when the ice reached the North Bay area and opened the Mattawa-Ottawa Valley outlet, thus ushering in the Nipissing Great Lakes.

The beaches formed during the Fenelon Falls stage, when the lake was lowered by the opening of the Trent Valley outlet, were largely destroyed by the rising waters that culminated in the succeeding or "two-outlet" stage. Isolated exposures of these earlier beaches occur in small bays, and their preservation is due to the building of bars across the bay mouths by the rising water. With the formation of the highest Algonquin beach, here called "the Algonquin beach", and the successive lower beaches, the lake bottom was covered with sands, silts, and clays derived from the erosion of the shores and the glacial streams pouring in from the north. In places the beach deposits were thick enough to survive the erosive power of the waves at lower levels, but in others the deposits were carried out into deeper water. The final retreat of the lake left the lowest land covered with lacustrine deposits of sand, silt, and clay of varying thicknesses.

PLEISTOCENE DEPOSITS

The Pleistocene deposits consist of glacial, glacio-fluvial, and lacustrine materials. They occupy the greater part of the map-area, bedrock being exposed only over a comparatively small part in the north. The glacial deposits are of till, which can be divided into calcareous and sandy types. They are chiefly in the forms of ground moraines, recessional moraines, and drumlins. The glacio-fluvial deposits are of roughly stratified sands and gravels, and occur as kames and crevasse fillings. The lacustrine deposits consist of stratified sand, silt, and clay, and were laid down on the bottom and along the shores of Lake Algonquin.

Deposits of Glacial Origin

Ground Moraine

Glacial till, the unstratified deposit of the ice-sheet, occupies only a small part of the surface of the Orillia area, but is extensive over much of the area beneath a covering of lacustrine sediments. The term "boulder clay" is not used in this report as being synonymous with till, but is reserved for that type of till that, as its name suggests, is a mixture of bouldery and fine materials. Till, on the other hand, may be composed almost entirely of material of one particular size, whence it should be qualified by the addition of the appropriate term - clay, sandy, or stony.

In the northern part of the area the till, deposited as ground moraine, is generally thin and in places almost entirely absent, the bedrock of limestone or granite outcropping with little or no drift covering. In most instances the thin covering of drift consists largely of cobbles or boulders, the finer material being carried to lower altitudes by the subsiding lake. The till, where underlain by granitic rocks, is sandy, and contains many crystalline cobbles and boulders but only a small proportion of rock flour. Immediately south of the Precambrian border the till remains sandy, but becomes thicker and more calcareous as the distance from the border increases. The thickening is due to the fact that the underlying limestones were more easily eroded by the ice-sheet than the granites. In all probability a thin covering of Palaeozoic strata covered the Precambrian rocks at the beginning of Pleistocene time for some distance north of the present contact, but were removed by repeated glaciation. The till is unevenly distributed over the flat-lying Palaeozoic rocks, mostly forming heaps and mounds where no depression in the bedrock existed, the general effect being to increase the relief and make the surface rougher.

The drift derived from the Precambrian rocks is mainly a sandy till with many granite boulders and minor amounts of finer grained material. It is slightly reddish. Many of the granitic cobbles and boulders were carried

in an englacial or superglacial position in the ice-sheet, which accounts for their abundance in the drift many miles south of the Canadian Shield. The till derived from the Ordovician limestones is a blue-grey, limy boulder clay containing a large proportion of rock flour. It is usually very stony. The cobbles and boulders are angular to subangular, and are set in a matrix of fine-grained material that in many places is partly cemented by limy material deposited from percolating calcareous solution to form "hardpan". The calcareous till is variable in composition. It always contains some granite boulders, and may contain irregular masses of sand, silt, or gravel. These latter materials may be of sub-glacial stream origin, or may represent lacustrine or fluvial material ploughed up by the glacier and incorporated in its load. A clay till occurs at the northwest corner of Lake St. John. It contains bits of shale or sandy shale, and is derived from the shales and sandy shales at the base of the Ordovician system. These basal beds are coloured alternately green and purple, and impart these colours to the till.

In the southwest part of the map-area and in Ardtrea Island the unconsolidated surface deposits are at least 150 feet thick. Just how much of this is ground moraine of the latest or Wisconsin stage of glaciation is difficult to estimate. A well driller reported sand containing bits of wood at a depth of 145 feet on Ardtrea Island. Another reported marl at 60 feet below the surface near East Oro. A massive, blue clay till, containing but few stones, was encountered below 60 to 70 feet of varved clay in the bed of North Creek in the northwest corner of lot 1, con. II, Orillia North tp. This clay till appeared quite fresh and may have been Wisconsin, or older. Two tills are exposed in Hawkestone Creek under No. 11 highway. The lower till, exposed in the creek bed, is similar to that found on North Creek. The overlying till contained much sand and weathered brownish red in contrast with the fresh appearing blue-grey lower till. From the above it seems fairly certain that the Wisconsin did not scour the limestone underlying the highlands in its advance, but overrode pre-existing unconsolidated deposits of either interglacial or earlier glacial age. The irregular masses of sand and gravel in the Wisconsin till may have been picked up by the ice from these earlier deposits.

Drumlins

Drumlins are widely distributed in this area, but do not occur north of the Precambrian border. On the east side of Lake Couchiching they form a drumlin field, thus breaking the monotony of an otherwise flat lowland. On the west side of the lake they occur singly or in groups of twos or threes in the lowlands. The drumlins rarely attain typical form, but are variable in shape and size. In places two or three merge to form elevated parallel ridges; some have two tails; others are little more than irregular mounds. In height they range from an indefinite swell, 3 or 4 feet above the plain, to ridges or hills 60 or 70 feet high. They are generally elongated, and often the nose and tail have the same slope. The tops may be dome shaped or flat, or may form symmetrical ridges. The sides generally have gentle slopes. The drumlins have been modified to varying degrees by the water of Lake Algonquin in its lower stages: tops of the higher drumlins have been wave washed, leaving the surface strewn with boulders; those on the west side of Lakes Couchiching and Simcoe show steepening on their northwest sides due to wave action more than do those on the east side of these lakes.

The drumlins are composed mainly of boulder clay, but in places this becomes very stony or sandy. A drumlin on the west shore of Lake Simcoe and another on the south side of Bass Lake are unusual in that the sides slope as much as 50 degrees and the till is extremely stony, being composed mainly of large limestone boulders. In places sand and gravel form part of the drumlin, and some drumlin-like mounds are composed entirely of stratified sand and gravel. These will be discussed under features of glacio-fluvial origin.

The general orientation of the drumlins is south 35 degrees west. Those in the drumlin field conform to this within a few degrees. Wider variations are found on the west side of Lake Couchiching. North of Bass Lake a drumlin trends south 50 degrees west; 2 miles east of this is a drumlin with its axis trending south 12 degrees east. The apparent cause of this divergence is the highland near Bass Lake, which forced the ice to follow the lowlands on either side.

