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MEMOIR 256

PLEISTOCENE GEOLOGY OF THE LAKE SIMCOE DISTRICT, ONTARIO

BY

R. E. DEANE

GEOLOGICAL SURVEY
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
OTTAWA
1950

Abandoned strand lines of Lakes Algonquin and Nipissing at Waubaushene (16-2, 16-3; 1946). (Pages 39, 75.)

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CONTENTS

	Page
Preface	vii
CHAPTER I	
Introduction	1
Scope of investigations	1
Location and area	2
Previous work	2
Outline of field work	2
Acknowledgments	2
Bibliography	3
CHAPTER II	
Physical features	4
General account	4
Physiographic divisions	4
Rock-knob lowlands	4
Limestone plains	5
Algonquin Lake plain	5
Drumlin fields	5
Lake Simcoe till plains	6
Relief	6
Drainage	6
CHAPTER III	
General geology	8
Table of formations	8
Bedrock	9
Features of the Precambrian rocks	9
Features of the Palæozoic rocks	9
Pleistocene deposits	10
General statement	10
Deposits of glacial origin	11
Ground moraine	11
Drumlins	12
Ice-block ridges	14
Terminal moraines	15
Mechanical analyses of tills	16
Table of mechanical analyses	17
Till of the glacial deposits	25
Deposits of glacio-fluvial origin	31
Kame moraine	31
Kames and kame terraces	32
Eskers	33
Outwash	34
Deposits of glacio-lacustrine origin	34
Beach sands and gravels	35
Lacustrine sands, silts, and clays	35
Varved clay	36
Recent deposits	41
Direction of ice movement	42

PAGE

CHAPTER IV

Lake Algonquin and associated beaches 43
General discussion 43
Description of beaches 44
Tabular summary 44
Details of beaches 72
General statement 72
Algonquin beach 72
Ardtrea beach 73
Upper Orillia beach 74
Lower Orillia beach 74
Wyebridge beach 74
Penetang beach 74
Cedar Point beach 75
Payette beach 75
Nipissing beach 75
Waubaushene beach 75
Other beaches 75
Impounded beaches 76
Interpretation of results 76

CHAPTER V

Historical geology 81
Preglacial drainage surface 81
Effect of glaciation on preglacial valleys 84
Sequence of events during deglaciation 85
Niagara escarpment spillways and kame terrace stage 85
Lake Schomberg stage 86
Fenelon Falls outlet stage 87
Lake Simcoe moraine stage 89
The 'two-outlet' stage 89
Summary of events in the history of Lake Algonquin 90

Index 106

Illustrations

Map 992A. Lake Simcoe District, Ontario (Pleistocene and Recent deposits and bedrock outcrops) ..... In pocket
993A. Lake Simcoe District, Ontario (physiographic divisions and locations of soil samples) ..... "

Plate I. Abandoned strand lines of Lakes Algonquin and Nipissing at Waubaushene, Ontario ..... Frontispiece
II. A. *Roche moutonnée* 93
B. An escarpment in the limestone plains 93
III. A. Ablation moraine overlying ground moraine 94
B. A drumlin rising above sand and clay flat of Lake Algonquin 94
IV. A. A drumlin partly composed of sand and gravel 95
B. A large drumlin containing two beds of sand and silt 95
V. Stratified sand beds in a drumlin 96
VI. Aerial photograph of ice-block ridges 97
VII. A. Side view of elongated type of ice-block ridge 98
B. Pocket of sand and gravel in till of ground moraine 98
VIII. A. Stratified sand of ice-contact deposit overlain by a compact sandy till 99
B. A single bluff of a constriction or spillway 99

PAGE

Plate IX. A. Cross-section near the head end of an esker..... 100
B. Excellent sorting and stratification near the south end of an esker..... 100
X. A. Stones in varved clay..... 101
B. Ripple-marked varved sand and silt..... 101
XI. A. Truncated varved clay..... 102
B. Algonquin bluff and heavily boulder strewn terrace..... 102
XII. A. Algonquin bluff and sandy terrace..... 103
B. Spillway or narrow connecting channel of Lake Schomberg.... 103
XIII. A. Varved silt and clay of Lake Schomberg..... 104
B. Contorted and folded varved clay overlain and underlain by a compact sandy till..... 104
XIV. A. Fossiliferous sand and clay overlying unfossiliferous sand..... 105
B. Deltaic sand and gravel deposit at the entrance of Little Lake Valley..... 105

Figure 1. Location of map-area..... 1
2. Tri-linear chart showing mechanical analyses results..... 22
3. Mechanical analysis record curves for soil samples representing each of nine types..... 23
4. Mechanical analysis record curves for colour-differing tills..... 28
5. Mechanical analysis record curves for tills that differ lithologically..... 30
6. Shoreline and isobases of Lake Algonquin.....In pocket
7. Profile of abandoned water-planes..... "
8. Bedrock surface contours and present drainage system..... "
9. A. Ice-fronts at the Niagara escarpment spillways, kame terraces, and interlobate moraine stage..... "
B. Ice-fronts at the Lake Schomberg stage..... "
C. Ice-front at the Fenelon Falls outlet stage..... "
D. Ice-front at the Lake Simcoe moraine stage..... "

PREFACE

Pleistocene or glacial deposits mantle the bedrock formations throughout much of Canada, and represent the unconsolidated materials from which our soils are derived and from which much of our ground-water supply is obtained. Their varied characteristics are also of vital concern in most engineering projects, and in the supply of road metal and other constructional materials. For all such agricultural and industrial purposes, so fundamental to the progress of civilization, it is becoming increasingly important to have on record all pertinent data relative to the extent, thickness, character, and origin of such deposits and their ground-water possibilities.

The present report deals with an area of some 1,300 square miles around, and including, Lake Simcoe, in southwestern Ontario. It describes the physiography or land forms of this region, deals with the bedrock and unconsolidated material comprising these forms, and discusses in some detail the origin and mode of accumulation of the glacial deposits. It relates the historical events following the retreat of the last continental glacier from the region and subsequent inundation of much of the land by glacial Lake Algonquin, and details an account of the differential uplift that resulted when the great mass of ice was removed. The report is accompanied by two maps, on a scale of 1 inch to 2 miles, illustrative respectively of the geology and physiography of the region. Ground-water data are not included, but are being published in separate water supply papers for each of the townships in the map-area.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, March 15, 1949

Pleistocene Geology of the Lake Simcoe District, Ontario

CHAPTER I

INTRODUCTION

SCOPE OF INVESTIGATIONS

The object of this report is to present the results of investigations of Pleistocene deposits and physiographic features in the Lake Simcoe district, Ontario. The region embraced in the discussion of the glacial deposits is largely that of the Lake Simcoe basin, but in dealing with the history of glacial Lake Algonquin it has been necessary to range far beyond the limited area mapped, and to correlate the results obtained by the writer with those found by other investigators.

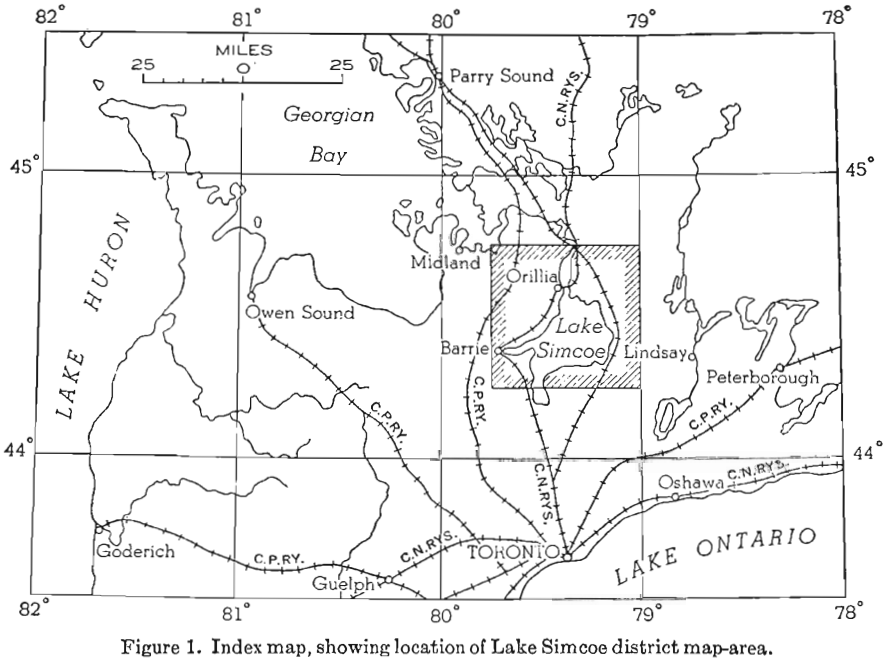

Figure 1. Index map, showing location of Lake Simcoe district map-area.

The direct economic importance of the deposits is limited to their use in the construction of roads, buildings, dams, tunnels, and drainage and irrigation canals, or in other engineering projects. Pleistocene deposits are of the utmost importance in agriculture, and in the supply of ground water essential to both rural and urban settlement.

LOCATION AND AREA

The area mapped (*See* Figure 1) lies in the western part of south-central Ontario, about 75 miles north of Toronto. It extends from latitude 44° 15′ to 44° 45′ and from longitude 79° 00′ to 79° 45′, and covers an area of approximately 1,300 square miles, of which nearly a quarter is water.

PREVIOUS WORK

Since 1852 the history of the Great Lakes has been the subject of numerous investigations, and various writers have published papers pertaining to it. The classical report is by Leverett and Taylor (18)[1]. Goldthwait (10) and Johnston (14) traced the Algonquin shoreline in the Lake Simcoe area. In more recent years Stanley (20, 21, 22) has reported on the lower Algonquin beaches around Georgian Bay.

The glacial deposits have received less attention. W. A. Johnston, for the Geological Survey of Canada, spent the summers from 1907 to 1912 in mapping the Pleistocene deposits of Lake Simcoe map-area, with the exception of the northwest corner. However, this work was not published, and no detailed accounts are available. The physiography and soils have been described by Putnam and Chapman (2, 3).

OUTLINE OF FIELD WORK

Field work on which this report is largely based was conducted by the writer for the Geological Survey of Canada during the summers of 1945, 1946, 1947, and 1948. It was concerned mainly with three problems: Pleistocene geology, beach elevations, and ground-water survey. Accompanying maps show the glacial deposits (Map 992A) and physiographic divisions (Map 993A). The glacial material was classified from whatever natural and artificial exposures, such as those of shore cliffs, ravines, road cuts, railway cuts, and wells, could be found, but most of the information was obtained from holes dug to a depth of 3 or 4 feet.

More than eight hundred readings of elevations of beaches, bars, and spits of Algonquin and lower Algonquin shorelines were taken to show the relation of the various beaches to each other and to determine the amount of differential uplift that has affected the area since glaciation. Ground-water conditions in each of the townships within the map-area are described in water supply papers issued, or to be issued, by the Geological Survey of Canada.

ACKNOWLEDGMENTS

The writer is indebted to the Geological Survey of Canada for the opportunity to study the Lake Simcoe area for a doctorate thesis. He is especially grateful to Professor A. MacLean of the University of Toronto, under whose guidance this report was prepared, for interesting discussion and suggestions, and to Professor E. S. Moore for a critical review of the manuscript.

To Dr. J. F. Caley of the Geological Survey of Canada, Dr. D. F. Putnam and Mr. W. M. Tovell, of the University of Toronto, Mr. L. J. Chapman, of the Ontario Research Foundation, Mr. R. F. Legget of the National Research Council, and Mr. A. K. Watt of the Ontario Depart-

[1] Figures, in parenthesis, refer to publications listed in Bibliography at end of Chapter I.

ment of Mines the writer is deeply indebted for expert criticism and helpful discussion of the theories and many problems pertaining to Pleistocene time.

In the field, the writer was ably assisted in 1945 by E. Kostener; in 1946, by E. B.Owen, J. A. Elson, and R. R. S. Miller; in 1947, by E. C. Halstead, N. Pring, D. K. Erb, and R. K. Mudford; and in 1948, by E. I. K. Pollitt, A. A. McGregor, K. E. Turner, R. C. Nelson, and D. H. Henshaw.

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CHAPTER II

PHYSICAL FEATURES

GENERAL ACCOUNT

The northern fringe of Lake Simcoe map-area is underlain by the Precambrian rocks of the Canadian Shield. South of this border the area is underlain by Ordovician strata. During glacial advances of Pleistocene time, the granitic terrain was scoured, leaving numerous outcrops and, between them, depressions filled with drift. The Palæozoic strata are exposed near the Precambrian border, or are thinly veneered with a till sheet, but the drift thickens rapidly to the south, particularly in the western half of the map-area. Within the area, the Precambrian rocks lie within a zone of erosion, and most of the Palæozoic rocks within a zone of deposition. Flint (8, p. 86) states that the border between these two zones coincides fairly closely with the Precambrian-Palæozoic contact. It would be strange indeed if this coincidence were related to position with respect to the ice-sheet. The facts suggest that lithology was the determining factor. The hard, granitic, Precambrian rocks were not easily eroded, with the result that the subglacial load in the glacier was light. Very little drift now covers these rocks and the original surface prior to any glacial stage suffered very little change. On the other hand, the soft Ordovician rocks were more easily eroded, both by plucking and abrasion, resulting in a relatively heavy subglacial load of drift, that was soon deposited, mainly as ground moraine. South of the Precambrian border, the narrow, marginal limestone plains that contain very little drift indicate that the base of the advancing ice was not overloaded and that scouring action prevailed for a short distance over the Palæozoic rocks before sufficient material was picked up to necessitate deposition. The flat-lying attitude and compactness of the limestone rocks may have been contributing factors where scouring prevailed. The present surface of the Canadian Shield within the area is relatively flat, and shows no deep preglacial valleys, whereas the Palæozoic rocks, though flat over large areas, were eroded by preglacial streams that left many deep valleys, now partly filled with drift and occupied by present streams.

PHYSIOGRAPHIC DIVISIONS

The map-area may be divided into physiographic divisions, which although the boundaries are by no means definite, nevertheless contain forms that bear a degree of uniformity. The divisions adopted are those of Putnam and Chapman (2). The factors considered in making the divisions are; bedrock, composition of the drift, and topography. The following paragraphs briefly describe these divisions.

ROCK-KNOB LOWLANDS

Rock-knob lowlands form the most northerly division and occupy an almost continuous fringe across the northern part of the map area, with a

maximum width of 4 miles. The distinguishing feature here is the numerous outcrops of Precambrian granite and gneiss in the form of *roches moutonnées* that give a rugged appearance to the landscape (*See* Plate II A). The area is low, generally less than 800 feet above sea-level, but rises to the north and east to become the uplands described by Putnam and Chapman (2). These lowlands were covered by glacial Lake Algonquin, and during the lower stages of this lake the waves swept the rock-knobs clear of drift and deposited this material on top of the drift in the depressions between the outcrops.

LIMESTONE PLAINS

A limestone plain extends as a narrow belt along the south border of the Canadian Shield. The belt is about 10 miles wide at the east side of the map-area but narrows to the west. Flat-lying limestone outcrops within much of the belt, and, as in the rock-knob lowlands to the north, much of the drift left by the retreating glacier was subsequently removed from the higher parts by the waters of glacial Lake Algonquin. Lacustrine deposits and drift thinly cover the low-lying areas. Escarpments varying from 3 to 25 feet in height are common (*See* Plate II B), and result from the plucking action of the glacier. Many of them are step-like and continuous for 2 or 3 miles. A few drumlins occur on the limestone plains, and some of them may be rock drumlins. At the east side of the belt gravel and cobble ridges are common where the ground reached the level of Lake Algonquin. Georgina and Thorah Islands in Lake Simcoe are isolated remnants of the limestone plains.

ALGONQUIN LAKE PLAIN

Included in the Algonquin Lake plain are those areas that were covered by Lake Algonquin and whose characteristic features are flat plains of sand, silt, or clay. The altitude of the main Algonquin beach increases northward from 740 feet at the south end of Cook Bay to more than 900 feet at the northeast corner of the map-area. In general, clay flats are most common in the depressions, with silt and sand, respectively, occupying the areas marginal to the shorelines. During maximum inundation by Lake Algonquin, and during its successive lower stages, sand was deposited close to the shorelines, silt was carried some distance off shore, and only clay reached the deeper water. With each lower stage this succession was repeated, giving a lateral sequence of sand, silt, and clay, respectively, away from the shoreline, and in the thick deposits a vertical sequence grading down from sand to clay. The depressions were isolated ponds in the final stages of inundation, and, hence, wave action was so reduced that the clay was not covered by silt and sand.

Beach deposits are common along the shorelines of Lake Algonquin at its various stages. Gravel bay-mouth bars, spits, and beach ridges are best developed along the main Algonquin beach, with sand counterparts more common along the lower Algonquin shorelines.

DRUMLIN FIELDS

Drumlins are numerous and widespread within the area mapped, but most of them are concentrated into two fields, one in the southeast centring around Cannington, and the other in Mara and Rama townships east of Orillia. Those around Cannington are the typical oval hills with a height

of as much as 200 feet. Those along the northeast shore of Lake Simcoe are long, narrow ridges rarely more than 50 feet high. The drumlins, because of their wide distribution, merge with all adjoining deposits. Those submerged beneath Lake Algonquin are somewhat modified by wave action, but still retain their drumlinoid form although the swales between them are floored with lacustrine deposits. In general, the larger drumlins are found where the drift is thick, whereas the smaller drumlins occur where the drift is thin. No drumlins have been identified in the rock-knob lowlands.

LAKE SIMCOE TILL PLAINS

The Lake Simcoe till plains are made up of several islands, peninsulas, and headlands of ancient Lake Algonquin. The plain is mainly an undulating ground moraine, but contains the Bass Lake kame moraine, a few drumlins, and ice-contact deposits. The general elevation of the plain is 1,000 feet above sea-level, but the effect of a plain is broken in one place by the broad belt of kame moraine, sand, and gravel that reaches an elevation of 1,350 feet, and in other places by deep valleys that form the straits and bays of Lake Algonquin and generally are below 800 feet. The material comprising the ground moraine in the northern part is a sandy till derived mainly from the granites of the Canadian Shield. This till contains a great many, large, igneous boulders that now litter the surface. In the central and southern part, the till becomes progressively more calcareous. In addition to the ground moraine there are areas of outwash sand and gravel that are quite flat; the largest is south of Barrie.

RELIEF

Relief in the map-area is varied; in the Lake Simcoe till plains region it is accentuated by the rolling hills of kame moraine that reach an altitude of 1,350 feet, and the steep-sided valleys that drain into Georgian Bay, where the altitude is 581 feet. The rock-knob lowlands and limestone plains have little relief, for although the Precambrian topography is rugged and the limestone plains are broken by a few drumlins and escarpments, few of the *roches moutonnées*, drumlins, or escarpments rise more than 25 feet above the plains on which they occur. In the drumlin fields the topography is rolling, particularly in the southeast part of the area where the drumlins generally rise slightly more than 100 feet above the intervening swales. Lake Algonquin had a dual effect on the topography: along its shoreline the waves cut into the headland and left steep bluffs that rise to a maximum height of about 80 feet, thus accentuating the relief; on the other hand, lacustrine deposits cover many of the irregularities of the lake bed, thus subduing the relief. This latter process was particularly effective in the rock-knob lowlands, in the limestone plain, and in the drumlin field east of Orillia.

DRAINAGE

Rivers in the Lake Simcoe map-area are small and unimportant commercially or economically. They are, in order clockwise from the northeast corner; the Black, with its tributary the Head, Beaverton, Pefferlaw Brook, Black (there are two Black Rivers), North, Coldwater, and Sturgeon. Black River (in the northeast) and its tributary, Head River, flow westward through low rock banks in the rock-knob lowlands. The rivers are

still in a youthful stage, as evidenced by rapids and falls between slow, sluggish stretches. The water is black in contrast with the green water of Severn River, which the Black joins above Washago. Beaverton River flows northward through the drumlin field in the southeast part of the area. It is a sluggish, meandering stream, flowing in an extensive swamp through most of its course. Its youthful stage is exhibited near the mouth by a few small rapids. Black River (south of Lake Simcoe) and Pefferlaw Brook are two small, sluggish streams flowing on the Lake Algonquin plain into Lake Simcoe.

In the northwest part of the area are three rivers draining into Georgian Bay. North River, which forms the outlet of Bass Lake, is a meandering stream flowing between low banks through the rock-knob lowlands over most of its course. It has the appearance of a youthful stream only in the upper 3 or 4 miles, where rapids, falls, and deep, narrow gullies in Algonquin terraces mark its course. Coldwater and Sturgeon Rivers both flow through deep glacial valleys. These valleys are floored with thick deposits of lacustrine material into which the rivers are only slightly entrenched. The gradient of both rivers is fairly uniform at about 8 feet a mile.

All of these rivers, with the exception of the North, Head, and Black (in the northeast), follow preglacial drainage systems of which the deep glacial valleys are the present expression. There is no evidence of preglacial valleys along the courses of North and Black Rivers, and, hence, they follow the natural slope of the country, meandering between low banks in depressions in the bedrock and thin drift. Downcutting by the present streams is slight, as most of them are misfits occupying glacial valleys with low gradients. Gullying occurs mainly in terraces and bay-mouth bars crossed by the streams.