Recessional Moraine

A long ridge rising 20 to 40 feet above the plain north and east of Mud Lake, and a shorter, lower ridge 3 miles north of the lake, mark the only recessional moraines in the area. They were formed during a temporary halt or a slight readvance of the ice and were laid down in water, for the glacier formed the north shore of Lake Algonquin during its retreat in this region. The material is a mixture of sandy till, sand, silt, and gravel, and shows a rough stratification in some parts. The ridges are formed at right angles to the long axis of the drumlins. They are comparatively low, with rounded tops and fairly smooth sloping sides that are quite in contrast with moraines deposited on land. The southern part of the moraine over-rides three drumlins. Waves have modified the moraine to some extent, spreading the finer material over the bottoms on both sides.

Deposits of Glacio-fluvial Origin

Kames

Kame deposits occur in scattered localities in the area. The largest deposits lie to the west of Orillia and form the rolling, hilly country that rises to 1,060 feet above sea-level south of Bass Lake. This kame area continues for many miles west and southwest of Bass Lake. The material is largely sand and gravel, and is roughly stratified in places. The kames are predominantly sand, contain a sparse vegetation, and, where cultivated, are subject to wind erosion. Till shows through in many of the stream valleys that cut the kame deposits, indicating that a thick glacial drift underlies the area. At the undulating borders of the kames the material is an unstratified sand containing some pebbles and grades into a sandy till, making the kame boundaries difficult to place. The variable nature of the material is well illustrated in the several gravel pits started but soon abandoned.

Just south of Fawkham in Rama township is a stratified sand and gravel deposit. It is probably a kame, for it is quite irregular in shape, rising 60 feet above the sandy plain to form the highest ground for several miles in all directions, and lying within a mile of a recessional moraine. A current gravel pit exposes 30 to 40 feet of well-sorted and stratified sand and gravel. Unlike the kame west of Orillia this deposit was below Lake Algonquin and hence was reworked by the waves at lower stages, producing a gently rolling topography.

Associated with the drumlins east of Lake Couchiching are several deposits of sand and gravel of glacio-fluvial origin. The road between cons. XI and XII, Mara tp., crosses, in lot 26, a drumlin that contains an extensive deposit of roughly stratified sand and gravel on the northwest face. Large excavations have been made on both sides of the road and when examined in September 1945 the calcareous till was exposed at the bottom of the pit 20 feet below the surface. This deposit was plastered on the side of the drumlin, and is undoubtedly glacio-fluvial in origin. Other deposits associated with the drumlins are less easy to classify. They consist mainly of sand with some gravel, and may form either the tail end or nose of a drumlin, or may override a drumlin almost completely, or may form an independent feature that has all the appearances of a drumlin and is oriented with them. A gravel pit on the Canadian National Railway, in lot 22, con. IX, Mara tp., shows well stratified, cross-bedded sand and medium size gravel 18 feet below the surface. These can hardly be beach deposits, for they rise to altitudes

equal to that of the associated drumlins, and no higher shorelines occur on the east side of Lake Couchiching. The regular outlines are not suggestive of either kames or eskers, but they probably belong to one or the other. The orientation and form suggest a drumlin even though sand drumlins are rare or non-existent. However, the stratification requires water as an agent of deposition, and this precludes their classification as deposits of strictly glacial origin.

Crevasse Fillings

Good examples of crevasse fillings are lacking, though in cons. XII and XIII, between lots 16 and 20, Oro tp., are odd features that are here classed as such. They are roughly circular to elliptical in outline, oval in cross-section, and rise 3 to 6 feet above the gently undulating ground moraine on which they occur. The material of these deposits is sand and gravel. They are oriented in the direction of ice movement, and this trend is further emphasized in aerial photographs by the dark colour of the willows and swampy vegetation enclosed by these deposits.

Lacustrine Deposits

Beach Sands and Gravels

Beach deposits of sand and gravel are almost everywhere associated with the abandoned shorelines of Lake Algonquin. These shorelines are absent from the eastern half of the map-area, because no land projected above the higher stages of the glacial lake and during the later stages the numerous drumlins that emerged as islands divided the shallow water into narrow straits, thus reducing the action of the waves. Beach ridges, bars, and spits are common on the west side of Lake Couchiching and provide the extensive sand and gravel deposits used for road making and constructional material. The deposits are associated with the Algonquin and lower beaches, the thickest deposits occurring in the bay-mouth bars and spits of the Algonquin beach. Sand deposits are found mainly in areas removed from the Algonquin beach and are the result of concentration during successive lower lake stages. In many places the terraces of the higher beaches have been washed free of the finer material, leaving the surface covered with boulders and producing what is known as a boulder pavement.

Lacustrine Sands, Silts, and Clays

Lacustrine sands, silts, and clays carried in by glacial streams or eroded from the shore bluffs by wave action, settled on the irregular bottom of Lake Algonquin, and during lower stages of lake level were washed from the sides of the drumlin islands and shores and finally deposited as layers of varying thickness in swails and broad valley bottoms. The deposits are by no means uniform. Many clay areas contain lenses of sand, clay pockets occur in sandy deposits, and the two types also grade into one another. However, a definite surface pattern can be recognized. Clays are found in the drumlin field covering the swails with a thin layer that is underlain by sand or till. Sand is associated with the recessional moraine north of the drumlin field, and fills the depressions between the roches moutonnées of the Precambrian north of the recessional moraine. Sand deposits also occur along the west side of Lake Couchiching and in the lowlands immediately below the Algonquin shorelines. A second clay belt lies in the broad valley occupied in part by North River in the area north of Uthhoff and Hampshire Mills. This belt is in a region where Palaeozoic and Precambrian outcrops are numerous, and where it would be expected that the surface deposits would be of sand similar to that of the till deposits in the northwest part of the map-area. However, this is the lowest part of the area, and was the last to be occupied by the

retreating Lake Algonquin. Drainage was to the north and hence the clays and silts were brought in from the area to the south, which is underlain by Palaeozoic rocks.

An excellent deposit of varved clays has been exposed by North Creek beneath the bridge on the road between cons. I and II, Orillia North tp. The varving is well marked, the coarser grained, grey, summer layers averaging three-quarters inch in thickness, and the finer grained, dark brown, winter layers a little less than half an inch. Approximately 50 feet of the varves are exposed. They are overlain by lacustrine sands and gravels containing some cobbles and boulders, and underlain by a compact blue-grey clay till containing few stones.

RECENT DEPOSITS

The only Recent deposits of consequence in the area consist mainly of a blackish muck, which together with swampy vegetation occupies the depressions in both the highlands and lowlands, although more extensive in the lowlands. The swampy conditions are due to poor drainage in the underlying compact boulder clay. The deposits vary from a few inches to several feet in thickness, and are usually underlain by sand, silt, or clay.

A small deposit of greyish white marl, 3 to 4 feet thick, occurs half a mile east of Silver Creek station. Some fluvial deposits occur in the valleys of the streams, but because of the poor drainage in the area and the small size of the streams these deposits are limited and unimportant.

STAGE AND DIRECTION OF ICE MOVEMENTS

The glacial and glacio-fluvial deposits are features of the latest, or Wisconsin, stage of glaciation. The recessional moraine resulted from a temporary halt or readvance of the ice-sheet. Two sets of glacial striae in the flat-lying limestone exposures at Unthoff indicate a readvance of the ice-sheet. The two sets differ in direction by 7 degrees, the older set trending south 35 degrees west and the later set south 28 degrees west. Only the deepest grooves of the older striae remain, the finer scratches having been obliterated during the readvance of the ice. The younger set shows fewer deep grooves, but innumerable fine scratches still appear relatively fresh. No lacustrine deposits are known to be overlain by till, and where two tills have been found in contact the underlying deposit shows no weathering, hence it is improbable that any considerable time elapsed during the retreat and the readvance of the ice. The deposits are weathered on the surface to only a slight degree, indicating their origin during the Wisconsin stage. No definite records exist of glacial deposits of the Illinoian, Kansan, and Nebraskan stages, though it is possible that the underlying till in Hawkestone Creek and the till beneath the varved clays in North Creek belong to one of these stages.

The direction of the last ice advance or readvance was south 35 degrees west as shown by the general trend of the drumlins, but variations occurred where the ice tended to follow local depressions. Chatter marks, grooves, and roches moutonnées are characteristic of the granitic rocks in the north, and indicate the same general direction of ice movement as do the drumlins.

ALGONQUIN AND LOWER ALGONQUIN LAKE BEACHES

GENERAL DISCUSSION

The excellent exposures of the abandoned Algonquin beach in the Orillia map-area have been cited by Taylor, Goldthwait, Johnston, and others.

However, little or no mention has been made of lower stages of Lake Algonquin. In the work of mapping the area numerous lower beaches and ridges were observed. The work done by Stanley in the Penetanguishene, Cape Rich, and Sucker Creek areas on the lower Algonquin beaches acted as a stimulus to these investigations, and a surprising agreement exists in the results of the Georgian Bay and Orillia areas.

Elevations were taken of all beaches and ridges that were sufficiently well developed to give accurate measurements. In addition, many measurements were made on less well defined features in order to analyse the results and thereby gain experience and confidence in future work of a similar nature. Three hundred and fifteen readings were taken. All measurements were made with a telescopic alidade and self-reading stadia rod. Readings were made to the nearest tenth of a foot, and the tabulated results are given to the nearest foot.

Altogether, six beaches lower than the Algonquin are recognized. The three upper ones, here named, in descending order, the Ardtrea, Upper and Lower Orillia, constitute the "upper group of Algonquin beaches" mentioned by Taylor. These beaches are well defined in only a few localities. The Upper Orillia is the strongest of the three, and in one place forms a 25-foot bluff. These three beaches are not recognized by Stanley in the Georgian Bay area, although many elevations of beaches and ridges between the Wyebridge and the Algonquin in the Georgian Bay area correspond in elevation to the newly named beaches in the Orillia area. The names for the three lower beaches, the Wyebridge, Penetang, and Cedar Point, given by Stanley in the Georgian Bay area, are retained here. The distances of these beaches below the Algonquin and the slopes of the water-planes (See Figure 1) agree almost exactly with the respective beaches farther west. During the formation of these lower Algonquin beaches it is very doubtful if Lake Simcoe or Lake Couchiching were part of Lake Algonquin, but it is interesting to note that the lowest beach, the Cedar Point, is exposed 19 feet below the level of Lake Couchiching, and, therefore, the two major lakes existed independently from Lake Algonquin before the formation of this lowest beach.

Figure 1 shows, in profile, the water-planes of the several stages of Lake Algonquin. These planes represent the imaginary surfaces of the now extinct lake stages. Due to recovery of the depressed land surface after retreat of the ice-sheet, these planes are now inclined or tilted. In the figure, north 21 degrees east, established by Goldthwait, Johnston, and others, has been adopted as the direction of maximum tilt or inclination. This direction, with the south end at the left, is placed as the abscissa on co-ordinate paper and the beach elevations at the various localities plotted as ordinates. The centres of the symbols on the resulting profile mark the more reliable elevations. Warping is practically negligible over the extent of the profile, and the water-planes are, consequently, represented by nearly straight lines. Data concerning the water-planes in Orillia map-area is given in Table I.

TABLE I

Altitudes in feet and Descriptions of Abandoned Lake Algonquin Shorelines

Locality	Algonquin Beach	Ardtree Beach	Upper Orillia Beach	Lower Orillia Beach	Wyebridge Beach	Penetang Beach	Cedar Point Beach	Other Beaches
Two miles west of Oro on road between cons. V-VI Oro tp.	804 - Distinct 12-foot bluff north of railway. Terrace moderately boulder strewn.							
One mile west of Oro on road between cons. VI-VII Oro tp.	808 - Short, weak sand and gravel ridge just south of church.	800 - Moderate sand and gravel ridge just below Algonquin.						
Oro; on road between cons. VII-VIII, Oro tp.	809 - Strong 30-foot bluff north of railway. Terrace boulder strewn and hummocky.							
Two miles west of Hawkestone on road between cons. IX-X, Oro tp.	813 - Strong 25-30-foot bluff merging with lower beach east of the road.	801 - A 5 to 6-foot bluff below Algonquin. Distinctive on west side of road.						
One mile west of Hawkestone on road between cons. X-XI, Oro tp.	820 - Strong 20-foot bluff north of railway. 4 feet too high?							

Locality	Algonquin Beach	Ardtree Beach	Upper Orillia Beach	Lower Orillia Beach	Wyebridge Beach	Penetang Beach	Cedar Point Beach	Other Beaches
Hawkestone, on road between cons. XI-XII, Oro tp.	820 - Strong 30-foot bluff north of railway. Terrace boulder strewn.							
1 mile east of Hawkestone road between cons. XII-XIII, Oro tp.	824 - Strong 30-foot bluff north of railway. Terrace boulder strewn.							
2 miles north-east of Hawkestone on road between cons. XIII-XIV, Oro tp.	833 - Strong 30-foot bluff north of railway, 6 feet too high ?		785 - well marked sand and gravel ridge, 700 feet north of Lake Simcoe; terrace boulder strewn on both sides. 780 - 15- to 18-foot bluffs of a small strait north of above ridge. 790 - Sand and gravel ridge, $\frac{1}{2}$ mile east of above.					799 - Sand and gravel ridge on gravel pit 2,000 feet north of Lake Simcoe.
3 miles north-east of Hawkestone road between cons. XIV, Oro, and Orillia tps.	829 - Road curves around base of 25-foot bluff just north of railway. Bluff diminishes to north		790 - Strong beach ridge west of road, and 1,000 feet south of railway. Probably a continuation of above ridges.					