The lakes, in order of size, are Simcoe, Couchiching, Dalrymple, Canal, Bass, St. John, and Little. Lake Simcoe is generally shallow, but reaches a maximum depth of 140 feet at the mouth of Kempenfelt Bay. Lake Couchiching is extremely shallow, with rocks and shoals everywhere within a few feet of the surface of the water. These two lakes owe their present existence to: (1) damming of the preglacial drainage system by glacial drift; (2) damming of outlets by lacustrine deposits (a ditch in the valley west of Barrie, 6 miles long, with a maximum depth of 50 feet, would initiate a stream that would soon drain Lake Simcoe completely); (3) depressions that are largely glacial in origin; and (4) differential uplift. Since the formation of the Algonquin beach, the outlet of Lakes Simcoe and Couchiching at Washago has been uplifted 140 feet higher than the south end of Cook Bay. Were the land depressed this amount these lakes would be completely drained except for a small pond in Kempenfelt Bay.

The other lakes are all relatively shallow. Dalrymple and Canal Lakes occupy depressions that were originally valleys of the preglacial drainage system. Glacial drift now blocks the southern end of these depressions. Lakes Couchiching, St. John, and Dalrymple are 'glint' lakes, namely, lakes lying on the border between the Canadian Shield and the Palæozoic rocks.

CHAPTER III

GENERAL GEOLOGY

TABLE OF FORMATIONS

The subdivisions of the Pleistocene, and the bedrock formations referred to in this report are as follows:

Era	Period	Epoch	Age (Stage)	Sub-age (Substage)
Cenozoic	Quaternary	Recent		
		Pleistocene	Wisconsin	Mankato
				Cary
				Tazewell
				Iowan
			Sangamon[1]	
			Illinoian	
			Yarmouth[1]	
			Kansan	
			Aftonian[1]	
			Nebraskan	
Unconformity				
Palæozoic	Ordovician	Middle Ordovician	Sub-epoch	Formation
			Trenton	Cobourg
				Trenton
			Black River	Leray
				Lowville
				Pamelia?
Unconformity				
Precambrian				

[1] Interglacial units of the Pleistocene epoch are in italics.

BEDROCK

FEATURES OF THE PRECAMBRIAN ROCKS

The minor amount of drift now present in the rock-knob lowlands as compared with the innumerable outcrops of granite and granite-gneiss is a remarkable feature of the narrow fringe of the Canadian Shield in this area, in view of the fact that the glaciers had up to this point advanced mainly over granitic rocks throughout their entire journey. It can only be concluded that the base of the ice was not overloaded, and that scouring action prevailed, with the result that the area is now studded with *roches moutonnées* (*See* Plate II A) that rise from a few feet to about 40 feet, and the little drift deposited fills depressions between the outcrops. Most of the outcrops of granite have the typical *roche moutonnée* form, with a gentle stoss and steep lee ends, and with the long axis parallel with the direction of ice movement. In the granite-gneisses, structure was a controlling feature. Where folds and fractures were transverse to the direction of ice movement, the plucking action of the ice left very rugged and irregular forms; where the structure paralleled ice movement, deep grooving and long ridges are common.

Grooving and chattermarks are common in the hard granitic rocks, whereas striæ are rarely seen.

While the Lake Simcoe area was inundated by glacial Lake Algonquin, wave action removed any drift left on the outcrops by the glacier, and, in places, deposited sand, silt, or clay over the drift in the depressions.

The material contributed to the load of the glacier by these granites and granite-gneisses varied from exceedingly large boulders to sand-sized particles. The coarse granular texture and the hardness of the rocks tended to produce the coarser particles rather than rock-flour, which is a characteristic product of shales and limestones.

FEATURES OF THE PALÆOZOIC ROCKS

Palæozoic rocks of Ordovician age overlie the Precambrian rocks unconformably. The basal beds are sandstone or arkose (Ordovician or Cambrian?) and are well exposed on the east side of Lake St. John. Overlying these are red and green shales. These two series constitute the Pamelia formation and are local only, as Lowville limestone rests directly on Precambrian crystalline rocks in many localities. Limestone of the Lowville and Leray formations is exposed along the Precambrian-Palæozoic contact. Trenton limestone, overlying the Leray formation, is the most widespread of the Ordovician strata, forming large outcrops and underlying the drift throughout most of the area. The Cobourg argillaceous limestone, overlying the Trenton, outcrops in Pefferlaw Brook. It is the highest member of the Ordovician rocks exposed in the area. The Ordovician strata are generally nearly flat-lying, with a low dip of about 25 feet per mile to the southwest (13).

Escarpments, the result of glacial plucking or quarrying, are common in the limestone plains. Most of the escarpments vary in height from 3 to 20 feet (*See* Plate II B). An exception is the 90-foot cliff, at the base of which Head River flows, 3 miles northeast of Dalrymple Lake. This cliff marks the course of a preglacial stream, and is mainly the result of stream erosion.

The drift derived from the Ordovician rocks is composed of material varying in size from large blocks, the result of plucking, to rock-flour, the product of abrasion. Rock-flour is a typical product of glacial abrasion of limestones and shales, as these soft rocks yielded readily to the grinding action of the harder granitic fragments embedded at the base of the moving ice-sheet. Large limestone boulders are rare; cobbles and pebbles of limestone or shale often make up a large proportion of the drift where bedrock lies at or near the surface. Whereas *roches moutonnées* and chatter-marks are characteristic of the crystalline rocks, fine grooving or striæ are characteristic of the limestone. Weathering has removed any evidence of striations on exposed surfaces, but where the limestone is covered by even a few inches of drift the scratches are usually well preserved.

PLEISTOCENE DEPOSITS

GENERAL STATEMENT

The surficial deposits that cover most of Lake Simcoe map-area differ from the bedrock that underlies them in that they are unconsolidated; are glacial, glacio-fluvial, or glacio-lacustrine in origin; and are vastly younger. 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 the surface covering that existed prior to their advance, so that the soils of the area have almost all formed on these young, unconsolidated deposits. Except for swamp muck, Recent deposits are insignificant.

During the Pleistocene or Glacial epoch, the continental glaciers advanced from their gathering grounds far to the north. All exposures indicating 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 excavation would uncover both glacial and interglacial deposits of earlier stages. All evidence in this area shows that the latest, or Wisconsin, glacier advanced through the region from the northeast. During the advance of the ice, much of the loose material lying in its path was transported for 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-front retreated, the glacier left the land surface covered with accumulations of transported material in the form of ground moraine, drumlins, and eskers. During periods of temporary halts or readvances, terminal moraines, kame terraces, kame moraines, ice-contact deposits, and outwash were left to mark the position of the ice-front. Glacial lakes, ponded in front of the retreating ice, modified or covered the glacial deposits they inundated.

The Pleistocene deposits are interesting and complex. Almost all glacial types are present, representing mainly the last stages of Wisconsin glaciation in minor readvances and temporary halts. These deposits occupy the greater part of the area, being absent only on the outcrops of crystalline and limestone rocks. They can be divided into three groups: (1) deposits of glacial origin, composed mainly of till in the form of ground moraine, terminal moraine, drumlins, and ice-block ridges; (2) glacio-fluvial deposits of stratified sands and gravels in the form of kames, kame moraines (in part), kame terraces, ice-contact deposits, eskers, and out-

wash; and (3) glacio-lacustrine deposits of stratified sand, silt, and clay that were laid down on the bottom and along the shores of the glacial lakes.

DEPOSITS OF GLACIAL ORIGIN

Ground Moraine. Under 'ground moraine' is classified drift that is not definitely terminal moraine nor drumlins, and has not been reworked by water. Certain areas that were covered by glacial Lake Algonquin are mapped as ground moraine, but they lie close to the shoreline and most of the lacustrine deposits were subsequently removed by the receding water, leaving a boulder pavement covering the till. Ground moraine of thin or very much attenuated drift covers bedrock in parts of the rock-knob lowlands and limestone plains. The land surface is generally flat, but may be broken here and there by outcrops and drumlins. These areas were inundated by the waters of Lake Algonquin, but the deposits of sand, silt, and clay are thin, usually a foot or two thick, and the presence of the till is identified by the numerous boulders on the surface. The greater part of the drumlin-field areas are also classified as ground moraine, which includes the swales between the drumlins and the gently rolling hills that are not definite enough to be called drumlins. Many of these swales are floored with clay deposits laid down in temporary lakes during deglaciation or carried down from the slopes of drumlins by sheet erosion, but generally they are not thick enough nor extensive enough to warrant distinction as a separate class.

Large areas of the Lake Simcoe till plains are also mapped as ground moraine. The land surface is undulating to rolling. Some of the hills resemble drumlins, but are not distinct enough to be classified as such. North of the Bass Lake kame moraine, numerous, large, igneous boulders once littered the surface of the ground moraine, but in places these boulders have been cleared from the land and used to make stone fences. The drift in the till plains is anywhere from 100 to more than 400 feet thick, in sharp contrast with the thin drift of the limestone plains and rock-knob lowlands. Ice-block ridges, the deposits of stagnant ice-fields, are characteristically found associated with ground moraine.

The ground moraine of the rock-knob lowlands is composed of a loose, sandy, reddish till derived from granitic rocks. In the northern parts of the Simcoe till plains the ground moraine consists of a loose, brown, non-calcareous, sandy till formed from eroded Precambrian formations; stones are abundant on the surface. In the southern parts, the presence of minor amounts of limestone increases the clay content slightly, making the till more compact. Boulder-clay tills or hard, sandy tills predominate in the ground moraine of areas other than the Lake Simcoe till plains.

The upper 2 to 6 feet of ground moraine is in many places composed of a loose, sandy, brown till, in some places gravelly or stony, and is commonly classified as ablation moraine. Generally it is in sharp contact with the underlying till (*See* Plate III A). Flint (8, p. 113) described ablation moraine "as being superglacial till, repeatedly washed by trickles and rills of meltwater during its existence as ablation moraine. This explains its coarser average grain size, less worn constituents, and looser texture. In some places a thin layer of stratified drift separates the two layers of till. Probably this was deposited by meltwater flowing beneath the thin ice in the terminal zone while ablation moraine was accumulating above it".

Ablation moraine is much more evident in the Simcoe till plains than elsewhere, and it is closely associated with ice-block ridges. In the drumlin fields and areas where ice-block ridges are not found, the sandy till of ablation moraine is usually absent.

Drumlins. Drumlins are widely scattered throughout the map-area but most of them occur in two fields, one centring around Sunderland and the other east of Orillia. Smaller fields are found south of Lake Simcoe, north of Kempenfelt Bay, and north of Bass Lake. The shape and size of the drumlins vary considerably; only a few conform to the text-book variety with steep stoss and gentle lee slopes, semi-ellipsoidal shape, and smooth, gently rounded sides. The drumlins in the two major fields contrast sharply. Those east of Orillia are long, narrow ridges, generally less than 50 feet high, with steep sides somewhat accentuated by wave action. Ridges, as much as 8,000 feet long and 600 feet wide, with level tops are common. In some drumlins the length is nearly fourteen times the width. The ridge-like appearance of these drumlins is slightly exaggerated by flat deposits of lacustrine clay in the swales (*See* Plate III B). Some bedrock is exposed in the drumlin field, and nowhere is the drift in the swales more than 50 feet thick. The orientation of the long axes of the drumlins varies between south 35 degrees west and south 45 degrees west.

In the drumlin field centring around Sunderland, the shape of the hills is semi-ellipsoidal with gently sloping sides. The stoss ends are generally steeper than the lee slopes. The drumlins are short and wide, with maximum lengths of 3,000 feet and widths up to 1,200 feet; a ratio of $2\frac{1}{2}$ to 1. The maximum height of the hills is 150 feet. The long axes in the northern part of the field trend south 60 degrees west and swing to south 35 degrees west in the southern part. The trend of the long axes of the drumlins indicates the direction of ice movement during the last readvance of the glacier. This direction was from the northeast, except where topography exerted a local, controlling influence.

These two types of drumlins appear to be related to the thickness of drift. In the limestone plains and thin drift areas, the long, thin, ridge-type predominates and may be erosional in origin, whereas in areas of thick drift, generally more than 100 feet, the broad, semi-elliptical forms are most common, and may be depositional in origin. The drumlins are mainly composed of boulder-clay till; a few in the northern part of the area are stony, and some in the southern part are of sandy till. In the northern drumlin field, 4 miles east of Orillia, several of the drumlins are made up of stratified sand and gravel. In form they differ in no way from other drumlins and are mapped as such. However, it is possible that they are eskers modified by wave action, or eskers overridden by the last readvance of the glacier.

All large drumlins within the map-area are composed, in part, of stratified material in the form of a capping over the boulder-clay till. These deposits are so remarkably consistent that they deserve special mention. In general, all drumlins that rise above an altitude of about 850 feet contain stratified sand and gravel on the top, ends, or sides. The stratified material is always found near the crests, always on the southeastern slope, and in some cases at one or both ends. In a few, the deposits form the

crest and extend a little way down both sides. The thickness varies from a foot or two to 40 feet, with the thicker deposits on the higher drumlins. Where gravel pit excavations give good exposures, the material is seen to be moderately well sorted and stratified and contains subangular to rounded pebbles, indicating only moderate abrasion. Where observed, the coarser gravels were on the surface and grade down into sand, below which was a compact, sandy or boulder-clay till.

The origin of the stratified materials is obscure. They are younger than the main mass of the drumlin, yet form an intrinsic part of it, blending in with the general shape (*See* Plate IV A). They mainly occur at altitudes well above the Algonquin shoreline, but as they have no common elevations, and as no visible trace of a former shoreline exists, it is improbable that they are of glacio-lacustrine origin, formed in temporary glacial lakes prior to Lake Algonquin. The writer suggests the following possible explanations: (1) they are of glacio-fluvial origin, formed during the stage of deglaciation. In the stagnant ice stage, the tops of the drumlins would eventually become exposed. The heat of the sun, together with run-off water, enlarged the opening around the drumlin, particularly on the south side, and into this opening poured the meltwater, bringing with it a load of sediments. The discharge from the drumlin-tops would be over the ice or through crevasses at this stage. No stratified sand and gravel accumulated on the lower slopes or at the bases of the drumlins, because in the later stages, as melting progressed, temporary lakes may have formed in some of the swales and left only the deposits of clay found there now. (2) Another suggestion, which, however, does not explain the absence of material on the northwest slopes, is that the material was left in large crevasses or moulins extending deep enough into the stagnant ice to reach the drumlins. (3) Still another explanation may be esker-like deposition by englacial streams in openings between the base of the ice and the tops of the drumlins. Such openings have been discovered in the lee of obstructions in Alpine glaciers. In the Sunderland drumlin field, the direction of ice movement changed from southwest to south; this may have been due to shove by an ice-lobe in the Lake Simcoe basin, causing a decrease in pressure on the side of the drumlin away from the applied force, thus leaving an opening. The shape of the stratified deposits, moulded to the drumlin form, is best explained by this process. The undisturbed stratification makes it improbable that there was any readvance of the ice after the water-sorted material was deposited, or that there was any slumping.

Evidence of the origin of drumlins suggests the operation of both erosional and depositional processes. The theory of their formation through the erosion of pre-existing deposits is supported by the undisturbed stratified sediments making up part or all of the drumlins. In addition to those drumlins east of Orillia, already mentioned, a drumlin 2½ miles southeast of Sutton showed 10 feet of silty till overlying 15 feet of fine sand. An excavation in a drumlin 1 mile south of Bradford shows crossbedded sand overlain and underlain by a boulder-clay till (*See* Plate V). Evidence to support the depositional theory is more difficult to obtain, as the till comprising the main mass of a drumlin is structureless. A road cut in the top of a drumlin 5 miles east of Alliston shows two beds of sand parallel with the side of the drumlin (*See* Plate IV B), and suggests an accretion of till on top of each sand bed during repeated ice advances.

The formation of drumlins necessitates forward-moving ice, and may, in this way, bear some relationship to terminal moraines that may be formed at the margin of readvancing ice or at a stationary ice-front, but whether or not the drumlins were formed at a distance of some miles from the ice-front and under deep ice, as stated by Thwaites (25, p. 39), is debatable. The drumlins of Lake Simcoe map-area do not appear to bear any systematic relationship to terminal moraines. The Lake Simcoe moraine overlies drumlins without mutilating them, and the orientation of the drumlins is the same on both sides of the moraine. The drumlin fields in the southern part of the area are continuous almost to the Oak Ridges moraine. Drumlins around Lake Simcoe appear to be more influenced by the load in the ice and the load available for pick-up than they are by the ice margin. Drumlin fields are not found in the scour zone of the Precambrian area where the basal load was light, but when the glacier passed into regions of softer Palæozoic strata the basal load became so excessive, from both the rocks eroded and the drift picked up, that it was soon deposited. There appears to be no radial arrangement of the drumlins, as is so characteristic of those associated with the ice-lobe in the Lake Ontario basin.

Ice-block Ridges. Closely associated with ground moraine and indicative of stagnant ice are the fields of ice-block ridges. Like the drumlins, they occur in groups or fields. As topographical features they are not conspicuous and may escape notice on the ground, but show up strikingly in air photographs (*See* Plate VI). The ridges are either long, sinuous, or branching (*See* Plate VII A), or elliptical in plan. An individual ridge of the first type may have a length of 1,000 feet or more, but the elliptical variety has a major diameter of from 100 to 400 feet and a minor diameter of from 25 to 200 feet, and generally encloses a swamp or pond. In cross-section the ridges are semi-oval, with a maximum height of 8 feet and a width of about 100 feet. The ridges are more common in valleys and depressions, but are also found on slopes and occasionally on heights of land. Ice-block ridges may be closely related to kames, kettles, and crevasse fillings, but differ sufficiently to warrant special mention.

Several suggestions have been put forth to explain these interesting forms. They have been called terminal moraines, kettles, and crevasse fillings, but the ridges fit into none of these categories. They differ from annual terminal moraines in that the trend of the long ridges and the major axes of the elliptical ridges are in the direction of ice movement and, therefore, at right angles to the trend of terminal moraine ridges. They differ from kettles in that the elevation of the ground on both sides of the ridges is the same. Thwaites (25, p. 45) defines crevasse fillings as ridges of well-sorted gravel, sand, or silt, whereas these ridges are composed mainly of sandy till (*See* Table I, samples 47, 14) although ridges composed of silty or clay tills have been observed. Another suggestion is that the ridges were squeezed up between isolated blocks of ice. This would be possible, particularly if the drift were rich in clay. A final possibility is that the ridges were formed from material that slumped from isolated blocks of stagnant ice. Longitudinal cracks and meltwater crevasses would explain the reticulated pattern. By this theory, an appreciable amount of drift would have to be present on the surface of the ice during the final stages to prevent rapid melting and to furnish sufficient material to build the

ridges. Whatever the origin they undoubtedly represent stagnant ice conditions, and were the last deposits of the glacier.

Within the map-area, ice-block ridges are confined mainly to the Simcoe till plains. The largest fields are found north and south of Kempenfelt Bay; isolated patches occur north of Bass Lake kame moraine and near Keswick.

Terminal Moraines. These are ridge-like accumulations of drift built along the margin of the ice-front. Two such ridges, beginning abruptly near Lake St. John, extended southeasterly across Rama, Mara, and Eldon townships and mark temporary halts in the oscillating retreat of the ice-front within the map-area. The two moraines, lying close together, are here called the Lake Simcoe moraine. The younger of the two ridges is the less pronounced, and lies 1 mile to 2 miles northeast of the older moraine. Both are strong ridges, 20 to 40 feet high at the north end, but in the central and southern parts they are little more than isolated, irregular mounds distinguished with difficulty from ground moraine. Gaps in the moraines are frequent. The material is mainly a sandy to bouldery till, interbedded with lenses and pockets of stratified sediments.

The subdued topography and the stratified material suggest deposition in water, and this is substantiated by the position of the ice-front at the time of deposition. The moraine can be traced east of the map-area, extending south to Kirkfield and Fenelon Falls, to just south of Lindsay; therefore, the glacier had closed the Fenelon Falls outlet and raised the level of Lake Algonquin so that the ice-front formed the north shore of the lake. The elevation of the tops of the moraines varies from 740 to 800 feet, whereas the elevation of the Lake Algonquin water-plain was about 875 feet. Although the stratified material indicates that part of the moraine was formed of material carried forward in the ice and dumped into water at the ice-front, the main till mass of unsorted material signifies that, in part at least, the morainic ridge was actually shoved into place from drift plowed up by the advancing glacier.

The position of the ice-front west of Lake Couchiching is unknown, but a deltaic deposit of sand and gravel 5 miles west of Washago may indicate the margin at this stage. The absence of morainal ridges in the rock-knob lowlands is a feature related to the bedrock, and signified glacial scouring rather than deposition.

Associated with these morainic ridges are deltaic and kame deposits. Between Lake St. John and Dalrymple Lake, stratified deposits of sand and gravel interrupt the till ridges and mark a delta left by streams that emerged from tunnels in the ice. North from the moraines, these sand and gravel deposits merge into an esker. However, this delta, unlike the more resistant material in the moraines, was in part reworked by waves during lower stages of Lake Algonquin, and is mapped with the lacustrine deposits. South of Canal Lake, Logans Hill forms a high ridge in direct line with the moraine. The hill is composed of stratified sand and gravel, and represents a kame deposit at the mouth of a glacial stream.

A long stand of the ice-front is marked by the kame moraine north of Barrie. This deposit consists mainly of stratified sand and gravel, and is described in the section dealing with glacio-fluvial deposits.