<p>Road between cons. I-II, Orillia South tp.</p>	<p>836 - No. 11 highway passes over strong 35-foot bluff. Base sandy and sloping. 836 - $\frac{1}{2}$ mile north of No. 11 highway and west of road. Bluff sandy and merges with terrace. 839 - 845 - 1 mile north of No. 11 highway. Grouse Creek cuts a bay-mouth bar of a small embayment. Creek exposes 70 feet of gravel and cobbles. Several lower ridges associated with this strongly developed bar.</p>	<p>824 - A strong gravelly ridge 150 feet east of main ridge and 15 feet lower. 821 - A strong sandy ridge 300 feet east of main ridge and 18 feet lower.</p>	<p>789 - Lot 12. A moderate 4-foot bluff behind school house.</p>		<p>745 - 200 feet north of Lake Simcoe. Gentle slopes of poorly developed beach. No well marked terrace.</p>	<p>820 - Impounded shore bluff in north end of lagoon. 833 - Two converging ridges parallel to main ridge on lagoon side. Probably due to high water stage of Lake Algonquin.</p>
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Locality	Algonquin Beach	Ardtree Beach	Upper Orillia Beach	Lower Orillia Beach	Wyebridge Beach	Penetang Beach	Cedar Point Beach	Other Beaches
	<p><u>842</u> - Lot 10, 1 mile north of No. 11 highway. Sand and gravel bluffs at ends of bay-mouth bar. May be depositional in part.</p> <p><u>840-845</u> - Bay-mouth bar cut by small creek. Several lower ridges associated with this strongly developed bar.</p>	<p><u>830</u> - A sand and gravel ridge 100 feet east of main ridge and 11 feet lower.</p> <p><u>827</u> - A sand and gravel ridge 200 feet east of main ridge and 14 feet lower.</p>	<p><u>798</u> - A sandy ridge 900 feet east of main ridge.</p>					<p><u>839</u> - Mild slope north of road in the lagoon. May represent a rising stage of Lake Algonquin.</p> <p><u>842</u> - A gravelly ridge on the lagoon side and parallel to main ridge.</p> <p><u>834</u> - A gravelly ridge on the lagoon side parallel to main ridge and 500 feet west of it. Origin doubtful.</p> <p><u>816</u> - Impounded shore bluff in the lagoon on west side of road.</p>
No. 11 highway and road between cons. II-III, Orillia South tp.		<p><u>821</u> - North of No. 11. Two gravel ridges 500 feet north of highway above gravel pit.</p>	<p><u>794</u> - South of No. 11 is a strong 10-foot bluff and cut-terrace. On north side of No. 11 is a 12-foot bluff at <u>796'</u>. This becomes stronger to the east.</p>	<p><u>770</u> - South of No. 11 and just below Upper Orillia beach. A strong 12-foot bluff and sandy terrace.</p>	<p><u>754</u> - South of No. 11 and just below Lower Orillia beach. No distinctive base and terrace. Base is sandy and gullied.</p>			<p><u>810</u> - A gravel ridge south of No. 11 just above Upper Orillia beach.</p>

<p>Intersection of roads between cons. II-III, and 9-10, Orillia South tp.</p>	<p>838 - A strong 60-foot bluff and boulder strewn terrace</p>	<p>823 - South of corner by the barn. A moderate 8-foot bluff.</p>	<p>794 - South of corner and below barn. A moderate 8-foot bluff here, but diminishes to the east and west.</p>	<p>773 - moderate slope marking Lower Orillia beach. Base not well defined. Terrace sandy and cultivated.</p>	<p>749 - A steep 12-foot slope marks southern end of a sandy terrace. Base of this slope sandy and forested.</p>		
<p>No. 12 highway and road between cons. I-II, Orillia South tp.</p>	<p>845 - Northeast of this corner is a strong 35-foot bluff. Base sandy and gently sloping. 853-855 - A spit joined on the east to bluff above. Spit curves slightly to the north and is strong for 1/2 mile west of bluff.</p>	<p>840 - Below bluff and running parallel to spit is a broad, sandy ridge 13 feet below spit. Only violent storms could be responsible for this.</p>					
<p>Intersection of roads between cons. III-IV and lots 5-6, Orillia South tp.</p>	<p>858 - Roads south and west of this corner cut by a strong, gravelly bay-bar. Strong development of this bar and spit (above) due to northerly storms. 855 - 1/2 mile east of corner a 25-foot</p>	<p>837 - A small sand ridge parallel to and north of bay-bar. 21 feet below bar. 831 - A boulder strewn slope below Algoquin</p>					

Locality	Algonquin Beach	Ardtree Beach	Upper Orillia Beach	Lower Orillia Beach	Wyebridge Beach	Penetang Beach	Cedar Point Beach	Other Beaches
	bluff con- tinuing strong to north but merging with bay-bar to south. Ter- race narrow and boulder strewn.	bluff and ter- race. Swamp at base of slope 24 feet below Algon- quin.	Upper Orillia Beach	Lower Orillia Beach	Wyebridge Beach	Penetang Beach	Cedar Point Beach	Other Beaches
	<u>852</u> - $\frac{3}{4}$ mile north of cor- ner and $\frac{1}{2}$ mile west of road between cons. III-IV. A strong 70- foot north- easterly facing bluff. Terrace not extensive. Elevations vary from 850 to 855.	<u>842</u> - A gravel ridge parallel to Algonquin bluff, 14 feet high for Ard- tree and may be a submerged Algonquin ridge. <u>830</u> - A gentle slope and nar- row terrace be- low ridge (above) 22 feet below Algonquin	798 - East of Algonquin bluff an 18-foot bluff. The ma- terial is sandy and the slope becomes gentle to the north and south.					<u>824</u> - A strong gravel ridge 700 feet east of Algonquin bluff.
Road between cons. II-III, Orillia South tr., 1 mile north No. 12 highway.	<u>847</u> - Strong 70-foot north facing bluff, base gently sloping, ter- race exten- sive and boul- der strewn. Readings vary from 841 to 854 on dif- ferent points of slope.	<u>836</u> - A strong steep-sided ridge, paral- lel to, and 500 feet north of Algonquin bluff and 11 feet below.	798 - $\frac{1}{4}$ mile north of main Algonquin bluff. A strong, 25- foot bluff, well marked at this point but less so to the east and west. Terrace below is flat and boulder strewn.	<u>778</u> - A gentle slope 500 feet north of Upper Orillia beach. Slope slightly boulder strewn. Terrace sandy and gullied.				