MECHANICAL ANALYSES OF TILLS

Mechanical analyses were made of one hundred and twenty samples of tills and other material collected by the writer. Sampling was done to show, mainly, the differences of material, with the hope that an analysis would serve to classify a till. The following results give an account of mechanical analysis as an aid to the geologist without recourse to chemical or mineralogical investigations. In addition to sampling of undoubted tills, material was collected from drift whose origin was doubtful, as well as sand, silt, and clay of glacio-lacustrine and glacio-fluvial deposits.

The tills are here divided into eight types (Table I), with an arbitrary division based on the percentage of the various components—gravel, sand, silt, and clay. All material in each sample above 1 millimetre in diameter is considered as gravel; the remainder of the sample is subdivided into sand (0·050 mm. to 1·00 mm.), silt (0·005 mm. to 0·050 mm.), and clay (below 0·005 mm.). The term clay as here used refers to grain size only and not to the groups of true clay minerals. Type 9 includes those samples that by their stratification are known to be lacustrine or glacio-fluvial in origin, and are included to show the gradation between water-laid material and tills that are high in sand, silt, or clay.

Table I shows the results of the mechanical analyses together with the sorting and a brief field description of the tills. The numerical value of the 'sorting' represents the degree of sorting or the spread of the size distribution or cumulative curve. Trask (26, p. 71) defines the coefficient of sorting as $\sqrt{Q_1 / Q_3}$ where Q_1 and Q_3 are the first and third quartiles, determined as the diameter values corresponding to the intersection of the curve with the 25 and 75 per cent lines respectively. The closer Q_1 and Q_3 are to each other the better is the sediment sorted. According to Trask, if sorting is less than 2·5 the sediment is well sorted.

The clay tills, type 1, are those tills containing more than 50 per cent clay, about 25 per cent silt, minor amounts of sand, and little or no gravel. They are found principally in the southern part of the area, and were probably derived largely from a lacustrine clay picked up and redeposited by the ice without much transportation and mixing. The sorting varies between 2·7 and 6·6. The shape of the curves and the position of the samples when plotted on the trilinear chart in Figure 2 differ little from those of varved clay of type 9.

The type 2 tills contain about 30 per cent each of sand, silt, and clay. They differ from type 1 in the increase in sand and gravel content at the expense of clay. These tills are widely scattered, and indicate a derivation from a mixture of granitic and calcareous drift with overridden lacustrine deposits. Sorting is poor, varying from 4·1 to 6·6. In the field, these would be classified as clay tills, or boulder-clay tills if studded with boulders.

The type 3 tills are analogous to those of type 1, with silt replacing clay. Generally they contain more gravel, and silt forms about 50 per cent or less of the till. These are found mainly in the southern part of the area, and indicate a derivation, in part, from lacustrine deposits high in silt but more varied and mixed than type 1. Samples 12 and 84 were taken from tills that overlie lacustrine deposits. Sorting is good (2·2) to poor (4·7). The field classification for this type was silty or clay till.

TABLE I

Mechanical Analyses of Drift Showing the Percentage Composition of Gravel, Sand, Silt, and Clay

Type	Description and colour symbol[7]	Sample[1] number	Location and field description	Depth below surface	Percentage				Sorting[6]
					Gravel[2]	Sand[3]	Silt[4]	Clay[5]	
				Feet					
1	Clay tills.	57A	Massive blue-grey till with few stones 6 inches below contact of overlying brown, sandy till.	6	1	7	30	62	2·7
		T-2*	Lowest till from the Illinoian (?) complex, Don Valley Brickyards, Toronto. Light to medium grey in colour.	90	1	8	24	67	2·7
		46	Cut-bank of stream, 5 feet above creek and 4 feet below contact with a sandy to gravelly till. Blue-grey in colour.	15	1	8	29	62	2·9
		58	Blue-grey till exposed in creek bed.....	1	3	10	27	60	3·1
		85	1- to 2-foot layer overlain by sand and gravel and underlain by a grey-brown sandy till. A few small pebbles in the till. (*See* 85A below.)	4	0	20	22	58	6·6
2	Till having about equal proportions of sand, silt, and clay; low gravel.	5A	Blue-grey till, overlain by a brown gravelly till. (*See* 5 below.)	7	7	41	32	20	4·1
		T-3*	Brown, weathered till from excavation of Chemistry Building, University of Toronto.	8	4	24	39	33	4·5
		86	Near top of drumlin, overlain by 16 feet of sand and gravel. Hard, compact, grey till.	17	8	27	40	25	4·7
		27	Compact grey-brown till from low ridge of terminal moraine.	4	5	37	35	23	4·8
		88	Brown till of ground moraine.....	6	11	29	40	20	5·0
		50	Grey-brown till of ground moraine. Very few boulders.	6	5	27	38	30	5·1
		38	Brown till of ground moraine. Pockets of sand in the till.	5	6	39	30	25	5·4
		81	Grey till from ground moraine in swale between two drumlins.	5	8	32	32	28	5·6
		18	Brown till with few stones. Overlain by 3 feet of sandy till.	4	2	31	30	37	5·6
		70	Brown till exposed in the Algonquin bluff.....	5	7	38	30	25	5·8
		52	Brown till exposed in cut-bank of creek. Overlain by 2 feet of lacustrine sand.	6	8	37	28	27	6·2
		84	Exposure in Lake Simcoe bluff. Till overlain and underlain by sand and gravel.	6	11	32	30	27	6·5
		76	Brown till of ground moraine.....	5	5	30	30	35	6·6

TABLE I—*Con.*

Mechanical Analyses of Drift Showing the Percentage Composition of Gravel, Sand, Silt, and Clay—Con.

Type	Description and colour symbol[7]	Sample[1] number	Location and field description	Depth below surface	Percentage				Sorting[6]
					Gravel[2]	Sand[3]	Silt[4]	Clay[5]	
				Feet					
3	Silty tills with moderate amounts of sand and clay; low gravel.	T-4*	Grey, unweathered till from excavation of Chemistry Building, University of Toronto, 3 feet below sample T-3.	11	1	34	52	13	2·2
		12	Grey-brown till from cut-bank in creek, overlying stratified silt and clay.	5	9	20	50	21	2·8
		73	Brown till exposed in railway cut through drumlin-like ridge. Till overlain by 4 feet of gravel.	6	4	19	50	27	3·0
		80	Brown till of ground moraine.....	10	7	16	46	31	3·6
		87	Brown till exposed in road-cut through the Algonquin bluff.	7	7	19	41	19	3·6
		91	Grey till on the side of a drumlin; overlying stratified sand.	10	5	25	43	27	3·8
		79	Grey till exposed in road-cut through the Algonquin bluff.	5	7	19	43	31	4·2
		82	Grey-brown till with few pebbles.....	5	1	18	42	39	4·7
4	Gravelly tills with moderate amounts of sand and silt; minor clay.	8	Compact till exposed in a cut-bank of creek through terrace of Lake Algonquin. Till overlain by 10 feet of sand.	13	15	38	38	9	3·6
		85A	Grey-brown till overlain by 1½ feet of clay till. (*See* 85 above.)	7	12	37	40	11	4·2
		24	Grey-brown, bouldery till in road-cut through Algonquin bluff. Overlain by 3 feet of sand.	10	16	37	34	13	4·4
		17	Grey-brown, bouldery till in a lower Algonquin bluff...	5	17	40	29	14	5·2
		51	Blue-grey till in a newly dug well. Till is compact and overlies a blue-grey, loose sandy till. (*See* 51A below.)	29	11	45	21	23	6·0
		3	Purplish till derived from the red and green shales of the basal Ordovician strata.	5	25	38	29	8	6·1
		31	Grey-brown, bouldery till of ground moraine. Overlain by 2 feet of varved clay.	4	22	39	23	16	6·2
		4	Grey till in the stoss end of a drumlin.....	10	22	33	32	13	6·4
		16	Grey-brown till in the lee end of a drumlin.....	4	22	31	30	17	6·8
		5	Yellow-brown till overlain by lacustrine clay and overlying a blue-grey till. (*See* 5A above.)	5	24	41	20	15	7·0
		T-1*	Lowest till (Nebraskan or Kansan?) underlying the interglacial Toronto formation, Don Valley Brickyards, Toronto.	144	19	26	23	32	9·6

		6	Grey till exposed in bluff of a lower Algonquin bluff. Overlain by varved clay.	10	33	26	21	20	20·0
5	Sandy tills with moderate amount of silt; minor clay and gravel.	83	Grey till in a Lake Simcoe bluff on Fox Island. Till contains pockets of sand and gravel.	12	9	45	39	7	2·1
		53	Grey-brown till of ground moraine	4	8	47	37	8	2·5
		25	Loose, brown, sandy till of ground moraine	5	6	44	41	9	2·6
		30	Brown, sandy till from top of a drumlin	4	3	50	39	8	2·6
		15	Brown, sandy till from undulating ground moraine	5	10	57	25	8	2·9
		62	Grey-brown, sandy till overlain by ice-contact sand and gravel.	6	8	60	21	11	3·0
		10	Loose, brown, sandy till of ground moraine	5	9	53	29	9	3·1
		2	Loose, grey-brown, sandy till of ground moraine	8	8	55	28	9	3·2
		65	Loose, grey-brown, sandy till of ground moraine	7	10	58	21	11	3·3
		49	Grey-brown, sandy till of ground moraine	6	7	51	31	11	3·5
		14	Brown, sandy till from area of ice-block ridges	4	7	55	31	7	3·6
		75	Grey-brown, sandy till near base of Algonquin bluff	15	9	52	27	12	3·7
		66	Grey-brown, sandy till in a slight rise of ground moraine surrounded by outwash.	5	8	55	25	12	3·9
		71	Grey-brown, massive, compact till from a 40-foot exposure in a cut-bank of creek. (*See* 71A below.)	20	7	55	23	15	4·0
		54A	Blue-grey till in bank of creek. Overlain by bouldery, sandy till. (*See* 54 below.)	6	6	45	32	17	4·2
		71A	Blue-grey, massive, compact till from a 40-foot exposure in a cut-bank of creek. (*See* 71 above.)	35	6	54	23	17	4·7
6	Sandy tills with moderate amount of silt; minor clay and gravel content slightly higher than type 5.	33	Loose, brown, sandy till in kame area. No stratification or sorting.	8	11	68	16	5	2·3
		72	Compact, sandy till of ground moraine. Overlain by 2 feet of gravel.	6	11	64	15	10	2·8
		11	Loose, brown, sandy till in road-cut in the Algonquin bluff.	7	13	54	24	9	2·9
		59A	Compact, brown, sandy till containing lenses of sand and gravel. (*See* 59 below.)	14	12	58	21	9	2·9
		69	Grey-brown, sandy till of ground moraine	7	12	61	18	9	3·0
		63	Grey-brown, sandy till of ground moraine	12	12	59	18	11	3·1
		34	Grey-brown, sandy till of ground moraine	5	11	57	22	10	3·3
		48	Loose, grey-brown, sandy till of ground moraine	4	11	56	23	10	3·4
		26	Massive, grey-brown, sandy till in road-cut in Algonquin bluff.	6	15	49	27	9	3·6
		51A	Loose, blue-grey, sandy till in a newly dug well. Till underlies a compact boulder-clay till. (*See* 51 above.)	32	12	53	22	13	3·7
		47	Loose, brown, sandy till in an ice-block ridge	4	11	55	22	12	3·8
		32	Grey-brown till from the lee of a drumlin	4	17	51	22	10	3·8
		42	Grey-brown, sandy till of ground moraine	6	15	52	23	10	3·8
		7	Loose, brown, sandy till of ground moraine	6	18	48	25	9	3·9
		13	Grey-brown, sandy till of ground moraine	6	14	46	29	11	3·9

TABLE I—*Conc.*

Mechanical Analyses of Drift Showing the Percentage Composition of Gravel, Sand, Silt, and Clay—Conc.

Type	Description and colour symbol[7]	Sample[1] number	Location and field description	Depth below surface	Percentage				Sorting[6]
					Gravel[2]	Sand[3]	Silt[4]	Clay[5]	
				Feet					
		23	Grey-brown, sandy till of ground moraine. Contains many boulders.	7	15	45	29	11	4·0
		60	Loose, grey-brown, sandy till of ground moraine.....	5	11	51	27	11	4·0
		57	Compact, sandy till in wave-cut terrace of Lake Algonquin. Overlies a clay till. (*See* 57A above.)	5	14	48	27	11	4·1
		28	Loose, brown, sandy till of terminal moraine.....	4	13	50	26	11	4·3
		56A	Reddish brown, sandy till in wave-cut terrace of Lake Algonquin. Overlain by a grey-brown till. (*See* 56 below.)	6	11	50	27	12	4·3
		29	Loose, brown, sandy till of ground moraine.....	4	18	45	26	11	4·5
		56	Grey-brown, sandy till overlying a reddish brown, sandy till. (*See* 56A above.)	4	15	44	28	13	4·7
		19	Grey-brown, sandy till of ground moraine. Overlain by lacustrine sand and gravel.	4	18	44	27	11	4·8
		55	Grey-brown, sandy till in wave-cut terrace of Lake Algonquin.	5	15	43	26	16	4·8
		77	Compact, grey-brown, sandy till of ground moraine.....	6	14	45	25	16	5·0
7	Gravelly tills with high amounts of sand, moderately low silt, and low clay.	44	Loose, brown, gravelly till of ground moraine.....	6	21	58	15	6	3·2
		59	Loose, brown till containing lenses of sand and gravel in wave-cut terrace of Lake Algonquin. (*See* 59A above.)	8	22	60	13	5	3·2
		45	Loose, brown till of ground moraine.....	4	22	56	16	6	3·4
		22	Loose, brown till of wave-cut terrace of a lower Algonquin lake level.	4	19	52	22	7	3·5
		21	Blue-grey, sandy till in bed of North Creek. Overlain by 40 feet of varved clay.	1	20	53	16	11	3·5
		67	Compact, grey-brown, sandy till of ice-contact deposit. Overlain and underlain by stratified sand.	7	32	51	14	3	4·5
		9	Grey-brown, sandy till exposed in a road-cut in the Algonquin bluff.	15	23	47	18	12	5·2
		54	Bouldery, sandy till in bank of Hawkestone Creek. Overlies a blue-grey, sandy till. (*See* 54A above.)	4	41	38	17	4	5·2
8	Sandy tills, low in gravel, silt, and	74	Loose, brown, sandy till of ground moraine.....	13	7	79	8	6	1·9
		61	Brown, sandy till in the Algonquin bluff.....	5	6	76	11	7	2·0
		35	Loose, brown, sandy till of ice-contact deposit.....	6	9	71	14	6	2·1

	clay.	41	Compact, sandy till in kame area, 3 feet below contact of stratified sand and gravel.	14	5	72	16	7	2·2
		64	Loose, brown, sandy till of ice-contact deposit.....	6	7	65	20	8	2·3
		1	Loose, brown, sandy till of ground moraine.....	6	9	69	16	6	2·3
		37A	Brown, sandy till of ice-contact deposit. Overlain by stratified sand.	15	7	71	14	8	2·4
		68	Loose, sandy till in area of outwash deposits.....	5	2	69	21	8	2·4
		39	Loose, brown, sandy till of ice-contact deposit. Till overlies 15 feet of stratified sand. (*See* 39A below.)	9	8	65	19	8	2·6
		36	Compact, grey-brown, sandy till in cut-bank of creek...	20	9	65	16	10	2·9
9	Stratified sand, silt, and clay.	39A	Stratified, crossbedded, fine sand. Overlain by a loose, brown, sandy till. (*See* 39 above.)	11	0	84	13	3	1·3
		78	Stratified, white sand from ice-contact deposit.....	6	0	73	27	0	1·4
		43	Light grey, fine sand of ice-contact deposit.....	4	0	94	6	0	1·5
		40	Light grey, finely crossbedded silt of kame deposit.....	5	0	19	78	3	1·5
		20A	"Summer" layer of varved clay. (*See* 20 below.).....	10	0	2	81	17	1·6
		37	Grey, stratified, fine sand of ice-contact deposit. Underlain by a sandy till. (*See* 37A above.)	13	0	82	15	3	1·6
		89	Grey-brown, lacustrine silt.....	4	0	14	71	15	1·8
		92	Grey-brown, stratified silt.....	4	0	29	60	11	2·1
		90	Lake Algonquin varved clay.....	7	0	9	30	61	2·8
		20	"Winter" layer of varved clay. (*See* 20A above.).....	10	0	15	25	60	3·7

[1] Numbers refer to samples collected by the author in the field.
[2] Gravel includes all particles above 1·0 mm. diameter.
[3] Sand includes particles between 0·050 and 1·0 mm. diameter.
[4] Silt includes particles between 0·005 and 0·050 mm. diameter.
[5] Clay includes all particles less than 0·005 mm. diameter.
[6] For explanation of sorting refer to text.
[7] For colour symbols refer to graph and map.
* Four samples from the Toronto area are included in the table for comparison.

Tills commonly found near the border of the Precambrian Shield are those of type 4. These tills are generally stony, as indicated by the high gravel content of about 20 per cent, which separates them from the type 3 tills. The proportions of sand, silt, and clay vary somewhat, with sand usually higher than either silt or clay. Sorting is generally poor, varying from about 4·0 to 20·0. In the main, these tills are derived from granitic rocks or deposits made up of granitic detritus.

Tills of types 5, 6, and 7 are widespread on the west side of Lakes Couchiching and Simcoe. In the field, they were classified as sandy tills with a loose or compact texture. The texture depends largely on the clay and silt content; those low in these two end products were loose and friable; those with a combined clay and silt content of about 40 per cent or higher were generally massive and compact. The sand content of these three types is uniformly constant, generally about 50 per cent. The amount of gravel increases from types 5 to 7, with a corresponding decrease in combined silt and clay. The tills occur mainly as ground moraine, and are probably derived largely from granitic rocks, with some mixing of limestone or deposits derived from limestone. Water action may have removed some of the clay prior to deposition. Sorting is good to poor in all three types, with type 5 the best sorted and type 7 the least.

Type 8 tills are those closely related to the stratified sands, silts, and clays. They are generally classified in the field as loose, very sandy tills, or as sand and stones. They are closely associated with glacio-fluvial deposits such as ice-contact deposits, kame moraines, and outwash in the southwestern part of the area. They indicate a considerable amount of water action that flushed the finer particles out prior to deposition. The tills consist of 65 per cent or more of sand, about 15 per cent silt, and the balance equally divided between clay and gravel. Sorting is very good, and corresponds closely to water-deposited material, but with a smaller variation in the spread of sorting.

Figure 3 gives the cumulative curves of a representative sample from each of the nine types, and shows the results of Table I in graphic form. The curves move across the chart fairly smoothly, with a gradual transition from one extreme to another. The type 1 curves of the samples consisting mainly of clay are concave downward, and the curves flatten through types 2 and 3 to type 4, which represents least sorted material. From type 4 the shape of the curves changes to a concave-convex form culminating in type 8. This latter type shows a close relationship to type 9, the water-deposited material.

It will be noted that all the curves are of the same general shape—concave downward in the coarser particle divisions and convex downward in the finer particle divisions. The curves of all soils in which the bulk of material falls into the divisions in the intermediate diameters, and contains minor amounts of larger and smaller diameter particles, will conform to this shape. Legget (17, p. 541) has noted that the downward concavity is a marked feature of curves for glacial drift. From a consideration of soil analysis charts based on a semi-logarithmic scale, it is evident that all curves of natural soil samples, either glacial, fluvial, or lacustrine, will be, to a lesser or greater degree, concave-convex in form, if the analysis is made, where possible, to the limits of the grain sizes on the chart, or carried beyond them. A sample of uniform grain size, say 0·060 mm.

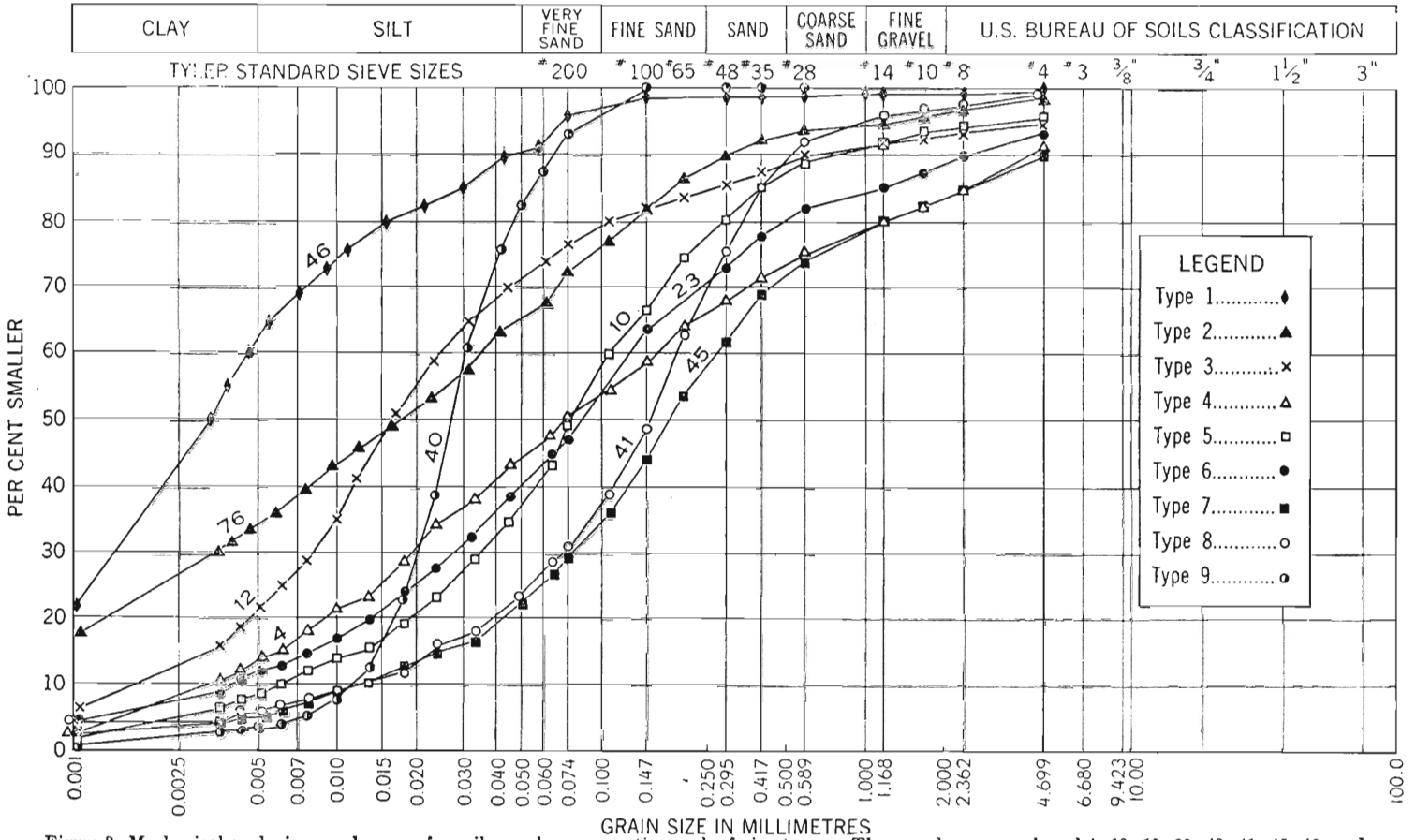


Figure 3. Mechanical analysis record curves for soil samples representing each of nine types. The samples are numbered 4, 10, 12, 23, 40, 41, 45, 46, and 76 respectively.

diameter, would give a vertical straight line, but such a material would not exist in nature, as particles of smaller and larger diameters are always present, and a curve of such a sample would be concave-convex. Type 9 in Figure 2 illustrates the steeply graded curve of such a well-sorted natural material.

A common till is that which gives a curve deviating only slightly from an oblique straight line. The curves for types 2 and 4 represent this form in which there is a nearly uniform increase in the grain size of the particles, but sufficient deviation to give a slightly concave-convex curve. Another curve that appears to have no concavity is type 1, the clay tills. However, the last two points plotted in the clay division on the left of Figure 2, which give particle sizes of 0·0035 and 0·001 mm., are those for 2- and 24-hour readings respectively. If hydrometer readings between 2 and 24 hours and beyond 24 hours had been taken the left part of the curve would show the usual convex-downward form. A curve that is rarely seen in tills is one that appears convex downward only. It would represent a material composed largely of coarse particles with decreasing amount of finer particles. A coarse gravel would probably give this type of curve.

Polymodal curves giving several secondary maxima are common, particularly for the poorly sorted tills of types 2 and 4. As Krumbein (16, p. 390) has pointed out, this irregular distribution of different sized particles in the tills may be due to a mixture of several materials and contributed by the drift picked up by the ice in its advance. The writer has found that irregularities are rare in well-sorted material. Other factors responsible for irregularities are: (1) defective sieves; (2) accumulation of material on the hydrometer; readings that give a grain size of approximately 0·060 mm. are those taken after the hydrometer had been immersed for 120 seconds and always gave a reading that was low; (3) disintegration of an igneous pebble, which results in a higher percentage of gravel or sand.

The grouping of the samples analysed is more clearly shown on a trilinear chart (*See* Figure 2). The proportions of sand, silt, and clay-sized particles are plotted by considering all material in each sample below 1 mm. in effective diameter as 100 per cent, and then subdividing this into sand, silt, and clay-sized particles. The chart shows a broad curved zone into which most of the samples fall. This zone begins in the sand corner, sweeps across the sandy loam division, broadens out in the loam and clay loam parts, and narrows again high in the clay part near the line of zero sand. This zoning is similar to that obtained by Legget (17, p. 552) in his analyses of the drift at the Shand Dam. Fifty-five per cent of the points fall within the sandy loam division, 13 per cent in the clay loam, and 9 per cent in the loam, with the balance falling near the lines of zero clay and zero sand. Tills of types 5, 6, 7, and 8 are closely grouped and fall almost entirely within the sandy loam division. Tills of types 2, 3, and 4 are more widely spread within the loam and clay loam divisions. The clay tills form a group high in the clay division. This chart shows the close relation of the clay tills to the varved clays on the one hand, and of the very sandy tills to water deposited sand on the other.

The specific gravity of thirty-seven samples was determined by means of a Le Chatelier flask, using a 50-gramme sample. The values obtained varied between 2·70 and 2·77, with an average of 2·73 for all samples. The tills with high gravities were generally found close to the border of

the Canadian Shield and probably result from the presence of the heavier minerals such as magnetite, augite, hornblende, etc., of the igneous rocks. Those tills high in clay were generally found to have a slightly higher specific gravity than tills high in sand. This is due to the abundance of impure limestone rock-flour in the clay tills and to the high percentage of quartz and feldspar grains in the sandy tills.

TILL OF THE GLACIAL DEPOSITS

Till is a direct deposit of the ice-sheet, generally unsorted, but may contain pockets or lenses of stratified sediments (*See* Plate VII B). It is an accumulation of debris and attrited bedrock collected at or near the base of the ice during its advance. This load may be deposited beneath the ice, where the drift readily adheres to the underlying material to form ground moraine; carried or pushed to the front of the ice to form terminal moraine; or left in superglacial or englacial positions in stagnant, melting ice to form, eventually, ablation moraine or ice-block ridges.

The terms 'superglacial' and 'englacial', as used in this report, refer to position in the ice during the final stages of deglaciation. It is fully realized that all drift was originally subglacial, as there were no nunataks or high valley walls to contribute material as in mountainous regions. In the writer's opinion, it is quite possible for subglacial drift to be moved up from the base of the ice by shearing and overriding, and in this way to occupy an englacial position. Towards the final stages of melting some of the material would become exposed on the surface of the ice and thus occupy a superglacial position.

The term 'boulder clay' is not here used as synonymous with till, but is reserved for the type of till that, as its name suggests, is a mixture of bouldery and fine particles. 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, silty, sandy, gravelly, or stony.

The properties of till are affected by several factors. It is a widely accepted fact that, in general, the material picked up by the glacier is soon deposited and thus the nature of the ground over which the ice passed is reflected in the till. The influence of bedrock is well illustrated along the border of the Precambrian and Palæozoic rocks. In fact the contact could well be plotted without recourse to any outcrops. In the rock-knob lowlands the till is loose, sandy, and reddish in colour, and is non-calcareous except for small areas lying in the lee of inliers of Ordovician strata. Within a mile or two, and sometimes less, south of the contact, within the area of Palæozoic rocks, the till changes, becoming more compact, calcareous, and grey in colour, although still retaining a high percentage of sand. Farther south, the till loses much of its sand content and finally becomes the typical, compact, calcareous, grey-brown to grey-blue till.

Another contributing factor is the nature of the unconsolidated material picked up by the ice. In all probability the load of material picked up during the last readvance of the Wisconsin glacier was as varied as the present drift; consequently, the till shows great lateral variation. It may be clay, silty, sandy, or gravelly, depending on which type of deposit was overridden by the ice.

Other factors affecting the properties of the till are: distance the drift was transported, position in the ice, compaction, and the part played by meltwater. Stony tills are usually found where bedrock is close to the surface and the material suffered little transportation. Material carried subglacially suffered more abrasion, and hence yielded a till richer in clay than englacial material. Some of the compact 'hardpan' tills may have been tills of earlier deposits that were overridden and compacted under a load of very thick ice, or the till may have been cemented by calcareous material deposited from the water present in the drift. Water played an important part in flushing the finer particles out of the drift both during transportation and deposition, thus leaving in places a sandy till.

The amount of clay present in the tills determines largely their texture and structure. Tills with less than 10 per cent clay are generally loose and friable; slumping is prevalent in steep exposures. Tills with more than 10 per cent clay are massive, with a blocky structure; vertical cliffs composed of till with a high proportion of clay will stand for long periods without slumping.

The proportions of stones in till vary from almost nothing in clay tills to well over 50 per cent in stony tills. Stony tills are common where bedrock is exposed or only thinly covered. The softer stones may survive repeated transportation if held in a clay matrix. Limestone boulders predominate over granite only where limestone is exposed at the surface. The proportion of granite to limestone boulders increases towards the south of the map-area. The abundant igneous boulders that litter the surface, particularly in the Simcoe till plains, is thought to be due to their superglacial and englacial position in the ice during transportation, a position brought about by basal ice overriding stagnant or heavily loaded ice, and then left on top of the basal load when the glacier melted. A few of the boulders that lie on the ground show the effects of glacial erosion in their soled, faceted, and polished surfaces; most of them, however, have shapes inherited from the parent rock, bounded by joint and cleavage surfaces in the gneisses, schists, and limestones, or angular surfaces in the granites. These unaltered shapes point to either little transportation, transportation englacially, or crushing during transportation without subsequent abrasion. The shapes of the stones in the till are infinitely varied, ranging from well-rounded forms indicative of water action only, and angular fragments showing no abrasion, to well striated, polished, and soled forms. The efficiency of ice as an agent of transportation is well shown by the size of the boulders, many of which are more than 8 feet in diameter.

The colour of the unweathered tills is determined mainly by the colour of the bedrock from which the tills were derived. Granites give a pinkish or reddish colour; green and red shales give a purplish colour; limestones give a light grey colour; and black or grey shales a dark grey colour. Colour is also affected by oxidation of the till, which varies in depth from 2 feet to about 25 feet. Topographical position and permeability of the material are determining factors in the depth of oxidation. The upper, oxidized part of calcareous tills is brown to grey-brown, whereas the unoxidized zone is grey to blue-grey. The colour change is distinct, and has often led to the classification of the till into two stages of glaciation. The border between the two colours is generally irregular, and follows the elevation of the water-table; the distance from the surface increases on the

hills, and decreases in the depressions. It corresponds so closely with the position of the water-table that it is inferred that the depth of oxidation is controlled by this position. This change of colour has been noted in many types of deposits, including silts and varved clays. In swamps, where the water-table reaches the surface, the blue-grey colour has been seen at a depth of 1 foot.

Mechanical analyses of colour-differing till, one of a sample from above the colour line and the other from a sample below this line, showed almost no difference. In the hydrometer analysis to determine the grain size of the material passing the 200 sieve, it was noted that the megascopic particles of both colour varieties of the till were identical in colour; the brown and blue shades were confined to the microscopic, clay-sized particles. After 2 hours there was no change in colour of the suspension and after 24 hours only a slight decrease in intensity.

Figure 4 shows the cumulative curves for three sets of colour-differing tills. The solid lines in all three sets represent samples of the grey-brown till above the colour line, and the broken lines represent the blue-grey till from below this line. The curves for each set are almost identical with the widest variation in the silt content of samples 93 and 93A. The specific gravity was determined for only one set; 2·714 for the grey-brown till of sample 94, as compared with 2·724 for the blue-grey till of sample 94A.

For comparison, the results of the mechanical analyses are tabulated with the first sample of each set the upper till.

Sample No.	Percentage				Sorting
	Gravel	Sand	Silt	Clay	
71	7	55	23	15	4.0
71A	6	54	23	17	4.7
93[1]	5	53	30	12	3.0
93A	6	49	27	18	4.2
94[2]	20	52	18	10	3.9
94A	21	51	17	11	4.6

[1] Location not shown on map. Sample from creek bank, lot 7, con. XII, Gwillimbury W. tp.
[2] Location not shown on map. Sample from road-cut on No. 12 highway, lot 14, Tay tp.

It will be noted that the upper tills have more sand, less clay, and are better sorted; there is more gravel in one set and less gravel in two sets of the upper tills; the amount of silt is the same in one set, but greater in two sets of the upper tills. Goldthwaite (11, p. 7) found that "the upper and lower till layers differ markedly as to grain size distribution, with the upper having generally less silt and clay". His reasons for the twofold layers of till are: (1) discoloration of the surface part down to the water-table; and (2) differences between englacial and subglacial deposition. The latter might apply to tills with a colour difference within 5 or 6 feet of the surface, that is, within the zone of ablation moraine, but probably not where the colour line is deeply buried. The first reason is the more plausible, with the discoloration due to oxidation. The greater proportion of clay in the lower till samples may be due to migration downwards of the finer

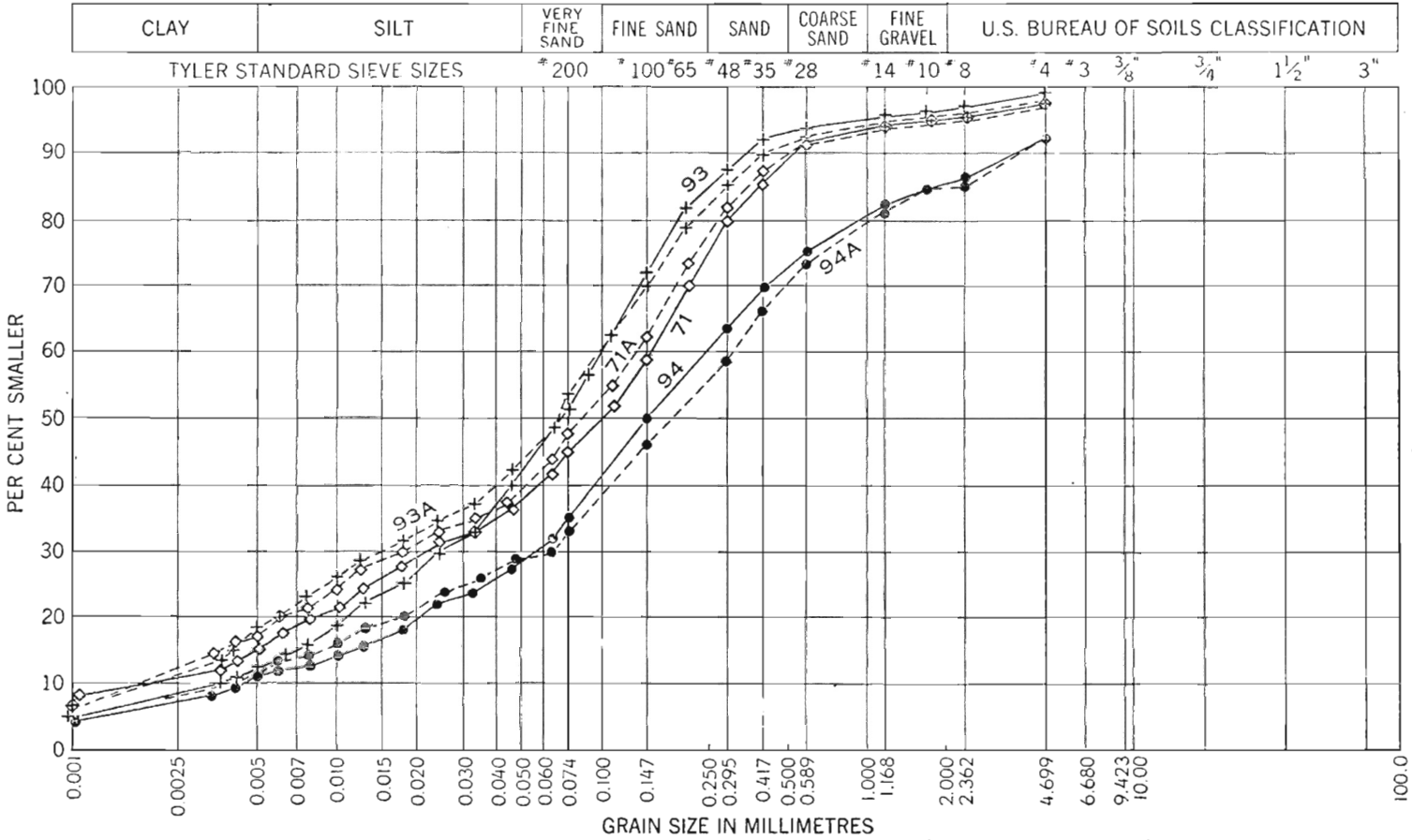


Figure 4. Mechanical analysis record curves of three sets of tills, each set of which is similar lithologically but differs in colour; the sets are numbered 71 and 71A, 93 and 93A, and 94 and 94A respectively.

particles by percolating water or to longer abrasion of the lower till. Sampling of the till in a vertical section at 1- or 2-foot intervals would show whether or not there is a steady increase of clay towards the base of the till.

The glacial, glacio-fluvial, and glacio-lacustrine deposits within the map-area are features of the latest, or Mankato, substage of the last, or Wisconsin, stage of glaciation. The stratigraphy of the deposits in the Lake Simcoe area differ remarkably from the stratigraphy in the Toronto area, with the Oak Ridges moraine forming the dividing line. In the Toronto area, erosion and deep excavations expose glacial and interglacial stages that preceded the Wisconsin. In places three or four distinct tills, differing remarkably in structure and material, are found in vertical cuts, and may, on the one hand, represent only minor fluctuations of the ice-front, or, on the other, may represent substages of the Wisconsin, although the evidence of substage intervals is generally lacking. In the Lake Simcoe area, the Mankato drift is in places uniform and thick; stream cuts have shown drift more than 50 feet thick without any change in lithology. Stream erosion is not deep enough to expose earlier glacial or interglacial deposits, although indirect evidence from well drillers confirms the logical assumption that they are present. Fragments of bark and leaves in sand beds were encountered at a depth of 148 feet in a well drilled 5 miles north of Orillia. The elevation of the top of the well is 968 feet above sea-level. A well driller reported a cedar log 2 feet in diameter at a depth of 60 feet, below which was sand containing fossil shells to a depth of 180 feet. The elevation of the top of this well, in Coldwater Valley 8 miles west of Bass Lake, is 775 feet.

There are no recognizable substages of the Wisconsin in the Lake Simcoe area. Although till is in places overlain and underlain by stratified deposits, these are usually found in ice-contact faces, and are taken to represent minor fluctuations in the ice-front. At several places, overlying tills differ lithologically from underlying tills, but hesitation is felt in placing the lower tills in the Cary, Tazewell, or Iowan substages because of the lack of interval evidence. Leached zones, loess, boulder pavement, and plant or animal fossil remains have not been found in the deposits underlying the surface tills, although it is possible that during at least one of the substage intervals the ice retreated beyond this region, and that the interval evidence, which would be less well developed than farther south, was removed by subsequent readvance of the glacier.