<p>Orillia</p>	<p>850 - Shoreline well developed in Orillia. Average of 7 readings taken at base of 20-30 foot bluffs in Golf Links. Readings vary from 848 to 853 feet. North of golf links in pasture base of bluff is gently sloping.</p>	<p>805 - Just north of Champlain Park and 700 feet west of railway. Slope indicates Upper Orillia beach and is continuous south-west through the town.</p>	<p>782 - A moderately well defined beach on North Street and 375 feet west of railway. Beach can be traced through Orillia. 784 - Road lots 5-6 and 500 feet west of railway. A moderate slope and terrace.</p>	<p>763 - On road lots 5-6 and 300 feet west of railway. A well defined beach and terrace.</p>	<p>700 - A strong 45-foot bluff part of which was made by the Penetang. Base well marked but no distinct terrace, as it is swamp covered.</p>	<p>724 - A strong, well-defined bench part way up a 45-foot bluff. A weak development of this beach to the southwest but not to the northeast.</p>	<p>755 - A well marked bluff 11 feet below the Wye-bridge beach, 2,400 feet north of railway. 821 - 1 mile north of railway and 2,500 feet east of road. Base of gentle slope. 755 - 580 feet east of road. A gentle slope 10 feet below Wye-bridge.</p>
<p>Road between cons. IV-V lot 2, Orillia North tp.</p>	<p>813 - A sand and gravel ridge crosses road. Not continuous far to the east or west. 807 - A second ridge just north of above.</p>	<p>790 - In lot 3 on west side of road. A strong sand and gravel ridge. 788 - 100 feet west of above is a second parallel ridge.</p>	<p>769 - In lot 3 on east side of road. A strong sand and gravel ridge.</p>	<p>766 - A moderate bluff in sandy material 600 feet north of railway. 766 - 1 mile north of railway and 700 feet east of road. A faint beach marked by increase in slope; in sandy deposits.</p>	<p>780 - 1 mile north of railway and 1,000 feet east of road. A gentle slope in sand becoming more pronounced east of barn. Readings 8 feet too low?</p>	<p>766 - 1 mile north of railway and 100 feet east of road. An obscure beach marked by a small rise.</p>	<p>755 - A well marked bluff 11 feet below the Wye-bridge beach, 2,400 feet north of railway. 821 - 1 mile north of railway and 2,500 feet east of road. Base of gentle slope. 755 - 580 feet east of road. A gentle slope 10 feet below Wye-bridge.</p>
<p>Island between cons. V-VI, Orillia North tp.</p>	<p>808 - 1 mile north of railway and 2,000 feet east of road. A mild slope merging with a terrace.</p>	<p>780 - 1 mile north of railway and 1,000 feet east of road. A gentle slope in sand becoming more pronounced east of barn. Readings 8 feet too low?</p>	<p>766 - A moderate bluff in sandy material 600 feet north of railway. 766 - 1 mile north of railway and 700 feet east of road. A faint beach marked by increase in slope; in sandy deposits.</p>	<p>780 - 1 mile north of railway and 1,000 feet east of road. A gentle slope in sand becoming more pronounced east of barn. Readings 8 feet too low?</p>	<p>766 - 1 mile north of railway and 700 feet east of road. A faint beach marked by increase in slope; in sandy deposits.</p>	<p>728 - 1 mile north of railway and 100 feet east of road. An obscure beach marked by a small rise.</p>	<p>755 - A well marked bluff 11 feet below the Wye-bridge beach, 2,400 feet north of railway. 821 - 1 mile north of railway and 2,500 feet east of road. Base of gentle slope. 755 - 580 feet east of road. A gentle slope 10 feet below Wye-bridge.</p>

Locality	Algonquin Beach	Ardtree Beach	Upper Orillia Beach	Lower Orillia Beach	Wyebridge Beach	Penetang Beach	Geary Point Beach	Other Beaches
Ardtree Island road between cons. VI-VII lot 3, Orillia North tp.	<p><u>856</u> to <u>865</u> - A 20-foot bluff with gently sloping base. In places slope levels off and a steeper slope below might indicate a lower beach terrace covered with large boulders and 700' to 900' wide.</p> <p><u>858</u> to <u>866</u> - A 15-foot west facing bluff continuing to the strong to the north but diminishing to south. Base of bluff slopes gently to merge with the terrace.</p>	<p><u>850</u> - East of the road and 775 feet east of Algonquin bluff is a strong, gravel beach ridge. It is parallel to bluff and on edge of its terrace.</p>						
Lot 4	<p>A series of strong gravel ridges occur to the west of the Algonquin bluff.</p> <p><u>856</u> - a ridge 350 feet west of bluff.</p> <p><u>853</u> - a ridge 430 feet west of bluff.</p> <p><u>843</u> - base of slope below ridge marking a possible beach. West of the road are several parallel curving ridges at elevations of <u>840</u>, <u>837</u>, <u>835</u>, <u>824</u>.</p>				<p><u>769</u> - In lot 5 con. VI, $\frac{1}{4}$ mile west of corner. A moderate 10-foot bluff and a narrow (50-foot) terrace. Slope and terrace swampy.</p>		<p><u>706</u> - In lot 6 con. VI, $\frac{1}{2}$ mile west of corner. Beach marked by a moderate boulder strewn slope which ends in a cedar swamp. Base not well marked.</p>	<p><u>762</u> - In lot 5 con. VI, $\frac{1}{4}$ mile west of corner. A 6-foot bluff in a cedar swamp, 7 feet below the Wyebridge beach.</p>

<p>Ardtree Island intersection of roads between cons. VI-VII, lots 5-6, Orillia North tp.</p>	<p><u>867 to 872</u> - A 35-foot west facing bluff. Terrace narrow and marked by a ridge on the outer border.</p>	<p><u>841</u> - A strong 20-foot bluff below the Algonquin terrace marks the Ardrees. Slope and terrace below are boulder strewn. <u>877</u> - At 420 feet east and at 1,200 feet north of corner is a strong gravel ridge.</p>	<p><u>814</u> - At northwest corner of intersection is a moderately well developed beach with a cedar swamp occupying terrace below. <u>815</u> - A strong well-developed bluff 1,200 feet due north of corner. The slope and terraces above and below are heavily boulder strewn. Terrace below is swampy and extends 1,000 to 1,500 feet to the north and northwest.</p>	<p><u>813</u> - Where lowest beach cuts the road the slope is gentle, but distinctive. Terraces above and below are boulder strewn.</p>	<p><u>858 to 876</u> - Strong south-east facing bluff. Beach not well-defined as slopes off gently in places. Evidence of two terraces here, indicating different lake levels at <u>875</u>, <u>864</u>, and <u>858</u>.</p>	<p><u>851</u> - A strong gravel ridge running parallel to the Algonquin bluff. <u>838</u> - A 10-foot boulder strewn slope below the terraces and beaches of the Algonquin.</p>	<p><u>829</u> - A strong gravel ridge east and south of corner.</p>	<p>Ardtree Island read between cons. VII-VIII lot 4, Orillia North tp.</p>
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Locality	Algonquin Beach	Ardtrea Beach	Upper Orillia Beach	Lowe Orillia Beach	Wabridge Beach	Penetang Beach	Caledonia Point Beach	Other Beaches
<p>Ardtrea Island road between cons. VIII-IX lot 6, Orillia North tp.</p>	<p>862 to 880 - Strong 35-foot bluff somewhat weaker to the north where it forms the northern extremity of Ardtrea Island. Terrace narrow with gravel ridge associated.</p> <p>872 - Gravel spit extending northward from tip of Island.</p> <p>869 - A gravel ridge east of spit above. Beaches on the north side of the island are 5 to 10 feet lower than beaches on the east side.</p>	<p>841 to 860 - A series of ridges and slopes marking approximate elevations of beaches.</p>						

DESCRIPTIONS OF BEACHES

Tabular Summary

Elevations of the shorelines are arranged in Table I commencing 2 miles southwest of Oro (Map 163A, Barrie) and ending at the northern tip of Ardtrea Island, a total distance of $19\frac{1}{4}$ miles. Readings were taken of the Algonquin beach in parts of the Sutton and Barrie map-areas because of the excellent exposures there and in order to obtain a more accurate tilt rate. Locality descriptions refer to the Barrie (163A), Sutton (162A), and Orillia (49A) map-sheets.