Figure 5 shows the cumulative curves of four sets of tills for which the localities are shown on Map 993A and the results of mechanical analyses in Table I. In the field, these tills exhibited differences in structure, texture, and composition. The contact between the two tills of samples 57 and 57A is sharp, and this set shows the widest divergence in composition of all four sets. This may be due to a change in direction of ice movement, or else may indicate a substage, although the underlying till is unleached. There is no sharp contact between the tills of samples 59 and 59A, and as the face of the exposure showed lenses and pockets of sand, these tills probably represent variations in the composition of the same deposit. In the tills of samples 51 and 51A, no sharp contact was noted, and the top 29 feet of till was a uniform mass that graded into a loose, sandy till at about 30 feet. Whether or not they represent tills of different

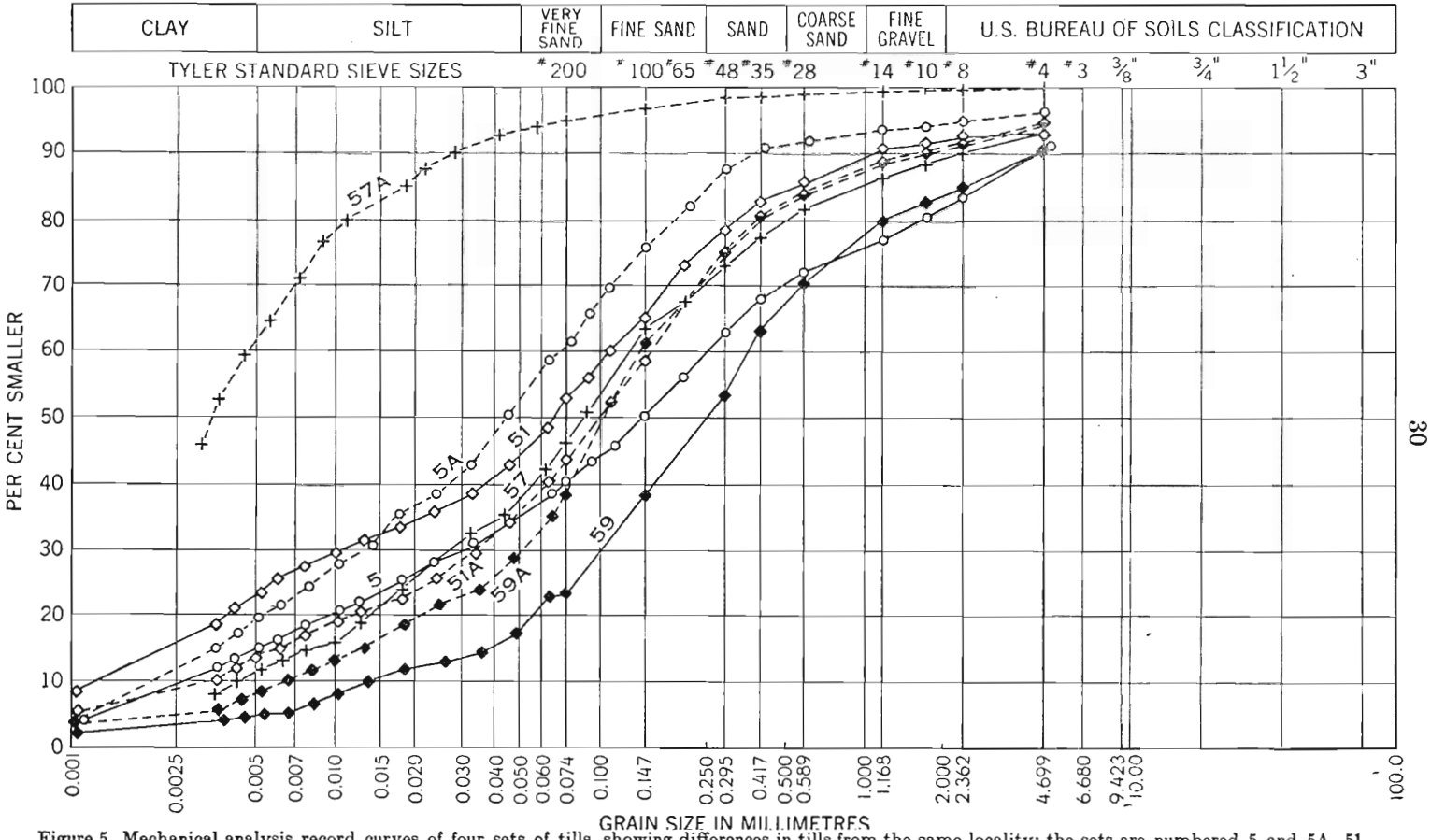


Figure 5. Mechanical analysis record curves of four sets of tills, showing differences in tills from the same locality; the sets are numbered 5 and 5A, 51 and 51A, 57 and 57A, and 59 and 59A respectively.

ages or different phases of the same age is problematical. The upper of the two tills of samples 5 and 5A contained more stones than the lower, and the two tills differed in colour, the upper grey-brown and the lower blue-grey, but they may represent different phases of the same till.

For comparison, the results of the mechanical analyses of the four sets are given below.

Sample No.	Depth	Percentage				Sorting
		Gravel	Sand	Silt	Clay	
	Feet					
57	5	14	48	27	11	4.1
57A	6	1	7	30	62	2.7
59	8	22	60	13	5	3.2
59A	14	12	58	21	9	2.9
51	29	11	45	21	23	6.0
51A	32	12	53	22	13	3.7
5	5	24	41	20	15	7.0
5A	7	7	41	32	20	4.1

The unusual point about this group is that the lower tills in each case show the better sorting, whereas, in the comparison of tills that were the same lithologically but differed in colour (*See* Figure 4), the upper tills were better sorted. In both groups the lower tills contained more clay, with the exception of sample 51A. These results are inconclusive, for although they show differences in sorting and content of gravel, sand, silt, and clay, the composition of tills varies so remarkably over short distances that mechanical analysis alone cannot be relied upon to distinguish their age relationships.

DEPOSITS OF GLACIO-FLUVIAL ORIGIN

In this category are included those accumulations of glacial drift not deposited directly by the ice, but carried, assorted, and deposited by meltwater streams in immediate contact with the ice or at a short distance beyond its borders. Those in contact with the ice are often termed ice-contact deposits and include kame moraines, kames, kame terraces, and eskers. Outwash is the stratified material deposited a short distance from the ice margin.

Kame Moraine. The kame moraine deposit in the map-area, here called the Bass Lake kame moraine[1], marks a fairly long halt during the retreat of the glacier. The moraine covers an area 15 miles long with a maximum width of 5 miles. Apparently it does not continue east of Bass Lake, but near Orr Lake, to the west, rolling sand hills probably mark its extension in that direction.

Rolling topography and uneven skyline are characteristic of the Bass Lake moraine, in which kettles and knolls predominate. The change from

[1] Kame moraine is here used as a particular kind of terminal moraine. The term is useful to designate those moraines composed of sand and gravel. Sand and gravel are generally closely associated with tills in terminal moraines, but in this area little or no till is present.

ground moraine or outwash to kame moraine is generally abrupt. On the west side the kame moraine slopes steeply to a narrow, Lake Algonquin valley floor. Drainage is excessive, and gullying is deep where the deposit forms the steep valley sides.

The material of the kame moraine is mainly sand and gravel, with only minor amounts of clay or boulders, and is water sorted to varying degrees. Stratification is observable in many parts of the moraine, but elsewhere it appears to be a uniform structureless mass of sand and gravel, which when analysed shows the presence of clay and silt. Deposits of fine sand and silt are rare.

The position of the ice-front when the Bass Lake kame moraine was formed is discussed in Chapter V. The material was deposited under maximum water of fluvial rather than lacustrine conditions, as the water was able to escape to lower elevations to the southwest, which precludes any ponded lake conditions. Drumlins and glacial striæ north of the moraine correspond in direction to those on the west side of Lake Simcoe, and show that the flow of ice over the entire map-area was generally uniform and from the northeast, so that this deposit could hardly be interlobate unless it was formed prior to the last minor readvance of the ice and the drumlins and glacial striæ to the north mark the direction of movement of this readvance that came up to, but did not override, the kame moraine.

Kames and Kame Terraces. Kames are isolated deposits of stratified gravel, sand, and silt that accumulated along the ice-front at the mouths of glacial streams. They are common throughout the area. Good examples of kames not associated with terminal moraines are found 3 miles east of Bell Ewart, 6 miles south of Beaverton, and 5 and 7 miles east of Beaverton. Examples of those closely related to a terminal moraine are found south of Canal Lake and northeast of Lake St. John, in which places gravel is more abundant than sand.

Another form of ice-contact deposit common in the area is that of those accumulations of silts and sands found along the sides of valleys or as ridges on higher ground and marking the lateral limits of ice-lobes. The material is generally finer than that found in kame moraines, sorting is better, and the silts and sands are commonly well stratified and cross-bedded. Abrupt changes in grain size are frequent, and in some cases the stratified material is intimately associated with till (*See* Plate VIII A). Deformation of the beds is common where overlain by till. Ice-contact deposits along the sides of valleys are a type of kame terrace. They are accumulations, not at the mouths of glacial streams but of streams that flowed along the sides of the lobes that filled the valleys. Many of these streams merged into lakes, giving the finer uniform deposits of sand and silt, whereas in other places abrupt changes of grain size indicate rapidly changing conditions over short periods of time. The skyline of these kame terrace deposits is regular, in contrast with the extreme irregularity of kame moraine, and their indented slopes were the result partly of protuberances of the ice and partly of post-glacial erosion.

Another type of ice-contact deposit is found on more elevated ground, and represents accumulations of sand and gravel of spillways or streams that flowed along the sides of ice-lobes that filled basins rather than valleys. Good illustrations of these can be seen along Highway No. 12, between

Barrie and Orillia, where the stratified material is piled up into ridges in the form of bars and spits. There, the ice-lobe probably filled all of Lake Simcoe basin and extended westward through the valleys of Little Lake and Kempenfelt Bay. The spillways enlarged into temporary lakes in places, as evidenced by the sand and clay filling the depressions. The ridge-like deposits represent stream deposits carried off the ice into these lakes or where the narrow spillway channels opened into a larger body of water. Plate VIII B shows a spillway bluff in a constriction between these bodies of water, where high ground formed one bank of the stream and the ice the other. A spit formed westward of this bluff where the constriction widens out. Further evidence of ice-contact deposits is found in abandoned spillways or drainage channels that carried away the meltwaters. These channels, many of which are unoccupied by even intermittent streams, were once V-shaped, but are now U-shaped, with flat floors.

Eskers. Excellent examples of eskers are found in the southeast part of the map-area in the form of long, narrow, rather sinuous ridges, broken by gaps, and with tributaries that form a pattern similar to that of a stream. The crests are smooth or broadly hummocky, and the sides are quite steep. The eskers are confined to the swales of the drumlin field and larger valleys.

The largest esker begins abruptly 2 miles southeast of Cannington and ends by merging into a kame moraine 2 miles south of Sunderland. The maximum height is about 60 feet, and the width about 300 feet; the total length, including gaps, is about 8 miles. A smaller esker 3 miles long, north and west of Cannington, is quite sinuous, but is remarkably uniform in section. It begins abruptly 1 mile north and ends 1 mile southwest of Cannington. Isolated patches, separated by gaps of a half mile, occur at both ends.

These eskers are composed of material varying from well stratified and sorted sand and gravel to poorly sorted pebbles and boulders. Silt and clay are rare, but lenticular beds of both silt and clay have been noted in gravel pits that expose the core of the esker. The coarsest material is at the north, or head, end of each esker, and decreases constantly in grain size towards the south. Plate IX A illustrates the bouldery content and lack of sorting and stratification at the north end of the esker 2 miles northeast of Cannington. The sediments are finer grained and well sorted at the south end (Plate IX B).

The general trend of the eskers is roughtly parallel with the direction of ice movement. Opinions, in general, seem to agree that the deposits are the accumulations of sand and gravel in tunnels at the base of the ice. They formed later than the drumlins as they wind around and between them and thus represent one of the final phases of deglaciation. The ice was probably thin and stagnant, and the meltwater entered the tunnels through crevasses and other openings. There is no evidence in these instances that the water was under hydrostatic pressure, as the eskers occupy valleys and do not rise over drumlins or other elevated features. The lateral gradation of grain size indicates that the esker was formed at the same time throughout its length. In addition, the narrow, steep-sided ridge at the north end, which broadens to the south and finally merges into kame moraine, substantiates simultaneous deposition. The presence

of undisturbed strata and crossbedding points to subglacial, rather than englacial or superglacial, origin. The abrupt beginning marks the point at which the surface meltwaters reached a subglacial tunnel through a moulin, and the volume of material suggests that the superglacial and englacial load of drift was considerable, because the esker is built above the surrounding ground composed of till, which is, presumably, mainly subglacial load. It is reasonable to suppose that most of the material was collected by the streams that flowed over the surface and in crevasses in the ice before entering the subglacial tunnel. A moderate length of time, during which the pebbles were transported by the stream, is involved, as indicated by the subrounded to rounded shape of the pebbles.

Another esker occurs 9 miles east of the upper end of Lake Couchiching. The form of this esker is broad and rounded in cross-section, the result of reworking by wave action during lower stages of Lake Algonquin. Large boulders are generally missing, as this represents the near southern extremity of a long esker. The esker probably extended southwards through the area now mapped as lacustrine sand and ended at the Lake Simcoe moraine. However, if it did so, wave action modified it to such an extent that recognition is now impossible.

Outwash. Two small deposits of outwash have been mapped, one along the south border of the Bass Lake kame moraine, and the other along the margins of the ice-contact deposits south of Barrie. The material is composed of well sorted and stratified sand and gravel that was picked up within the marginal zone of the ice and deposited beyond the front by meltwater streams.

The topography is flat to gently undulating. That of the smaller of the two deposits, south of the Bass Lake kame moraine, is in sharp contrast with the rolling topography of the kame moraine. There are no exposures to show the thickness of the outwash sediments. On the other hand, there is no sharp contrast between the topography of the outwash and the ground moraine south of Barrie. At this latter point, the stratified sediments are deposited on top of gently undulating ground moraine that projects through the outwash here and there as gentle rises of till. Because of the undulatory surface of the ground moraine, the outwash deposits are of variable thickness. The many gravel-pit exposures show that the material is generally gravelly on the surface and grading down into sand.

DEPOSITS OF GLACIO-LACUSTRINE ORIGIN

Glacio-lacustrine deposits are composed of stratified sediments laid down in standing bodies of water of glacial or semi-glacial lakes. The material was largely carried in by meltwater streams from the glacier, although some was brought in by streams from deglaciated areas and some was derived by erosion of shore bluffs. The sediments accumulated from the time the glacier was in the immediate vicinity, when glacio-lacustrine deposits, mainly represented by varved clays, were formed, until it had withdrawn far to the north, when the lake could be better termed semi-glacial and the deposits lacustrine. However, there is no sharp distinction either laterally or vertically between glacio-lacustrine and lacustrine deposits of glacial Lake Algonquin. The deposits include beach sands and gravels, lacustrine sands, silts, clays, and varved clays.

Beach Sands and Gravels. Beach deposits of sand and gravel are almost everywhere associated with the abandoned shorelines of Lake Algonquin. They are more pronounced where related to the main Lake Algonquin stage rather than to the lower stages. This follows logically, as these deposits are largely the result of wave action that was more effective during the main Algonquin stage when the extent of the lake was at a maximum. During the lower stages islands and promontories were effective in breaking the force of the waves. Beach ridges, bars, and spits are more common in the central and southern parts of the area where more land lay above the level of the lake.

Beach ridges are formed parallel with, and a few hundred feet off, shore. They are mainly sand and relatively shallow. Bay-mouth bars and bars constructed between drumlins are composed mainly of gravel and provide the best material for road making and construction work. These deposits are thick, many of them reaching a depth of 50 feet or more. Spits extend lakewards from promontories or islands, and are also good sources of sand and gravel.

The material of these beach sands and gravels is well sorted and stratified; pebbles are well rounded and are predominantly igneous, limestone pebbles being easily destroyed during processes of abrasion. In general, the top material of these deposits is coarser than the bottom material, as the finer sand was first deposited in the deeper water. Below the main Algonquin beach the deposits contain more sand than gravel. In places where deep water lay off shore, thick deposits accumulated to form wave-built terraces. Sand and gravel are lacking on wave-cut terraces as the thin covering was subsequently removed to deeper water by Lake Algonquin at its lower stages, leaving the surface covered with boulders and producing what is known as a boulder-strewn terrace or a boulder pavement.

Lacustrine Sands, Silts, and Clays. These materials, carried in by streams or eroded from the shore bluffs by wave action, settled on the irregular bottom, or were piled up along the beaches of Lake Algonquin. Some of the shoreline deposits, during lower stages of lake level, were washed from the terraces and added to the earlier accumulations. The deposits are by no means uniform; many clay areas contain lenses of sand and silt; clay pockets occur in sandy deposits; or the two types grade into one another. Silts, as such, are not mapped, for it is difficult to differentiate accurately in the field between very fine sand, silt, and clay because they have no sharp boundaries; sand and clay grade into silt. Generally, sand is found close to the shoreline or extends across areas that were not submerged far below the main Lake Algonquin level. Farther off shore the sand grades into silt, and finally the silt grades into clay. Clays usually are found at the surface in depressed areas or in sheltered localities, as in the drumlin field east of Orillia. In such places wave action was nullified by numerous islands and promontories that left narrow channels or land-locked bays. With further lowering of the lake level, the wave action in these small, isolated bodies of water was insufficient to carry sand and silt away from the shoreline to the deeper water.

In addition to lateral gradation, there may be a vertical gradation; sand is generally underlain by silt, which in turn is underlain by clay.

The thickness of the lacustrine deposits varies, for they cover a land surface as varied as that lying above the level of Lake Algonquin. On wave-cut terraces the sand is thin or absent, whereas in some of the valley bottoms the lacustrine sediments reach a thickness of 100 feet or more. In the rock-knob lowlands the sand or clay is generally thin, but can vary greatly within short distances. On the limestone plains the deposits are thin and uniform.

Generally the sands are horizontally bedded, but vary both horizontally and vertically from coarse to very fine. In many places cross-bedding is common, indicating current and wave action. The weathered sands are brown, and weathering is deep, particularly where the sands are well drained. Unweathered sands are usually grey to white. The bedding and weathering of the silts are similar to those of the sands. Surface clays, representing the deposits of the semi-glacial lake stage, are usually thin and massive; the varved clays are discussed below.

In addition to the lacustrine deposits of glacial Lake Algonquin, sands and clays are found in depressions and valley bottoms in areas above the shorelines of this lake. These are the results of deposition in temporary lakes that followed the retreat of the glacier but have long since disappeared. In part, they are also due to accumulations of material washed in from the surrounding slopes by rain water. The valley of Beaverton River between Cannington and Sunderland is a good example of a pre-existing lake bottom floored with thick lacustrine sands and clays. Damming the river at Cannington and raising the water level 10 feet would create a long, narrow lake in this valley.

Varved Clay. Varved clays are probably the widest known and most easily recongized deposits of the Glacial epoch. Flint (8, p. 141) describes them as "the fine-grained bottom sediments of many glacial lakes (that) occur in pairs of coarse and fine layers called varves, which are believed to represent annual cycles of deposition and are therefore used as a basis for determining the duration of the lake and for other time calculations".

The term 'varved clay' is useful, and should be retained even although the particles range in size from clay to gravel and the coarse-grained layer may contain only negligible amounts of clay.

The term 'summer' layer is widely used for the coarse-grained, light-coloured layer, and 'winter' layer for the fine-grained, dark-coloured layer. These seasonal terms are used because of the acceptance, by most geologists, of the annual deposition of each varve, mainly because they look like annual accumulations of summer and winter sediments and appear to fit the hypothesis. The writer presents the following field and laboratory observations, not with the view of proving that the varves represent a larger or smaller division of time than a year but with the suggestion that the accepted hypothesis leaves many points in doubt and that probably more research into the problem is in order.

Information gathered from wells, cuts, and auger holes shows that much of the area covered by glacial Lake Algonquin is floored with varved clay, although largely concealed by surface sand and silt. Where the clay is exposed, weathering has destroyed the varves to a depth of from 2 to 4 feet. Good exposures are rare, but three noteworthy examples will be mentioned. One of the best exposures is in a cut-bank of North Creek, 1½

miles north of Bass Lake. Altogether 65 feet of varved clays are exposed, overlain by 10 feet of lacustrine sand and gravel and underlain by a blue-grey sandy till (Table I, sample 21). Four miles north of Bass Lake, another good cut in a gully across a terrace of the Lower Orillia stage of Lake Algonquin exposes 40 feet of varved clay. This clay is overlain by 4 to 6 feet of beach sands and gravels; its base is not exposed. The thickness of the varves in both exposures varies from $\frac{1}{16}$ inch to 5 inches, with the coarse-grained layer generally the thicker of the two. At both localities the varves are generally thicker at the top of the section than they are at the bottom. A smaller exposure is seen in the banks of Coldwater River 7 miles west of Bass Lake. Only about 10 feet of varves are exposed, and these are fairly uniform at about $\frac{1}{4}$ inch per varve. These varves contain many stones varying from coarse gravel to cobbles.

From limited observations in this area the writer has noted: (1) the varves are thicker at the top of a vertical section than at the bottom; (2) stones of all sizes are the rule rather than the exception in the varves (*See* Plate X A); (3) varved silts and sands are common (*See* Plate X B); (4) coarse-grained layers are generally thicker than the fine-grained layers but not always so; (5) truncation of varves (*See* Plate XI A); (6) current ripple-marks are common (*See* Plate X B); (7) varving could not be reproduced by the writer from varved clays in the laboratory at room temperature; (8) mechanical analyses of varved clays from two localities showed better sorting in the 'summer' layers; and (9) the difference in colour between the light and dark layers is mainly due to the water content.

In the two exposures north of Bass Lake, and in sections on Nottawasaga River southwest of the map-area where thick deposits can be seen, the thicker varves are generally near the top although minor variations do occur. This necessitates either an advance of the ice-front, or an increase in volume of sediments brought in by the glacial streams, or both.

Stones may be widely scattered throughout the varved clays. They are more common in the coarse-grained layers, but some are completely enclosed in the fine-grained or 'winter' layers without any contortion or disturbance of the layers. Ice-rafting explains the stones in the 'summer' layers, but is not satisfactory for those in the 'winter' layers. The stones indicate proximity to the ice-front. Large 'boulders' of till in the clay, folded and contorted varves, and gravel in the 'summer' layers support this theory.

Plate X B shows current ripple-marks on sands and silts. These sediments are varved in the sense that they display alternating, dark-coloured, fine-grained, and light-coloured, coarse-grained layers. The 'summer' layers are of medium- to coarse-grained sand; the 'winter' layers consist of fine sand, silt, and clay. Only the coarse-grained layer is ripple-marked; the base of the overlying fine-grained layer retains the impression of the ripples, whereas the top is commonly smooth. Although it might be argued that these are not varves, there are other examples of indisputable varves that show ripple-marks. Crossbedding is also common in the 'summer' layers. If these varves were deposited in glacial Lake Algonquin at its highest level, the water was about 100 feet deep, a depth beyond the limit of wave action and where currents were unlikely except at the mouths of subglacial stream tunnels where the ice formed the shore of the lake. However, at the main Lake Algonquin stage the ice-front had retreated far to

the north, and it is more probable that the varves were formed at the ice-front during the earlier, low-water stages of the lake.

The relative thickness of the 'summer' and 'winter' layers ranges from 6-inch 'summer' layer and $\frac{1}{16}$-inch 'winter' layer, through equal thicknesses of both, to 1-inch 'summer' layer and 4 feet $5\frac{1}{2}$ inches of 'winter' layer. Such variations might be explained by distance from the ice-front, but it is difficult to comprehend such a vast amount of material represented by a thickness of 4 feet $5\frac{1}{2}$ inches staying in suspension until winter.

The truncation of varves also argues for deposition at or very near the glacier margin under fluctuating conditions of both ice-front and currents.

The difference in colour between the light and dark layers is due mainly to moisture content. In an exposed face this colour difference is one of the outstanding characteristics of varved clays. In a face exposed to the air, the light layer, containing more of the coarser material, loses some of its moisture, whereas the higher clay content of the darker layer retains the moisture. If both layers are completely saturated with water, or if the varves are dried thoroughly in an oven, the two layers are almost indistinguishable from one another. If there is any difference, it is mainly due to grain size, as the coarse particles are generally of quartz or feldspar, whereas the clay-sized particles contain more of the dark minerals and of limestone and shale.

The writer has tried, unsuccessfully, to reproduce varving in the laboratory at room temperature, using varved clays from north of Bass Lake. The light and dark layers together were thoroughly stirred and allowed to settle in a 1,000 cc. beaker. The result was complete separation into the different grain sizes. The same layers when treated separately also settled into the different sizes. Fraser (9, p. 56) reproduced varve-like deposits under exacting conditions in a laboratory in water at a temperature of 0°C., but *these varves were made in a period of 24 hours.* He concludes by stating that under certain conditions layer-pairs resembling varves do not necessarily represent a year's deposit, or yearly deposition.

The results of mechanical analyses of light and dark layers from Steeprock Lake and from north of Bass Lake are given below:

Locality	Layer	Percentage			Sorting
		Sand	Silt	Clay	
Steeprock Lake	Light	0	30	70	1·70
Steeprock Lake	Dark	3	25	72	2·45
20 (Bass Lake)	Light	2	81	17	1·55
20A (Bass Lake)	Dark	15	25	60	3·75

The amount of sand and silt in, and the poorer sorting of, the dark layers are difficult to explain if they represent material that remained in suspension until winter; the high proportion of clay in the light layer from Steeprock Lake is also inconsistent. Fraser (9, p. 51) has shown that maximum density (at 4° C.) has little effect on velocity of falling particles in the sand size, and that particles in the upper range of very fine sand (0·082

mm. diameter) will fall 4 feet in 197·5 seconds at a temperature of 2·7°C. The presence of silt and sand in the 'winter' layers is incongruous with Fraser's results. It might be argued that this coarse material was brought in by streams that flowed from the glaciers during the winter months, but such streams, if they did flow, must have been subglacial and entered the glacial lake below the frozen surface, and it is improbable that such streams would carry sand and stones for any great distances.

The thickness of a varved clay deposit and of the individual varves in it vary considerably. The Lake Schomberg clays range from 4 feet in thickness, and comprising a maximum of 100 varves, to a thickness of more than 30 feet and representing more than 200 varves. The total thickness and the thickness of each varve increase from north to south. Lake Schomberg was a narrow, marginal lake, and all material was deposited close to the ice-front. Lake Algonquin clays, on the other hand, increase in thickness and number toward the north. In Nottawasaga Valley, 2 miles south of Highway 89, the total thickness of the varves is 6 feet, whereas 10 miles to the north the varves have a total thickness of 65 feet. If the Algonquin clays had spread over the entire lake bottom, the number of varves should remain constant, and the thickness of individual varves should decrease to the south. However, in Nottawasaga Valley there is a marked decrease in both thickness and proportionate number of varves within 10 miles. Both the Algonquin and Schomberg clays can be explained only if the sediments were deposited at the ice-front, because under such conditions the total thickness and number of varves is dependent only on the time the ice-front remained at any one place and on the volume of sediments introduced. Antevs (1, p. 29) shows that there is rapid thinning of the varved clays away from the ice-front in the vicinity of Bracebridge, which he explains by "rapid flocculation and settling of the load to the bottom of the stagnant lower compartment of the semi-glacial lake". Suspension of the fine particles until winter is hardly in keeping with rapid flocculation. Also, when the ice-front retreated through the Lake Simcoe area, the early stages of Lake Algonquin must have been glacial and not semi-glacial, and under these conditions, according to Antevs, the varved clays should have spread over all the small expanse of the lake in this area. Johnston (15, p. 379) states that most of the sediment transported into Lake Louise, Alberta, is deposited on the bed of the lake, for the outlet stream is nearly clear. It is assumed that these observations were made in June, at the time of the author's investigations. If so, then all the material, with possibly the exception of the colloidal clays, must have been deposited soon after entering the lake and before the water carried them to the outlet—a condition not acceptable in a glacial lake, a category into which Lake Louise is placed.

Although Algonquin clays are widespread, many places inundated by the glacial lake contain no varved clays. In the rock-knob lowlands and limestone plains, outcrops are numerous, and no evidence was obtained to indicate that these were ever covered with deposits of varved clay. Varved clays are quite resistant to erosion, and vertical bluffs will stand almost as long as massive boulder-clay till. Varved clay comprises part of the steep Nipissing bluff (*See* Plate I) at Waubaushene, and stands as evidence of its resistance to wave erosion. Therefore, it is inconceivable that if these sediments had covered all of the area inundated by Lake Algonquin they would have been eroded by waves of lower stages of the

lake from localities where bedrock or till is now exposed at the surface, particularly as wave action at the lower stages was reduced by islands and promontories. Evidence in the field has shown that 50 or 60 feet of varved clay may be present at one locality and none at another 2 or 3 miles distant.

The writer offers the following comments relative to the above observations: (1) Varved clays accumulated at or very near the ice-front, and probably formed fan-shaped deposits around the entrance of superglacial, englacial, or subglacial streams, when ice formed the north shore of the glacial lake into which the sediments were carried. The presence of stones and ripple-marks, the truncation of varves, the varying thicknesses of deposits, individual varves, and layers in each varve, and the grain size of the particles in the layers of each varve all support this suggestion. (2) As the glacier retreated, the varved deposits were extended northward, not along the entire submerged ice-front, but confined to a fan-shaped area around the glacial streams feeding the lake. Thus the thickness and number of varves would vary with the volume of sediments carried into the lake and the rate at which the ice-front retreated. Absence of varved clays would indicate that no streams entered the lake at that point. (3) The deposits were laid down during the earlier, low-water stages of Lake Algonquin. (4) Because the varved clay deposits represent the fine-grained part of the load in the glacier, there must be deposits that contain the coarser particles. These deposits are the kame moraines, kames, kame terraces, outwash, and eskers, and for each deposit there will be an associated varved clay deposit corresponding in thickness and extent to the glacio-fluvial deposit. The most extensive varved clays will be found associated with the kame moraines, although this relationship might be obscured by lacustrine or glacio-fluvial sand overlying the clay. The varved clays associated with eskers will be confined to a smaller area and will not be as thick as those related to kame moraines. This relationship of glacio-fluvial deposits to glacio-lacustrine varved clays is evident in the Lake Simcoe area. The varved clays in Nottawasaga Valley are associated with the Bass Lake kame moraine; those in Orillia North township with the esker that extends north towards Severn River; and those in Mara and Rama townships with the esker in the north of Rama township. The esker in Brock township is associated with Lake Schomberg varved clays found in the southern part of the township. (5) The varve period may be a year; if so, then the coarse-grained layers were deposited under flood conditions probably in spring or early summer and the fine-grained layers were deposited during normal melting of late summer and autumn. (6) The varve period may be less than a year, possibly daily, or some longer period corresponding with our warm and cool weather lasting anywhere from 2 or 3 days to a month. All of the above observations are congruous with the daily period, the coarse-grained layer being deposited in the early afternoon when the stream flow was greatest; the fine-grained layer deposited in the night and early morning hours when the stream flow was least. The thin varves might correspond to dry, cool periods, the thick varves to warm periods or periods of heavy precipitation.

A comparison of Pleistocene glaciers with present day continental glaciers further supports the theory of the daily varve period. Most concepts of glaciation have been derived from observations of existing alpine glaciers, and the tendency has been to conclude that conditions at the ice-fronts during the Pleistocene epoch were similar to those at the fronts

of mountain glaciers, whereas, in all probability, they more nearly resembled conditions illustrated by the present continental glaciers of Greenland and Antarctica. Professor W. H. Hobbs[1], in his study of glacial conditions at the University of Michigan station at Mount Evans, in Greenland, has deduced the following important facts: (1) melting was limited to the short summer season of about 3 months; and (2) the streams were large or small according as the weather was relatively warm or cool; on warm days the meltwater was sufficient to flood the fiords from bank to bank whereas at night the volume of water shrank to a network of narrow braided streams on the outwash plain; on cool days the volume of water was much less, with a corresponding decrease at night.

The above observations do much to discredit the annual theory for the origin of varved clays, because such uniform deposition as exhibited in varved clays could hardly result when the glacial streams fluctuated so widely, not only diurnally but also periodically throughout the short summer months. On the other hand, all the features of varved clays fit into the daily theory if it is realized that the deposits might well be confined to the immediate vicinity of the place at which the glacial stream entered the lake and not spread over the entire lake.

RECENT DEPOSITS

The only Recent deposits of consequence in the area consist mainly of a blackish muck, which together with swampy vegetation occupies depressions in both the highland and lowland areas, although more extensive in the lowlands. The swampy conditions are due to poor drainage in the underlying material, which is a compact boulder-clay till, sand, silt, or clay. Swamps are most common in the larger valleys, and are due mainly to seepage from flanking, higher areas. Much of the land bordering the present lakes is so low that the water-table reaches the surface. Depressed parts of the rock-knob lowlands and limestone plains, where drainage is impeded, habitually contain swamp muck. Likewise, depressions between drumlins are commonly swampy, due to seepage from the sides of the hills. The thickness of muck varies from a few inches to several feet, and the muck is usually underlain by sand, which grades down into silt and clay. None of the swamp areas has been utilized like that of the Holland Marsh.

Loess is widespread throughout the area, and covers much of the surface to a depth of from a few inches to 2 or 3 feet. In some places the top foot of soil is faintly stratified and contains fragments of charred wood, indicating that at some time in the past forest fires swept over the area, which later received this thin veneer of silt. Dune sand is rare, although some is present on the Algonquin lake-bed east of Sutton, and increasing amounts appear a few miles south of Sutton and also west of Barrie in the Camp Borden area. Some old dunes, probably dating back to Lake Algonquin time, have been noted. These are now covered with forest, including rotted tree trunks 3 and 4 feet in diameter.

The only deposit of marl seen in the area lies 3 miles north of Orillia. The marl is greyish white, and from 3 to 4 feet thick.

[1] Hobbs, W. H.: The Glacial Anticyclone and the Continental Glaciers of North America; Proc. Am. Phil. Soc., vol. 86, No. 3, pp. 368-402 (1943).

All present stream valleys are floored with some alluvium, but because these deposits are so limited and unimportant, and because it is believed that most of the material in them accumulated shortly after the retreat of the ice, they may be more rightly classed as Pleistocene than Recent deposits.

DIRECTION OF ICE MOVEMENT

Glacial features that record ice movement can only be taken as indicators of the last readvance of the Wisconsin glacier. The direction of flow can be determined fairly accurately from drumlins and striæ, and roughly from terminal moraines, eskers, *roches moutonnées*, chattermarks, and ice-block ridges. Drumlins are better indicators than striæ, as they are far more numerous, and they result from a flow of the glacier over a definite point for a longer period of time than do striæ. The direction of striæ may be determined more accurately, but as the scratches may result from only a brief contact of the basal load with the bedrock, they represent, at best, only the direction at the point of observation, where the flow could have been deflected by many minor topographic irregularities. Their spotty distribution is the major drawback in their use.

Northeast of a line from Waubaushene to Cannington, the direction of ice movement changes from due south at Waubaushene to southwest at Cannington. The trend of the drumlins and striæ at several localities is as follows: 1 mile south of Waubaushene—striæ, south 2 degrees east; Uhthoff—drumlins, south 27 to 30 degrees west; the younger set of striæ south 28 degrees west; the older set, south 35 degrees west; east of Orillia—drumlins, south 30 degrees west; 6 miles north of Bolsover—striæ, south 46 degrees west; east or Brechin—striæ, south 46 degrees west; drumlins, south 46 degrees west; Argyle—drumlins, south 25 degrees west; Cannington—drumlins, south 45 degrees west. Between Cannington and Udora the drumlins swing from south 60 degrees west to almost due south.

Although the general flow was from the northeast, topography exerted a major influence in directing the movement of ice into basins, around highlands, and through the larger valleys. The controlling topographic features in the map-area were: in the northwestern section, the Simcoe till plains, which directed the flow into the major valleys; in the northeastern and eastern sections, the Lake Simcoe basin; and in the southwestern section, Kempenfelt and Cook Bays.

CHAPTER IV

LAKE ALGONQUIN AND ASSOCIATED BEACHES

GENERAL DISCUSSION

This chapter deals with a description of the beaches that were formed during the early stages of glacial Lake Algonquin, by the main Lake Algonquin, and during the later stages of this lake. To avoid confusion, the beach formed by the main Lake Algonquin will be referred to as the Algonquin beach; those formed during the earlier, rising stages of Lake Algonquin will be called the Early Algonquin beaches; and those formed during the later, falling stages of Lake Algonquin will be considered under two groups, the 'upper group' comprising the three beaches immediately below the Algonquin, and the 'lower group' comprising the four beaches named by Stanley (20) in the Georgian Bay region. One other beach, belonging to a lower stage of Lake Nipissing, has been added.

The well-formed, abandoned beaches of Lake Algonquin in the Lake Huron, Georgian Bay, and Lake Simcoe areas have been cited by Taylor, Goldthwait, Johnston, and others. However, little or no mention was made of later stages of Lake Algonquin until Stanley began investigations in the Penetanguishene (20), Cape Rich (21), and Sucker Creek (22) areas. In the work of mapping Lake Simcoe area, numerous lower beaches and ridges were noted, and when correlated with the work done by Stanley a surprising agreement was found between the beaches of the Georgian Bay and Lake Simcoe areas.

Elevations were taken of all beaches and ridges that were sufficiently well formed to allow 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. About eight hundred readings were taken. All measurements were made with a telescopic alidade and self-reading stadia rod. Readings were taken to the nearest tenth of a foot, and the tabulated results are given to the nearest foot.

Altogether, seven beaches lower than the Algonquin are recognized. The three upper ones, here named in descending order, the Ardtrea, Upper Orillia, and Lower Orillia, constitute the 'upper group' of Algonquin beaches mentioned by Taylor (18, p. 415). These beaches are well defined in only a few localities. The Upper Orillia is the strongest of the three, and in one place is marked by a 25-foot bluff. Many elevations of these three beaches have been taken by Taylor, Goldthwait, and Johnston, but the beaches were not traced for a sufficient distance to show their relationship to the Algonquin beach. Stanley's work around Georgian Bay was concerned mainly with the 'lower group' of beaches, although many eleva-

tions of beaches and ridges between the Wyebridge (the upper beach of his 'lower group') and the Algonquin taken by him correspond in elevation with the newly named beaches in the Lake Simcoe area. The names of the beaches comprising the 'lower group', the Wyebridge, Penetang, Cedar Point, and Payette, given by Stanley in the Georgian Bay area, are retained here. The name of one other beach, the Waubaushene, lying below the Nipissing, is added.

The abandoned Algonquin beach, marking a long stand of the glacial lake, is one of the outstanding features of the area, and can be traced for its entire length throughout the area, although not everywhere sufficiently well developed to provide dependable elevations. The beaches of the 'upper group' are fairly well developed in the northern half of the area, but become increasingly weak in the southern half. The beaches of the 'lower group' are not developed south of an east-west line through Orillia, as this area was above the elevation of the water-planes of this group. However, they do exist in the Minesing area west of Barrie. The lowest beaches, the Waubaushene, Nipissing, and Payette, are only present in the Georgian Bay area. During the formation of the 'lower group' of beaches, Lake Couchiching and Lake Simcoe were separated from Lake Algonquin. The Cedar Point beach is exposed 19 feet below the level of Lake Couchiching 5 miles north of Orillia, and, therefore, the two lakes, Simcoe and Couchiching, existed independently from Lake Algonquin before the formation of this beach.

The shorelines and isobases of Lake Algonquin are shown on Figure 6 (in pocket), which includes a larger region than that of the Lake Simcoe map-area in order to present a more complete picture of the bays, inlets, and archipelagos of this lake. Figure 7 (in pocket) shows, in profile, the water-planes of the several stages of Lake Algonquin along the lines A-B and C-D on Figure 6. 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 upwards to the north. In Figure 7, the direction of tilt, north 21 degrees east, established by Goldthwait, Johnston, and others, agrees with the writer's determination, and has been adopted as the direction of maximum tilt or inclination. The distances in this direction, with the south end at the left, are plotted as the abscissa on co-ordinate paper, and the beach elevations at the various localities as ordinates. The centres of the symbols on the resulting profile mark the more reliable elevations.

DESCRIPTION OF BEACHES

TABULAR SUMMARY

Elevations of the shorelines are arranged in Table II, commencing on the west side of Cook Bay, and following the shoreline northward along the west sides of Lake Simcoe and Lake Couchiching. The readings on the east side of the two lakes follow the same sequence, beginning on the east side of Cook Bay. Townships, concessions, and lots, referred to in connection with localities mentioned in Table II, are shown on Map 993A.

Table II

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Three miles north of Bradford on road between cons. IX-X, Gwillimbury W. tp.	*753*—Steep 20-foot bluff at railway crossing. Base well marked and moderately boulder strewn.										
Four miles north of Bradford on road between cons. X-XI, Gwillimbury W. tp.	*753*—Sloping bluff in cultivated field just west of railway.	*741*—Moderate 5-foot bluff. Terrace boulder strewn.									
Five and a half miles north of Bradford in con. XI, Gwillimbury W. tp.	*759*—Well-marked bluff makes a sharp break with slightly boulder-strewn terrace just west of railway.										
Two miles south of Gilford on road between cons. XII-XIII, Gwillimbury W. tp.	*761*—Steep bluff varying from 10 to 30 feet high on west side of railway. Terrace swampy.										
One mile south of Gilford on road between cons. XIII-XIV, Gwillimbury W. tp.	*761*—Steep 30-foot bluff just west of railway. Base not well marked. No boulders on terrace.										

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
One mile north of Gilford on road between cons. I-II, lot 22, Innisfil tp.	*764*—Gentle slope of drumlin forms the bluff and merges with terrace. Bluff and terrace cultivated.										
Quarter mile north of Lefroy, con. IV, lot 21, Innisfil tp.	*775*—Strong bay-mouth bar 200 feet wide and rising 30-35 feet above lagoon. Creek has cut through the bar.										
Two miles north of Lefroy on road between cons. V-VI, lot 22, Innisfil tp.	*772*—Moderate 30-foot bluff and boulder-strewn terrace. *776*—Strong bay-mouth bar 1,200 feet south of overhead railway bridge.										
Road between cons. IX-X, lot 25, Innisfil tp.	*780* to *785*—Strong 35-foot bluff and boulder-strewn terrace. Terrace gravelly and merges with bluff.										

Intersection of roads between cons. X-XI and lots 25-26, Innisfil tp.	*787*—Moderate 10- to 15-foot bluff merging with terrace. *785*—Beach ridge north of bluff.	*779*—A lower beach ridge parallel with and 600 feet east of the Algonquin ridge.									
Intersection of roads between cons. XII-XIII and lots 25-26, Innisfil tp.	*790*—Strong 25-foot bluff 1,500 feet south of intersection. Terrace heavily boulder strewn.										
North end of lot 26, con. XIV, Innisfil tp.	*795*—Gently sloping 15-foot bluff making sharp break with terrace. Several beach ridges on terrace. *792*—Beach ridge just north of above bluff.	*786*—Beach ridge just north of and parallel with the Algonquin beach ridge.									*769*—An intermediate beach ridge just north of and parallel with the Ardtrea beach ridge.
Minet Point on Kempenfelt Bay, Innisfil tp.		*773*—Short beach ridge 3,500 feet east of Minet Point.	*739*—Strong 10-foot bluff for 2,000 feet west of Minet Point. *743*—A weak, discontinuous beach 3,500 feet east of Minet Point.	*720*—Strong 7-foot bluff with flat sandy terrace just east of Minet Point.							*752* and *757*—Weak discontinuous beaches 3,500 feet east of Minet Point.
Intersection of roads between cons. VII-VIII and lots 25-26, Essa tp.	*774*—Strong 50-foot bluff 3,000 feet east of intersection. Terrace flat and sandy. *774*—Strong 50-foot bluff 2,500 feet south of intersection. These readings are high.										

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Road between cons. VII-VIII, lot 22, Essa tp.	*767*—Strong bay-mouth bar 15 feet high. Bar cut by a stream.										
Intersection of roads between cons. VI-VII and lots 20-21, Essa tp.	*762*—Moderate 15-foot bluff merging with slightly boulder-strewn terrace 1,000 feet south of intersection.										
Intersections of roads between cons. VI-VII and lots 10-11, Essa tp.	*755*—Strong 50-foot bluff 800 feet north of intersection. Sandy terrace.										
Road between cons. V-VI, lot 7, Essa tp.	*748*—Strong 20-foot bluff just east of road.										
Road between cons. V-VI, lot 3, Essa tp.	*746*—Moderate bluff developed on side of a drumlin just east of road.										
Road between cons. III-IV, lot 13, Essa tp.	*754*—Moderate bluff on west side of road. Terrace slightly boulder strewn.										