Details of Beaches

General Statement

An added description of the features listed in Table I is necessary to give a more complete picture of the succession of beaches. Various factors affect the normal development of the shorelines. Among these are: (1) kind of material forming the bluff and shore; (2) depth of water off shore; (3) reach of the water; (4) exposure to prevailing winds; and (5) slope and extent of terrace. The beaches in this area have all been influenced by these factors to varying degrees.

Algonquin Beach

The Algonquin beach is one of the distinguishing features of Orillia map-area. Commencing at Barrie as a moderate 15- to 20-foot bluff it rises to a strong 30- to 40-foot bluff, continuous to within 6 miles of Orillia. Between this latter point and Orillia the bluff is broken by bays that now contain small creeks. Each of these bays records the high-water level of Lake Algonquin in its bay-mouth bars. Between the bays the bluff continues to be well marked. The high land forming the north-western part of Orillia is a Lake Algonquin peninsula. On the south and east sides the shoreline is moderately strong, and can be easily traced through the town. Its steep slopes have been well utilized in the golf links. The 25-mile shoreline, extending almost without interruption from Barrie to Orillia, ends in a spit just north of the golf links. West of the peninsula is a north-facing bay. Halfway down the bay is a strong gravel bay bar that merges imperceptibly with the very low shorelines on either side. Lakewards from this bar the bluffs again become strong and well defined. On the west side of the bay the shoreline forms 70- to 80-foot bluffs. North of Bass Lake is another strong bay spit, joined on the east to the Algonquin bluff and curving in a concentric arc to merge with the sandy deposits to the west. The Algonquin bluff continues on the south side of Bass Lake, but is not well defined.

Ardtrea Island preserves the most northerly exposures of the shoreline in this area, and probably no other exposures exist between this island and Bracebridge, 24 miles to the north. The island is well situated for an ideal study of shorelines affected by all the factors mentioned previously. In addition, the island presents evidence that places a different interpretation on the sequence of events during the high water stages of Lake Algonquin. This interpretation will be discussed later. The Algonquin beach is well developed around the island, except in the sand and gravel deposits on the southern tip, and is best shown on the northern sides. In places the bluff merges with the terrace in a gentle slope, making accurate determinations of lake level difficult. In another place three distinct terraces and bluffs of the shoreline suggest that differential uplift occurred during this stage, a condition not recognized in the southern part of the area.

Ardtree Beach

This is by no means a strong, well-developed beach, and at best represents a brief period of quiescence in the differential uplift that closely followed the retreating ice front. Southwest of Orillia it is marked by a number of ridges associated with the bay-mouth bars. South of these bars the beach is noticeable at only two points: 2 miles west of Hawkestone, where it forms a 5-foot bluff immediately below the Algonquin bluff; and 1 mile west of Oro, where the lower of two ridges marks the Ardree. Elsewhere in the area south of Orillia, a mile-wide boulder-strewn terrace separates the Algonquin bluff from Lake Simcoe. Mild slopes occur on the terrace, suggesting lower beaches, but nowhere sufficiently definite to warrant taking elevations. The Ardree beach is strongest 1 mile northwest of Orillia, where it forms a 20-foot bluff. On Ardree Island is a series of beaches and ridges probably formed during local uplift, as noted above. Two miles southwest of Oro the Ardree beach is only 10 feet below the Algonquin; the convergence between the two is approximately 0.27 foot per mile, but this would decrease southward so that the beaches should possibly meet somewhere south of Port Elgin on Lake Huron. Goldthwait found beaches immediately below the Algonquin at the following localities at elevations that would correspond with those of the Ardree beach: Kincardine, 657 feet, 8 feet below the Algonquin beach; Kincardine, 660 feet, 7 feet below; Port Elgin, 702 feet, 8 feet below; Warton, 763 feet, 14 feet below; and Hogg Post Office, 761 feet, 17 feet below. Stanley notes a ridge at Sucker Creek at 776 feet, 16 feet below the Algonquin.

Upper Orillia Beach

The Upper Orillia is the most conspicuous of the beaches between the Wyebridge and the Algonquin. It is so named because of its prominence in Orillia, although it is better developed on the high land near the Mental Institute 2 miles to the southwest, and again at 1 mile north of Bass Lake, where it forms a 25-foot bluff. The most southerly evidence of this beach occurs on the Algonquin terrace near Carthew Bay, where it forms well-developed sand and gravel ridges, and, in a small bay, a shore bluff. Elsewhere in the area the beach is marked by shore bluffs, except on a height of land 1 mile northwest of Silver Creek station where sand and gravel ridges occur. The beach is well marked on Ardree Island, forming good bluffs on both sides near the centre and a well-marked bluff 1 mile north of the most northerly Algonquin bluff. No elevations were taken at this last point. Goldthwait again found other beaches that would correspond to the Upper Orillia, namely: Kincardine, 636 feet, 31 feet below the Algonquin beach; Port Elgin, 671 feet, 39 feet below the Algonquin; and Balsover, 806 feet, 51 feet below the Algonquin.

Lower Orillia Beach

The Lower Orillia beach, also conspicuous in Orillia, shows its best development just west of the Mental Institute. The beach is traceable for only about half the distance of the Upper Orillia beach. It is marked throughout by beach bluffs except at a point $1\frac{1}{2}$ miles southwest of Silver Creek station, where it forms sand and gravel ridges. No good exposures occur on Ardree Island. At Orillia this beach lies 68 feet below the Algonquin. A beach ridge noted by Goldthwait at Penetang at an elevation of 785 feet, 70 feet below the Algonquin, was probably formed during this stage.

Wyebridge Beach

The Wyebridge beach is not strong in the Georgian Bay area, and it is even less pronounced near Orillia. It indicates only a short pause on Lake Algonquin at this level. It may be that the lake at this

stage fluctuated, resulting in partial destruction of the beach by drowning, as suggested by Stanley. Measurements were taken over a distance of 9 miles.

Penetang Beach

The Penetang beach is exposed at two localities in the area, one of which is only a slight slope in sandy deposits on the west side of Ardtrea Island. The other locality, $4\frac{1}{2}$ miles north of Crillia on the road to Uthoff, is worthy of note. Part way up a steep, 60-foot bluff is a narrow (20- to 30-foot) bench. The terrace is boulder strewn, and the base of the bluff above is well marked. The northerly exposure of the bluff and the deep water off shore are undoubtedly factors that contributed to the only excellent exposure of the Penetang in this area. The distance between the two points at which elevations were taken is insufficient to determine the slope of the beach.

Cedar Point Beach

The Cedar Point beach is unique in that the shoreline as exposed is about 20 feet below the level of Lake Couchiching. A height of land separates the abandoned shoreline from the present lake. Again elevations were taken at only two points, which are separated by a distance of nearly $1\frac{1}{2}$ miles. The northerly locality is again on the west side of Ardtrea Island, and the base of the boulder strewn slope ends in a cedar swamp where accurate determinations are difficult. The other locality is at the base of the 60-foot bluff mentioned in the description of the Penetang beach. The base of this bluff is also a cedar swamp, but the elevations of the beach correspond so well with that of Stanley's that no hesitation is felt in their correlation. The distance below other beaches is also in agreement.