Road between lots 20-21, con. X, Tecumseth tp.	*741*—Moderate bluff on west side of road. Base not well marked.										
Road between cons. IX-X, lot 19, Tecumseth tp.	*741*—Strong 15-foot bluff with well-marked base and boulder-strewn terrace.										
Road between cons. VIII-IX, lot 12, Tecumseth tp.	*731*—Sloping bluff 1,000 feet south of road.										
Road between lots 10-11, con. IX, Tecumseth tp.	*733*—Good bluff developed on nose and side of drumlins.										
One mile south of Alliston on road between cons. XIII-XIV, lot 2, Tecumseth tp.	*736*—Moderate 12-foot bluff just south of road.										
One mile west of Alliston on road between cons. VI-VII, lot 2, Tosorontio tp.	*734*—Moderate 12-foot sloping bluff just south of Boyne River.										
Three miles west of Barrie on road between cons. VII-VIII, Vespra tp.	*783*—A 15-foot bluff developed on a sandy peninsula 3,500 feet north of No. 90 highway.										
One mile west of Barrie on road between cons. V-VI, Vespra tp.	*784*—Bluff developed in kame material. Base not well marked.										

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Two and a half miles northeast of Barrie on Ridge Road, Oro tp.	*788*—Sloping 60- to 70-foot bluff developed in a kame deposit. Base merges with sandy terrace.										
Three miles northeast of Barrie on Ridge Road, Oro tp.	*790*—Moderate 15-foot bluff just west of small bay on north side of Ridge Road.										
Two miles southwest of Shanty Bay on Ridge Road, Oro tp.	*791*—Moderate beach ridge crossed by Ridge Road.	*778*—Gentle slope developed on a gravel terrace, 300 feet south of railway just east of overhead bridge.	*754*—Gentle 15-foot slope and flat terrace, 600 feet south of Ridge Road and ¾ mile east of overhead bridge.								*770*—Gentle 10-foot slope and flat terrace, 400 feet south of Ridge Road and ¼ mile east of overhead bridge. *771*—Gentle slope developed on a gravel terrace 350 feet south of railway and just east of overhead bridge.
Shanty Bay, Oro tp.	*796*—A strong 12-foot bluff 1,200 feet west of Shanty Bay decreasing to a 6-foot bluff to the west.										

One mile east of Shanty Bay, on Ridge Road, Oro tp.	*800*—Strong 20-foot bluff with well-marked base. Terrace hummocky and boulder strewn.										
Two miles east of Shanty Bay, on Ridge Road, Oro tp.	*800*—Moderate 15-foot bluff. Terrace slightly boulder strewn and hummocky.										
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- to 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.										
Hawkestone, on road between cons. XI-XII, Oro tp.	*820*—Strong 30-foot bluff north of railway. Terrace boulder strewn.										

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
One mile east of Hawkestone road between cons. XII-XIII, Oro tp.	*824*—Strong 30-foot bluff north of railway. Terrace boulder strewn.										
Two miles northeast of Hawkestone on road between cons. XIII-XIV, Oro tp.	*829*—Strong 30-foot bluff north of railway. Terrace swampy.		*785*—Well-marked sand and gravel ridge 700 feet north of Lake Simcoe; terrace boulder strewn on both sides. *780*—A 15- to 18-foot bluff of a small strait north of above ridge. *790*—Sand and gravel ridge ½ mile east of above.								*799*—Sand and gravel ridge at gravel pit 2,000 feet north of Lake Simcoe.
Three miles northeast of Hawkestone road between con. XIV, Oro, and con. I, Orillia South 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.								

Intersection of roads between lots 15-16 and con. XIV, Oro tp., and con. I, Orillia South tp.	*836*—No. 11 highway passes over strong 35-foot bluff 900 feet west of intersection. Base sandy and sloping. *836*—½ mile north of No. 11 highway and west of road. Bluff sandy and merges with terrace. *839 to 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.	*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.									*820*—Impounded shore bluff in north end of lagoon. *835*—Two converging ridges parallel with main ridge on lagoon side. Probably due to high water stage of Lake Algonquin.
Road between cons. I-II, Orillia South tp.	*837*—Lot 12, ¼ mile west of schoolhouse. Strong 50-foot bluff and boulder-strewn terrace. *838*—Lot 11, ½ mile north of No. 11 highway. Road passes over 40-foot bluff. Base gently sloping.		*789*—Lot 12. A moderate 4-foot bluff behind schoolhouse.		*745*—200 feet north of Lake Simcoe. Gentle slopes of poorly developed beach. No well marked terrace.						

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
	842—Lot 10, 1 mile north of No. 11 highway. Sand and gravel bluffs at ends of bay-mouth bar. May be depositional in part. *840 to 845*—Bay-mouth bar cut by small creek. Several lower ridges associated with this strongly developed bar.	*830*—A sand and gravel ridge 100 feet east of main ridge and 11 feet lower. *827*—A sand and gravel ridge 200 feet east of main ridge and 14 feet lower.	*798*—A sandy ridge 900 feet east of main ridge.								*839*—Mild slope north of road in the lagoon. May represent a rising stage of Lake Algonquin. *842*—A gravelly ridge on the lagoon side and parallel with main ridge. *834*—A gravelly ridge on the lagoon side parallel with main ridge and 500 feet west of it. Origin doubtful. *816*—Impounded shore bluff in the lagoon on west side of road.
No. 11 highway and road between cons. II-III, Orillia South tp.		*821*—North of No. 11. Two gravel ridges 500 feet north of highway above gravel pit.	*794*—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 *795* feet. This becomes stronger to the east.	*770*—South of No. 11 and just below Upper Orillia beach. A strong 12-foot bluff and sandy terrace.	*754*—South of No. 11 and just below Lower Orillia beach. No distinctive base and terrace. Base is sandy and gullied.						*810*—A gravel ridge south of No. 11 just above Upper Orillia beach.

ntersection of roads between cons. II-III and lots 9-10, Orillia South tp.	*838*—A strong 60-foot bluff and boulder-strewn terrace.	*823*—South of corner by the barn. A moderate 8-foot bluff.	*794*—South of corner and below barn. A moderate 8-foot bluff here, but diminishes to the east and west.	*773*—A moderate slope marking Lower Orillia beach. Base not well defined. Terrace sandy and cultivated.	*749*—A steep 12-foot slope marks southern end of a sandy terrace. Base of this slope sandy and forested.						
Orillia, Orillia South tp.	*850*—Shoreline well developed in Orillia. Average of 7 readings taken at base of 20- to 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.		*805*—Just north of Champlain Park and 700 feet west of railway. Slope indicates Upper Orillia beach and is continuous southwest through the town.	*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.	*763*—On road lots 5-6 and 300 feet west of railway. A well-defined beach and terrace.						
Road between cons. IV-V, lot 2, Orillia North tp.			*813*—A sand and gravel ridge crosses road. Not continuous far to the east or west. *807*—A second ridge just north of above.	*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.	*769*—In lot 3 on east side of road. A strong sand and gravel ridge.	*724*—A strong, well-defined bench part way up a 60-foot bluff. A weak development of this beach to the southwest but not to the northeast.	*700*—A strong 60-foot bluff, part of which was made by the Penetang. Base well marked but no distinct terrace as it is swamp covered.				
Ardtrea Island between cons. V-VI, Orillia North tp.					*766*—A moderate bluff in sandy material 600 feet north of railway.						*755*—A well-marked bluff 11 feet below the Wyebridge beach, 2,400 feet north of railway.

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
			808—1 mile north of railway and 2,000 feet east of road. A mild slope merging with terrace.	*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?	*766*—1 mile north of railway and 700 feet east of road. A faint beach marked by increase in slope; in sandy deposits.	*728*—1 mile north of railway and 100 feet east of road. An obscure beach marked by a small rise.					*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 Wyebridge.
Ardtrea Island road between cons. VI-VII, lot 3, Orillia North tp.	*856 to 865*—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 700-900 feet wide.	*850*—East of the road and 775 feet east of Algonquin bluff is a strong, gravel beach ridge. It is parallel with bluff and on edge of its terrace.									
Lot 4	*858 to 866*—A 15-foot west-facing bluff continuing strong to the north but diminishing to south. Base of bluff slopes gently to merge with the terrace.	A series of strong gravel ridges occur to the west of the Algonquin bluff. *856*—A ridge 350 feet west of bluff. *853*—A ridge 430 feet west of bluff. *843*—Base of slope below			*769*—In lot 5, con. VI, ¼ mile west of corner. A moderate 10-foot bluff and a narrow (50-foot) terrace. Slope and terrace swampy.		*706*—In lot 6, con. VI, ½ mile west of corner. Beach marked by a moderate boulder-strewn slope that ends in a cedar swamp. Base not well marked.				*762*—In lot 5, con. VI, ¼ mile west of corner. A 6-foot bluff in a cedar swamp, 7 feet below the Wyebridge beach.

		ridge marking a possible beach. West of the road are several parallel curving ridges at elevations of *840, 837, 835, 824.*									
Ardtrea Island at intersection of roads between cons. VI-VII, lots 5-6, Orillia North tp.	*867 to 872*—A 35-foot west-facing bluff. Terrace narrow and marked by a ridge on the outer border.	*841*—A strong 20-foot bluff below the Algonquin terrace marks the Ardtrea. Slope and terrace below are boulder strewn. *837*—At 420 feet east and at 1,200 feet north of corner is a strong gravel ridge.	*814*—At north-west corner of intersection is a moderately well-developed beach with a cedar swamp occupying terrace below. *815*—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 north-west.									*829*—A strong gravel ridge east and south of corner.
Ardtrea Island on road between cons. VII-VIII, lot 4, Orillia North tp.	*858 to 876*—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 *875, 864,* and *858.*	*851*—A strong gravel ridge running parallel with the Algonquin bluff. *838*—A 10-foot boulder strewn slope below the terraces and beaches of the Algonquin.	*813*—Where lowest beach cuts the road the slope is gentle but distinctive. Terraces above and below are boulder strewn.								

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Ardtrea Island on road between cons. VIII-IX, lot 6, Orillia North tp.	*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. *872*—Gravel spit extending northward from tip of Island. *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.	*841 to 860*—A series of ridges and slopes marking approximate elevations of beaches.									
Intersection of roads between cons. III-IV and lots 5-6, Orillia South tp.	*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*—½ mile	*837*—A small sand ridge parallel with and north of bay-bar; 21 feet below bar. *831*—A boul-									

	east of corner a 25-foot bluff continuing strong to north but merging with bay-bar to south. Terrace narrow and boulder strewn. *853*—½ mile north of corner and ½ 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.	der strewn slope below Algonquin bluff and terrace. Swamp at base of slope 24 feet below Algonquin. *842*—A gravel ridge parallel with Algonquin bluff, 14 feet high for Ardtrea and may be a submerged Algonquin ridge. *850*—A gentle slope and narrow terrace below ridge (above) 22 feet below Algonquin.	*798*—East of Algonquin bluff an 18-foot bluff. The material is sandy and the slope becomes gentle to the north and south.								*824*—A strong gravel ridge 700 feet east of Algonquin bluff.
Road between cons. II-III, Orillia South tp., 1 mile north No. 12 highway.	*847*—Strong 70-foot north-facing bluff, base gently sloping, terrace extensive and boulder strewn. Readings vary from 841 to 854 on different points of slope.	*836*—A strong steep-sided ridge, parallel with and 500 feet north of Algonquin bluff and 11 feet below.	*793*—½ 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.	*778*—A gentle slope 500 feet north of Upper Orillia beach. Slope slightly boulder strewn. Terrace sandy and gullied.							
No. 12 highway and road between cons. I-II, Orillia South tp.	*843*—North-east of this corner is a strong 35-foot bluff. Base sandy and gently sloping. *853 to 855*—A spit joined on the east to bluff above.	*840*—Below bluff and running parallel with spit is a									

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
	Spit curves slightly to the north and is strong for ½ mile west of bluff.	broad, sandy ridge 13 feet below spit. Only violent storms could be responsible for this.									
West side of con. XIV, lot 8, Medonte tp.	*848*—Strong 30-foot bluff. Base is sloping and merges with terrace.	*825 to 829*—A gentle 4-foot slope 1,500 feet north of the Algonquin bluff.	*802*—A strong 8-foot and heavily boulder strewn terrace, swampy in places.								*812*—A strong 15-foot bluff north of and truncating the Ardtrea bluff.
West side of con. XIII, lot 9, Medonte tp.	*848*—Strong 50-foot bluff west of No. 12 highway. Terrace boulder strewn and merges with bluff. *850*—A continuation of the above bluff 2,000 feet west of No. 12 highway.										
Road between lots 10-11 in centre of con. XIII, Medonte tp.			*801*—Moderate 8-foot bluff and very heavily boulder strewn terrace.								

Road between lots 10-11 in west half of con. XI, Medonte tp.	*845 to 848*—Strong 50-foot bluff just south of road. Terrace swampy.										
Road between lots 8-9 in east half of con. VIII, Medonte tp.	*836*—Moderate 12-foot bluff decreasing to the south. Terrace boulder strewn.		*789*—Moderate 8-foot bluff and boulder strewn terrace 1,000 feet east of Algonquin bluff.								
Road between lots 8-9, in east half of con. VII, Medonte tp.	*835*—Strong 50-foot bluff on an island in Coldwater Valley.										
Eady, Medonte tp.						*713*—Moderate 8-foot sloping bluff 1,000 feet southeast of railway station.	*691*—Gentle slope and terrace in sandy deposits.				
West half of con. XI, lot 13, Medonte tp.						*715*—Moderate 8-foot bluff and sloping boulder strewn terrace. Bluff disappears to the east.					
Northeast corner of lot 25, con. XI, Medonte tp.							*703*—Gentle slope and marshy terrace.	*666*—Moderate 7-foot bluff and marshy terrace.	*632*—Moderate 5-foot bluff and boulder-strewn terrace.		*672*—Moderate 6-foot bluff.
One mile south of Waubaushene at overhead railway bridge, Tay tp.							*708*—Sloping 6-foot bluff 300 feet south of bridge.	*670*—Sloping 8-foot bluff just south of bridge.	*639*—Strong 10-foot bluff just north of bridge.	*617*—Base of a 30-foot boulder-strewn bluff. Below the Nipissing terrace.	

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Waubaushene, Tay tp.								*672*—Moderate 5-foot bluff. Sandy terrace.	*640*—A strong 5- to 10-foot bluff 700 feet west of station.	*621*—A strong 5-foot bluff 400 feet west of station.	*592*—A strong 10-foot bluff 200 feet west of station. Bluff mainly sand and gravel.
One-half mile west of Waubaushene, Tay tp.							*708*—Gentle slope and terrace near top of drumlin.	*671*—Strong 30-foot bluff truncated on the east by the Nipissing bluff.	*639*—Strong 30-foot bluff and sandy, boulder-strewn terrace.	*618*—Moderate 5-foot bluff not continuous to the west.	*694*—A strong intermediate beach on the east end of drumlin but diminishing to the west.
Lot 1, con. II, Gwillimbury N. tp.	*763, 770*—Strong 40-foot bluff on west side of a drumlin 1,500 feet west of No. 48 highway.										
Road between lots 5-6, Gwillimbury N. tp.	*769*—Strong 35-foot bluff with well-marked base just west of No. 48 highway.										
One-half mile southeast of Keswick, Gwillimbury N. tp.	*773*—Strong 30-foot bluff just east of No. 48 highway. Base well marked.										

Lot 13, con. IV, Gwillimbury N. tp., ¾ mile south of Bellhaven.	*774*—Moderate bluff increasing to the southwest but decreasing to the northeast. Bluff merges with terrace.										
Road between lots 15-16 in centre of con. V, Gwillimbury N. tp.	*776*—Moderate bluff developed on side of a drumlin. Base not well marked.										
Road between lots 15-16 in centre of con. VI, Gwillimbury N. tp.	*780*—A low 4-foot bluff at the base of a drumlin. Wave-washed boulders below this bluff but not above it.										
Road between lots 23-24 in east half of con. III, Gwillimbury N. tp.	*778*—Strong 25-foot bluff. Base merges with terrace.										
Intersection of roads between lots 20-21 and cons. III-IV, Gwillimbury N. tp.	*779*—Sloping 7-foot bluff north of intersection. *780*—Low baymouth bar extending to the southeast as three parallel ridges.										
Northwest corner of lot 23, con. V, Gwillimbury N. tp.	*781*—Strong 20-foot bluff. Base not well marked.	*770*—Gentle wave-washed slope with sandy terrace just north of No. 48 highway.	*743*—Gentle slope 500 feet north of No. 48 highway.								
Intersection of road between cons. VI-VII and No. 48	*786*—Strong 20-foot bluff with slightly boulder-										*759*—Sloping 5-foot bluff with boulder-strewn Al-

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
highway, Gwillimbury N. tp.	strewn terrace 2,000 feet southeast of intersection.										gonquin terrace above and sandy terrace below, 2,000 feet southeast of intersection. *760*—Gentle slope in gravelly terrace, just northwest of intersection.
One mile southwest of Sutton, lot 21, con. VII, Gwillimbury N. tp.	*779, 784*—Two bluffs separated by a narrow terrace. Upper bluff disappears to the north.										
North end of lot 15, con. VIII, Gwillimbury N. tp.	*785*—A strong bay-mouth bar, 12 feet high, extending between two drumlins.										
Lot 1, con. IV, Georgina tp.	*780 to 786*—Bluff developed on side of drumlin. Difficult to distinguish between base of drumlin and base of bluff.										

One-half mile west of Cedarbrae on road between cons. I-II, Georgina tp.	*782*—Strong 25-foot bluff. Terrace boulder strewn.		*763*—Sloping 5-foot bluff cut in the Algonquin terrace.								
Road between lots 6-7, con. VI, Georgina tp.	*788 to 792*—Strong 25-foot bluff with gravelly terrace. Higher readings may be due to beach ridge built on terrace. *790*—Strong beach ridge or spit joining above bluff 1,500 feet south of No. 48 highway.										
Two miles east of Sutton on No. 48 highway, lot 8, Georgina tp.	*790*—Moderate 10-foot bluff merging with boulder-strewn terrace, just north of highway.										
Intersection of roads between lots 6-7 and cons. IV-V, Georgina tp.	*786*—A low 3-foot bluff at base of a drumlin.										
Road between cons. IV-V, lots 9-10, Georgina tp.	*785, 790*—Bluff developed on side of drumlin. Base merges with terrace.										
North end of lot 8 on road between cons. III-IV, Georgina tp.	*795*—Moderate 15-foot bluff 500 feet south of road.										

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Udora, Georgina and Scott tps.	*785, 788*—A moderate bluff merging with sandy terrace. *791*—A broad bay-mouth bar ½ mile north of Udora.										
Road between cons. I-II, lot 23, Georgina tp.	*794*—Strong 15- to 30-foot bluff with well-marked base.										
Road between cons. IX-X, lot 1, Brock tp.	*801*—Moderate 12-foot bluff with well-marked base.										
One-half mile south of Wilfrid, lot 1, con. XI, Brock tp.	*801*—Strong 25-foot bluff on small island and side of drumlin. Base well marked; terrace boulder strewn.										
Centre of lot 1, con. XIII, Brock tp.	*805, 811*—Strong bluff developed on side of a drumlin. The lower elevation taken where base was well marked. *802*—A broad spit extending										

	southeast from tail of above drumlin.										
Road between Brock-Georgina tps., lots 4-5, Brock tp.	*821*—Strong beach ridge 12 feet high, 200 feet wide.										
Road between cons. I-II, lot 18, Thorah tp.	*810*—Sloping 7-foot bluff merging with terrace.										
Beaverton, Thorah tp.	*823*—Strong bluff just behind Anglican church. May be bedrock controlled in part.										*817*—A 5-foot sloping bluff below the narrow Algonquin terrace just behind church. *810*—A 4-foot sloping bluff just north of above bluff.
Three-quarters mile southeast of Beaverton on Argyle road, Thorah tp.	*830*—Coarse gravel and cobble ridge on edge of limestone plateau. May be ice shoved.										*817*—Boulder beach ridge below and just north of Algonquin ridge. *810*—Boulder beach ridge just north of above ridge.
Intersection of roads between lots 10-11, cons. III-IV, Thorah tp.	*834*—A low cobble ridge on edge of limestone plateau. May be ice shoved.										*820*—Base of 20-foot bluff just below cobble ridge.
South side of con. 1, on road between lots 5-6, Thorah tp.	*818*—Moderate bluff on the east side of road. *815*—Gravel spit extending southwest across road.										

TABLE II—*Con.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Con.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Road between cons. I-II, lot 4, Thorah tp.	*824*—A weak bay-mouth bar between two drumlins. *824*—Moderate 10-foot bluff merging with terrace and bar 1,200 feet south of road. *823*—Moderate 15-foot bluff 1,500 feet north of road.										
Road between cons. II-III, lot 5, Thorah tp.	*822 to 818*—A strong gravel spit, 300 feet wide, extending south from the lee end of a drumlin. *817*—A weak bluff on side and end of drumlin north of the spit.										
Road between cons. III-IV, lots 4-5, Thorah tp.	*826*—Moderate 15-foot bluff with sloping terrace. Base not well marked. *835*—A strong beach ridge or bar on both sides of railway.										