Other Beaches

Mention should here be made of beaches and ridges other than those referred to above, as they indicate the nature of the subsidence of Lake Algonquin. In the northern part of the area the strongest features were taken to mark the highest water-plane of the main Algonquin beach, but numerous ridges and slopes occur above and below the main beach. Similar features are associated with the Ardtrea beach. South of Orillia levels lower than the Algonquin are best marked on bay-mouth bars as a series of gravel and sand ridges between the Algonquin and Ardtrea beaches. Approximately 12 feet above the Upper Orillia beach are a few isolated features that may mark a temporary halt in the lowering of the lake. Numerous features that exemplify this stage have been found by investigators in other localities, but here it is not sufficiently well defined to give it a name. Ten feet below the Wyebridge is a moderate beach marked by bluffs in three localities on the west side of Ardtrea Island. This again agrees closely with observations made by Stanley. Apart from such temporary halts as noted above, the subsidence of Lake Algonquin between recognized beaches appear to have been rapid, with insufficient time to develop distinctive features.

Impounded Beaches

In each of the small bays of Lake Algonquin southwest of Crillia are ridges and bluffs that were at first thought to be correlated with similar features on the lake side of the bars and formed by the waters of the lagoon during temporary halts in the lowering of Lake Algonquin. However, the elevations inside the lagoons do not always correspond with elevations outside. In addition, the lagoons were of such limited size that it is improbable that wave action in the lagoon

was of sufficient strength to develop the beaches. The evidence for impounded beaches found on Georgian Bay substantiates the conclusion reached by Johnston that prior to the formation of the highest Algonquin beach Trent Valley was the sole outlet during which time the lake was considerably lower. With uplift of the Fenelon Falls outlet the lake level rose. It is suggested that these lagunal features are the result of wave action during the rising stages of the lake. The bay-mouth bars, built during the long stand of the lake at its highest level, prevented the destruction of these earlier features. Four miles southwest of Orillia is a steep bluff in the lagoon, the base of which is 20 feet below the Algonquin beach and corresponds to the Ardtrea beach. Two and a half miles southwest is a 10-foot bluff in a lagoon at an elevation of 815 feet, or 25 feet below the Algonquin and 7 feet below the Ardtrea. A second beach here is at an elevation of 827 feet, or 12 feet below the Algonquin and 6 feet above the Ardtrea. Running parallel to the bay-mouth bars in both these localities are well-marked ridges on the lagoon side at 6 to 7 feet below the top of the bar. It is probable that these were formed by strong wave action during the construction of the main ridge.

GENERAL RELATIONS OF THE WATER-PLANES

Critical facts derived from the profile map (Figure 1) have been arranged in Table II, together with the data adapted from Stanley of the water-planes in the Penetang area. Although the slopes of the water-planes are not in exact agreement yet they are sufficiently close to show a good correlation. Exposures of the lower group of beaches are limited in this area, consequently, no great reliance can be placed on the rate of slope, and the tilt rate as found by Stanley is probably the more accurate.

Several important conclusions may be drawn from a study of the profile map of the water-planes. The most striking feature is the general parallelism of the lower Algonquin beaches. Another important feature is the convergence of the uppermost beaches. Dotted lines associated with the Algonquin and Ardtrea beaches mark temporary halts in the rapid, local uplift that affected the northern part of the area.

Table II. Comparison of the Water-Planes in the Penetang and Orillia Areas

Water-plane	ORILLIA at Silver Creek Station				PENETANG at Giants Tomb Island			
	I	II	III	IV	I	II	III	IV
	Measured elevation of beach	Slope of water- plane per mile (feet)	Interval between success- ive water- planes (feet)	Converg- ence of suc- cessive water- planes (feet per mile)	Measured elevation of beach	Slope of water- plane per mile (feet)	Interval between success- ive water- planes (feet)	Converg- ence of suc- cessive water- planes (feet per mile)
Algonquin	856	3.52)	0.52	875	3.38))
Ardtree	836	3.00))	---	---))
			29)92	0.10			---	---
Upper Orillia	807	2.90))	---	---))
			22)	0.00			---	---
Lower Orillia	785	2.90))	---	---))
Weybridge	764	2.75	21)	0.15	785	---))
			40	---			37)
Penetang	724	---)	---	748	3.06))
			24	---			24	0.125
Cedar Point	700	---)	---	724	2.875))
Payette	Not present		---	---	686	2.75	38	0.125

INTERPRETATION OF RESULTS--

In determining the water-planes it is realized that lake levels may fluctuate from year to year, and the beaches as indicated here do not mark a long, constant stand of the water at that elevation. Also, it is realized that features such as bars, ridges, and spits may change in position and elevation even during one violent storm. However, similar conditions must have existed everywhere in such a small area as the Orillia district, thus giving a constant water-plane.

The Algonquin beach, although the most distinctive in Crillia map-area, provides the greatest difficulty in determining the actual elevations marking the water-plane. This difficulty increases from south to north and may be due to one or more of several causes. As the bluffs are higher in the north, slumping was greater there, and, where sand is present, the terrace merges with the bluff and the actual elevation of the beach could only be roughly estimated. If the evidence is correctly interpreted more tilting occurred in the north than in the south of the area, and this tilting was greater during the Algonquin than during later stages. As the uplift was not uniform new beaches would be formed as the shoreline was raised, and in protected localities the older beaches might be preserved whereas in open regions waves of lower levels could encroach on the bluffs and remove the evidence of higher beach levels. In the southern part of the area less tilting probably occurred, and as the uplift continued in the north the water level here would remain stationary or even rise, thus continuing to develop a single strong shoreline.

A detailed study of the profile of the abandoned shorelines indicates two stages of uplift. The first, or initial, uplift was local, confined to the area immediately in front of the ice-sheet, greatest close to the ice front and diminishing away from it. The second, or regional, uplift followed as the ice-sheet retreated. This stage merged with the initial uplift, tilting was less, it proceeded over a greater length of time, and was more uniform. Such an interpretation is necessary to explain the convergence of the upper Algonquin beaches and the approximate parallelism of the lower beaches. Initial uplift occurred during the formation of the Algonquin beach in the Ardtrea section. Following this and continuing through the Ardtrea and into the Upper Orillia beach stage in both the north and south was initial uplift merging with and gradually succeeded by regional uplift. It is suggested that the Ardtrea and possibly the Upper Orillia beaches are partly the result of initial uplift, hence their more marked convergence with the Algonquin. It is not inferred that no other stands of lake level occurred other than at the Ardtrea and Upper Orillia beach levels, for the numerous beaches and ridges at various altitudes between the Algonquin and Upper Orillia suggest a spasmodic tilting throughout, but that the period of quiescence was longer at these two stages. The Lower Crillia, Wyebridge, Penetang, and Cedar Point beaches were subjected to regional uplift only. Hence the lower the beach the more parallel it becomes with the one above.

Another factor, other than differential uplift, is responsible for the development of the lower beaches. This is the lowering of the lake level by the opening of lower outlets as the ice retreated northward. At some time following the Upper Orillia beach stage, both the Port Huron and Fenelon Falls outlets were closed; therefore, new outlets must be postulated, and these could only have been found in the Precambrian area between the Palaeozoic border and North Bay. The almost entire lack of shoreline features between pairs of lower beaches indicate that the lowering of the lake level between stands was uniform and moderately rapid. The Algonquin is by far the strongest of the beaches and, therefore, the times during which the water stood constant during the lower stages was relatively brief compared with that of the Algonquin beach stage.

It is suggested that for a brief time at least the water was much higher than the altitude taken as the highest water-plane. A gravel pit on the northeast end of the bay-mouth bar $2\frac{1}{2}$ miles southwest of Crillia shows stratified sands and gravels for 32 feet above the water-plane. The nose of the bluff on the southwest end of the bar is also composed of sand and gravel. It is very doubtful if even the most violent storms could deposit this material so high above the lake level.

Several conclusions may be drawn from a study of the ridges and bars. Ridges parallel to a shore bluff are generally of the submerged type, the top of the ridge 2 to 8 feet below the base of the bluff. It is possible that some of the beach ridges assigned to the Ardtrea in the profile map (Figure 1) belong to the Algonquin. Ridges developed on an island, the top of which was approximately level with the water or within the zone of wave action, are of the emergent type, and rise 2 to 8 feet above the water-plane. Bay-mouth bars and spits are always above the water-plane where joined to the headland and may rise 10 or more feet above the actual shoreline, although 5 to 6 feet is more common. The elevation of the centre of the bay-mouth bar depends on the length of the bar, the amount and kind of material supplied from the headland, and the strength of the waves and currents. These bars are arcuate in form. Spits decrease in height away from the headland to finally merge with the terrace.

Ridges are less commonly associated with the lower beaches, and the best evidence of them is on the lake side of the bay-mouth bar of a higher beach where conditions were more favourable for their development. The paucity of these features may be explained by more protected terrain of the lower beaches, which resulted in less violent wave action. No bays are associated with the lower beaches, as the bay-mouth bar of the Algonquin effectively sealed pre-existing bays. Another factor is the small development of the cut terraces of the lower beaches due to the relatively brief time the lake remained at these levels; hence no parallel ridges occur.

In all instances in this area north-facing beaches and bars show a greater development than do those facing in other directions. The bluffs are steeper and higher, rising to 80 feet in most places, and bay-mouth bars and spits are generally 3 to 6 feet higher. This suggests that the prevailing winds in glacial times were northerly and storms from this direction more violent than others. Assuming that the ice had retreated only a short distance into the Precambrian, the reach of the waves would have been extensive. However, it is not inferred that the reach exceeded that to the east and southeast. The equal development from both ends of east- to southeast-facing bay-mouth bars indicates that southerly storms were also common. Another explanation for the strong development of north-facing beaches may have been the calving of the glacier. It is probable that the ice front formed the north shore of Lake Algonquin at this time, and if the glacier stood close to the land, large blocks of ice falling from the face of the glacier into the deep water could have produced exceedingly large waves. However, in view of the fact that the ice must have retreated into this area during the early stages of Lake Algonquin when the Fenelon Falls was the only outlet, it would be necessary to postulate a long stand of the front in this area between the Fenelon Falls and the "two outlet" stages, and no recessional moraine marks such a stand.

SEQUENCE OF EVENTS IN THE ORILLIA AREA

The succession of the various stages of Lake Algonquin in the Orillia area may be enumerated as follows:

(1) As the Wisconsin ice-sheet retreated into the general vicinity of Orillia the Trent Valley outlet was opened, thus lowering the water level of early Lake Algonquin with the result that the Port Huron outlet was closed and discharge was by way of Fenelon Falls.

(2) Initial uplift along the ice front raised the Fenelon Falls outlet until discharge was distributed between Fenelon Falls and Port Huron. This is the "two-outlet" stage during which the lake level rose at least 60 feet, destroying most of the evidence of lower beaches. It was during this stage that the strong Algonquin shoreline was formed, and it represents the longest stand of the water at a constant level in the history of the lake.

(3) The Ardtrea beach was formed during a temporary halt in the initial uplift. This beach is weak, and the time required for it to form was relatively short. Minor beach features occur above and below the Ardtrea and represent even shorter cessations of uplift.

(4) The Upper Crillia beach marks a longer resting period in uplift, when the discharge had been largely diverted to the Port Huron outlet. The glacier had retreated sufficiently far to the north so that initial uplift at the ice front had little or no effect in this area, with the result that the beach is fairly strong and not marked by anomalous features that are so commonly associated with the higher beaches.

(5) A drop in lake level of 20 feet resulted in the formation of the Lower Crillia beach, when, in all probability, the Fenelon Falls outlet was entirely closed and the discharge at Port Huron greatly reduced. This beach is almost as strong as the Upper Orillia, but both represent a relatively short lapse of time. The drainage of the lake was probably due to the opening of a lower outlet in the north.

(6) A further drop in lake level of 20 feet, when still other outlets were found, resulted in the formation of the Wyebridge, a beach of approximately the same strength as the Upper and Lower Orillia beaches. A minor lowering of the lake another 10 or 12 feet followed, with the building of rather weak beaches.

(7) Forty feet below the Wyebridge the lake again remained fairly constant to form the Penetang beach, the strongest of the beaches since the Algonquin.

(8) Another drop of 25 feet in lake level resulted in the Cedar Point beach, which represents a stage equal to or longer than the Penetang. Following this stage Lake Algonquin was drained from the Orillia area, but evidence of lower stages are to be found on Georgian Bay. The drop in lake levels between successive stages after the Upper Orillia was rapid, and no beaches worthy of note formed between stages already noted. The present lakes in this area were independent of Lake Algonquin at some time following the Penetang stage.

(9) Following the withdrawal of Lake Algonquin from Orillia area the water levels were successively lowered until finally the opening of the Mattawa-Ottawa outlet ushered in the Nipissing Great Lakes. Prior to this last event regional uplift occurred on a major scale, raising all Algonquin Lake beaches to nearly their present elevations. During and after the Nipissing Great Lakes stage uplift has continued on a minor scale, resulting in the present height of the land above sea-level.

CONCLUSIONS

At least six beaches lower than the Algonquin can be recognized in Orillia map-area. The upper three have been given local names; the lower three correspond to beaches in the Georgian Bay area, and the names employed there have been adopted for this area. The water-planes of these beaches are nearly parallel, convergence being greater in the higher beaches and parallelism increasing with each successive pair of lower beaches. The multiplicity of beaches associated in the northern part of the area with the Algonquin and Ardrea beaches was the result of rapid initial uplift followed by temporary quiescent periods. The other beaches were formed at successive lower lake levels, when the lake was drained by the opening of new outlets to the north.

Minor regional uplift followed the initial uplift. At about the time of the disappearance of Lake Algonquin, and prior to the formation of the Nipissing Great Lakes, a great regional movement resulted in the deformation of the Lake Algonquin beaches, and was again followed by minor uplift. A comparison of the Nipissing water-plane with the water-planes of Orillia area shows that the major movement produced greater tilting than subsequent uplift.

The time during which the water level remained constant in the formation of the lower beaches was relatively short as compared with the time during which the Algonquin beach was formed.

The prevailing winds during Algonquin times were northerly, as evidenced by the greater development of bluffs, gravel bars, and spits on north-facing shorelines.

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