Road between cons. IV-V, lots 3-4, Thorah tp.	*831*—Moderate 10-foot bluff with well-marked base and boulder-strewn terrace. *837*—Low, gravel bay-mouth bar 2,000 feet south of road.										
Northeast corner of lot 1, con. V, Thorah tp.	*835*—Moderate 10-foot bluff at base of a drumlin-like rise. Bedrock close to surface.										
Intersection of roads between lots 5-6 and cons. VI-VII, Thorah tp.	*831*—A series of strong gravel ridges around this intersection.										
Intersection of roads between lots 20-21, and cons. I-II, Eldon tp.	*846* to *850*—Strong gravel beach ridge extending to the south of intersection.										
Con. III, ½ mile east of Bolsover, Eldon tp.	*863* to *867*—Strong bay-mouth bar developed as a series of parallel ridges. *857*—A lower beach ridge parallel with and northwest of main bar.										
Con. IV, 2 miles north-east of Bolsover, Eldon tp.	*854*, *857*—Strong 20-foot bluff of limestone. Terrace boulder strewn.		*808*—Moderate 5- to 10-foot bluff 500 feet north of Algonquin bluff.								

TABLE II—*Conc.*

Altitudes in Feet and Descriptions of Abandoned Lake Algonquin and Lake Nipissing Shorelines—Conc.

Locality	Algonquin beach	Ardtrea beach	Upper Orillia beach	Lower Orillia beach	Wyebridge beach	Penetang beach	Cedar Point beach	Payette beach	Nipissing beach	Waubaushene beach	Other beaches
Road between cons. VII-VIII, ¼ mile south of Kirkfield lift lock, Eldon tp.	*881 to 884*—Strong gravel beach ridge. Ridge is 15-18 feet too high. *875*—Base of 8-foot bluff developed on north side of beach ridge. Terrace 30 feet wide, disappearing to the east but widening to the west. *867*—A weak bluff cut in above terrace. A limestone plain at base of this bluff.										
Intersection of roads between lots 3-4 and cons. II-III, Carden tp.	*843, 847, 849, 851, 857*—A series of branching and parallel beach ridges varying from 2 to 10 feet high.										
Road between cons. VII-VIII, Carden tp.	*884*—Strong gravel beach ridge, 7 feet high, in lot 6. (Barometer reading.) *890*—Three low, parallel										

	beach ridges, 3 to 5 feet high in south end of lot 8. (Barometer reading.) *883*—Strong gravel spit, 6 feet high, in lot 12. (Barometer reading.)										
Road between lots 20-21, con. VII, Carden tp.	*894, 895, 897, 898*—Four parallel gravel and cobble beach ridges. Ridges from 4 to 8 feet high.										
Road between cons. I-II, lots 11, 12, and 13, Dalton tp.			*851*—A low boulder beach ridge in lot 11. *853*—A low limestone scarp probably marking a beach.	*830, 834*—A low limestone scarp and boulder-strewn terrace. *830*—A low boulder beach ridge in lot 11.	*811*—A weak 4-foot bluff in lot 12.						*796*—Moderate 12-foot bluff and sandy terrace in lot 13.
Uphill, lot 1, con. III, Dalton tp.	*924, 923, 919, 918, 916*—A group of beach ridges ½ mile north of Uphill. Bedrock close to surface. Ridges 2 to 6 feet high and mainly of cobbles. May be ice shoved. *909*—Moderate 8-foot bluff and boulder-strewn terrace below cobble ridges.	*892, 894*—Low gravel beach ridges on sloping Algonquin terrace.									

DETAILS OF BEACHES

General Statement. An added description of the features listed in Table II is necessary to give a more complete picture of the succession of beaches. Various factors affect the normal development of 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; (5) slope and extent of terrace; and (6) time. The beaches in this area have all been influenced by these factors to varying degrees.

Shorelines are strongest where the material in the bluff was a boulder-clay till or a compact sandy till; the land surface did not rise much more than 25 to 35 feet above the beach; the terrace was relatively narrow, and sloped rapidly into deep water off shore; and the reach of the water was extensive. Where glacio-fluvial material, lacustrine sand, or a loose sandy till formed the bluff, slumping destroyed the shorecliff and the sand sought its angle of repose, with the result that the bluff now merges with the terrace instead of retaining a sharp angle with it, thus preventing the taking of accurate elevations. Bluffs that reach a height of 70 or 80 feet also tend to collapse, depending on the relative inability of the material to resist erosion. In general, the Algonquin beach is the strongest because most of the factors listed above worked in its favour, particularly those of time, reach, and depth of water. With each lower stage, the depth of water decreased, and the areal extent of the lake diminished as islands and promontories rose above the surface to lessen the reach of water and the effect of waves.

Algonquin Beach. The Algonquin bluff and wide boulder-strewn terrace (*See* Plate XI B) is one of the distinguishing features of the map-area. On the west side of Lake Simcoe it can be followed northward about a mile inland, along the west side of Cook Bay, as a moderate 20- to 25-foot bluff following topographic indentions. Bay-mouth bars record the high-water level in each of the small bays. On the south side of Kempenfelt Bay, the well-defined base of the bluff is lost because of the protected topography and the sandy nature of the material in the bluffs. On the north side of Kempenfelt Bay, the bluff can be traced from Barrie almost continuously to Orillia. At Barrie the bluff is 15 to 20 feet high, but rises to a strong 30- to 40-foot bluff as it continues northeast (*See* Plate XII A). The high land forming the northwestern part of Orillia is a Lake Algonquin peninsula; the shoreline on the south and east sides 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, and halfway down the bay is a strong gravel bar that merges with the shorelines on either side. Lakewards from this bar the bluffs again become strong, and around the high land east of Bass Lake the bluffs are 70 to 80 feet high. Bass Lake was a small bay of Lake Algonquin, but the shorelines are poorly developed. The shoreline north of Bass Lake is marked by strong bay-mouth bars and gravel ridges, but in its westward extension around this part of the Simcoe till plain 50- to 80-foot bluffs are almost continuous for 4 miles. No. 12 highway crosses the shoreline at a strong bay-mouth bar in the only indentation along this shoreline section. In the major valleys, now occupied by Coldwater River, Sturgeon River, and Little Lake, the shorelines are poorly developed because of limited wave action.

In the Sutton area on the south side of Lake Simcoe, the beaches are preserved on the many small drumlin islands that rise above the abandoned lake bed. The shorelines are strongest on the islands that lie close to Lake Simcoe, for these received the full effect of the waves; the islands removed from Lake Simcoe were sheltered by those to the north and hence show only a weak shoreline. In the Beaverton area the shoreline is generally weak because of the many bays and islands. South of Canal Lake the beach is marked in places by limestone scarps, probably due in part to wave action and in part to ice erosion. In the northeastern part of the map-area good beaches failed to develop because of thin drift and numerous outcrops.

The most northerly exposures of the shoreline in this area are preserved on Lake Algonquin 'islands'; these are the only exposures for about 25 miles farther north to the granitic highlands around Bracebridge. Three localities, best suited to show the shorelines, are on Coldwater Island, between Coldwater and Sturgeon Rivers; Ardtrea Island, 6 miles north of Orillia; and Uphill Island, in the northeast corner of the map-area. The first two form part of the Simcoe till plain, and the latter is a limestone inlier. On Ardtrea Island, three distinct terraces and bluffs associated with the Algonquin beach suggest that local, initial uplift occurred here during this stage, a condition not recognized in the southern part of the area.

Ardtrea Beach. This beach, so called because it was first recognized on Ardtrea Island, 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 several ridges associated with 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 Ardtrea. Elsewhere in the area between Orillia and Barrie, a mile-wide, boulder-strewn terrace separates the Algonquin bluff from Lake Simcoe. Gentle slopes on the terrace suggest lower beaches, but nowhere are they sufficiently definite to warrant taking elevations. The Ardtrea beach is best defined 1 mile northwest of Orillia, where it forms a 20-foot bluff. Near Barrie and Sutton, good 6- to 10-foot bluffs mark the Ardtrea beach, but farther south the beach becomes indistinct.

The Algonquin and Ardtrea beaches tend to converge towards the south. This convergence is about 0·5 feet per mile just north of Orillia, and at Sutton it is about 0·3 feet per mile; the two beaches are separated by about 10 feet at the latter place. The convergence would continue to decrease southward, on Lake Huron the two beaches possibly meeting somewhere south of Port Elgin. The slope of the water-plane is 3·9 feet per mile at Uphill and 2·4 feet per mile at Keswick.

Goldthwait found beaches on Lake Huron, immediately below the Algonquin, at the following localities at elevations that would correspond with those of the Ardtrea beach: Kincardine, 657 feet, 8 feet below the Algonquin beach; Kincardine, 660 feet, 7 feet below; Wiarton, 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 beach.

When the level of Lake Algonquin dropped below the level of the Ardtrea water-plane, and before the Upper Orillia beach was formed, many new developments took place; the most important was the closing of the Fenelon Falls outlet, probably leaving the Port Huron as the only outlet (*See* Chapter V). In addition, the narrow channels at Barrie and through Coldwater Valley were closed.

Upper Orillia Beach. This 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 Ontario Hospital 2 miles to the southwest, and again 1 mile north of Bass Lake, where it forms a 25-foot bluff. Like the other lower beaches, the Upper Orillia is more pronounced on the islands and headlands in the northern part of the map-area. In the southern part, low beaches of this stage can be seen on the south shore of Kempenfelt Bay and again 4 miles west of Sutton. The slope of the water-plane of the Upper Orillia is 3·7 feet per mile at Uphill and 2·4 feet per mile at Keswick. The Upper Orillia is drowned by Lake Simcoe at the southern end of Cook Bay. The present Holland Marsh dates from this time although it had been a very shallow lagoon even in the Ardtrea stage.

Goldthwait found beaches that would correspond with the Upper Orillia, namely: at Kincardine, 636 feet, 31 feet below the Algonquin beach; at Port Elgin, 671 feet, 39 feet below; and at Bolsover, 806 feet, 51 feet below.

Lower Orillia Beach. This beach, although conspicuous in Orillia, shows its best development just west of the Ontario Hospital. It is marked by relatively few bluffs as compared with the Upper Orillia beach. Several low bluffs and gravel ridges mark this stage on the islands in the northern part of the area. The only good exposure in the southern half is in a 7-foot bluff about 2 feet above the high-water level of Lake Simcoe 1 mile east of Allandale. The slope of the water-plane is 3·3 feet per mile at Waubaushene and 2·4 feet per mile at Barrie. At the conclusion of this stage, the narrow channel of Sturgeon Valley was closed. 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. This beach is not strong in the Georgian Bay area, and is even less pronounced in the Lake Simcoe area. A few weak bluffs mark this stage on the islands north of Bass Lake, and the only evidence in the eastern half of the area is a 4-foot bluff 4 miles southeast of Uphill. The beach indicates only a short pause of Lake Algonquin at this level. It may be that the lake at this stage fluctuated, resulting in partial destruction by drowning, as suggested by Stanley (19, p. 1680). The slope of the Wyebridge water-plane is 2·7 feet per mile north of Orillia.

Penetang Beach. This beach is exposed only in the northwest part of the area where it is marked, on Ardtrea Island, by a gentle slope, in sandy deposits. Another locality, 4½ miles north of Orillia on the road to Uhthoff, shows an excellent exposure. 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 formation of this beach. A third locality is west of Eady, where a 7-foot bluff and sloping, boulder strewn terrace mark the position of the beach. The Penetang indicates a relatively long stand of the lake at this level, as the beach is stronger than any of the beaches between it and the main Algonquin beach.

Cedar Point Beach. Like the Penetang, the Cedar Point beach is confined to the northwest part of the map-area. It is found on the west side of Ardtrea Island and at the base of the 60-foot bluff mentioned in connection with the Penetang beach. At these points the shoreline is 20 feet below the level of Lake Couchiching and separated from it by a height of land. Couchiching and Simcoe must have existed as lakes separated from Lake Algonquin shortly after the Penetang stage. Further evidence of this beach is found in the Sturgeon Bay area. The upper strong bluff and terrace of the strand lines at Waubaushene (*See* Plate I) is not the Cedar Point but one of the intermediate beaches between it and the Penetang. The strong bluff of this intermediate beach disappears to the west, diminishing into a gentle slope on which are three weak terraces. The upper of these three terraces is the Cedar Point beach.

Payette Beach. This beach is well developed in the vicinity of Coldwater and Waubaushene. In Plate I, it is the strong middle bluff and terrace truncated by the lower (Nipissing) bluff. The southern limits of this shoreline in Coldwater Valley are marked by low gentle slopes in the lacustrine deposits near Eady.

Nipissing Beach. The Nipissing and Waubaushene beaches, although not belonging to the group of Algonquin beaches, are included to complete the record of abandoned shorelines in the map-area. The Nipissing marks the beginning of a new phase in the history of the Great Lakes, but the Payette beach, immediately above it in this area, does not necessarily represent the end of Lake Algonquin. As Stanley (20, p. 1953) has shown, the Payette beach was drowned by the Nipissing in the Wasaga Beach area, and the discordance between the two water-planes is accentuated by the convergence of the beaches in Waubaushene area. The lowest of the three strong bluffs in Plate I is the Nipissing, and, although not brought out forcibly in the photograph, it represents the longest stand of the Great Lakes since the formation of the main Algonquin beach.

Waubaushene Beach. This beach, well shown at Waubaushene, belongs to the Nipissing group rather than to the Algonquin, for it is not a drowned beach. It is developed in the lacustrine deposits of the Nipissing terrace. At Waubaushene, it is marked by 5-foot bluffs 20 feet below the Nipissing beach, and 37 feet above the water level at Georgian Bay.

Other Beaches. Mention should be made here of beaches and ridges other than those referred to above, as they indicate the nature of the subsidence of Lake Algonquin. In the southern part of the area there are only a few, other than the named beaches, developed, whereas the northern part includes numerous beaches and ridges, some above the Algonquin and some between the other beaches. The strongest features were chosen to mark the water-planes of each of the beaches described. The number of intermediate beaches is less in the 'lower group' than in the 'upper group'.

About 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 examples that mark this temporary level 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 several localities west of Ardtrea Island and also west of Uphill. 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 appears to have been rapid, with insufficient time to develop distinctive beaches at other levels.

Impounded Beaches. In each of the small bays of Lake Algonquin, southwest of Orillia, are ridges and bluffs that were at first thought to be correlative 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 seemed improbable that wave action there could be of sufficient strength to develop the beaches. They were later recognized as impounded beaches, which Stanley (21, p. 1672) defines as beaches that were submerged and protected behind a higher beach that was formed at a later stage of the lake. The evidence for impounded beaches found on Georgian Bay and in the Lake Simcoe area substantiates the conclusion reached by Johnston (14) that prior to the formation of the highest Algonquin beach Trent Valley was the sole outlet, and that during this time the lake was considerably lower. With uplift of the Fenelon Falls outlet the lake level rose. It is suggested that these lagoonal 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 a 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. Paralleling 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.

INTERPRETATION OF RESULTS

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

Critical facts derived from the profile map (*See* Figure 7) have been arranged in Table III, 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.

TABLE III

Comparison of the Water-planes in the Penetang and Orillia Areas

Water-plane	Orillia at Silver Creek Station				Penetang at Giants Tomb Island			
	I Measured elevation of beach	II Slope of water-plane per mile (feet)	III Interval between successive water-planes (feet)	IV Convergence of successive water-planes (feet per mile)	I Measured elevation of beach	II Slope of water-plane per mile (feet)	III Interval between successive water-planes (feet)	IV Convergence of successive water-planes (feet per mile)
Algonquin.....	856	3·52			875	3·38		
			20	0·52			.....	.....
Ardtrea.....	836	3·00	.....		.....	.....		
			29	0·10			.....	.....
Upper Orillia..	807	2·90	92		.....	.....	90	
			22	0·00			.....	.....
Lower Orillia..	785	2·90			.....	.....		
			21	0·15			.....	.....
Wyebridge.....	764	2·75			785	.....		
			40	.....			37	.....
Penetang.....	724	.....			748	3·00		
			24	.....			24	0·125
Cedar Point....	700	.....			724	2·875		
			35	.....			38	0·125
Payette.....	665	.....			686	2·75		
			30	.....			46	2·33
Nipissing.....	635	.....			640	0·42		
			19	.....			.....	.....
Waubaushene...	616	.....			.....	.....	60	0·42
			35	.....			.....	.....
Lake Huron....	581	0·0			580	0·0		

Exposures of the lower group of beaches are limited in this area; consequently, no great reliance can be placed on the rate of slope of the water-planes, and the tilt rate as found by Stanley should be taken as more accurate.

The following conclusions may be drawn from a study of the profile map of the water-planes: the first is the stability of most of the area during the formation of the main Algonquin beach; the second is the convergence of the uppermost beaches, indicating differential uplift; and the third is the general parallelism of the lower Algonquin beaches, again indicating stability.

The main Algonquin beach is the strongest and most distinctive of all the Algonquin beaches and indicates land stability during its formation, particularly in the southern parts of the area. In the northern part difficulty was encountered in determining the actual elevations marking the water-plane. In places, two or even three minor bluffs replaced the usual, strong, single bluff; well-formed beach ridges and bars were found both above and below the elevation taken for the Algonquin water-plane. These

anomalies were not encountered in the southern part of the area. They suggest an initial, or local, uplift, confined to the area immediately in front of the ice-sheet, greatest close to the ice-front and diminishing away from it. Thus the northern part of the area would be subjected to small, spasmodic uplifts that might not have extended very far to the south. Weak beaches would be formed during minor pauses in this initial uplift, and in protected localities the older, higher beaches might be preserved, whereas in open regions wave action at lower levels could encroach on the bluffs, removing the evidence of higher beaches, and leave a single, strong bluff. In the southern parts, where less tilting occurred, the water level would remain stationary, or even rise due to the uplift in the north, thus continuing to develop a single, strong shoreline. It is also possible that the minor beaches replacing the single Algonquin beach indicate a new, hitherto unknown, hinge-line just north of Orillia. Further investigation northward into the Canadian Shield would be necessary to prove the existence of a hinge-line.

The convergence of the uppermost beaches, particularly the Ardtrea with the Algonquin beach, indicates a period of crustal upwarping on a regional rather than local scale. This uplift may have commenced while the main Algonquin beach was being formed, but was interrupted by short periods of crustal stability during which the beaches of the 'upper group' developed. The uplift appears to have been rapid at first, as shown by the marked convergence of the Ardtrea and Algonquin beaches, but the rate decreased until movement had stopped at the Lower Orillia beach stage. It is not inferred that no other stands of lake level occurred other than at the Ardtrea and Upper Orillia beach levels during this period of uplift, for the numerous beaches and ridges at various altitudes between the Algonquin and Upper Orillia beaches suggest a spasmodic tilting throughout, but that the period of quiescence was longer at these two stages. The hinge-line for this upwarping appears to have been the Algonquin and Nipissing hinge-line (8, p. 420) that passes through the lower part of the Huron basin.

The general parallelism of the Lower Orillia, Wyebridge, Penetang, Cedar Point, and Payette beaches indicates crustal stability; the uplift that followed the main Algonquin beach stage had died out. Because of this parallelism, it must be concluded that a factor other than differential uplift is responsible for the development of the lower beaches. This is the lowering of the lake level by opening of other outlets as the ice retreated northward. Before the Lower Orillia beach stage, both the Fenelon Falls and Port Huron outlets were closed; therefore, new outlets must be postulated, and these could only have been found in the Precambrian regions between the Palæozoic border and the Ottawa River Valley or in the Ottawa Valley itself. Each outlet carried the whole discharge long enough for a beach to develop. As the glacier retreated, a new outlet would be found at a lower elevation, and the level of the lake would be rapidly lowered to this elevation, at which it stayed until a lower outlet was discovered. At some time following the Payette beach stage, the period of crustal stability was again interrupted by a differential uplift.

The Algonquin and Nipissing beaches are by far the strongest, and represent the longest stands of lake level. However, neither one is as strong as the combined 'upper and lower groups' and, therefore, it can be con-

cluded that the interval between the Algonquin and Nipissing beach stages was greater than the stand at either of these two stages. This conclusion is strengthened by the convergence of the water-planes. There is greater convergence between the water-planes of the Payette and Nipissing than between the Payette and Algonquin or the Nipissing and Lake Huron. If the uplift has been uniform, then the interval between the Payette and Nipissing is by far the greatest. If the uplift has been decreasing steadily, then this interval is still greater than the Algonquin-Payette interval. Only on the assumption that rapid regional uplift was confined to the Payette-Nipissing interval could this period be inferred to be shorter than the others.

There is no conclusive evidence that Lake Algonquin was at any time higher than the level represented by the main Algonquin beach. Ridges do occur up to 20 feet above the Algonquin beach, notably on the limestone plain at Uphill. These ridges are composed of blocks of limestone that show little or no rounding, and may represent ice 'ramparts'. Similar 'ramparts' have been noted about 5 feet above water level on the islands in Lake Couchiching. South of Kempenfelt Bay ridges of gravel have been noted about 100 feet above the Algonquin shoreline, but these are interpreted as ice-contact deposits laid down before the Early Algonquin stage, when the Simcoe basin was filled with ice.

Several conclusions may be drawn from a study of the ridges and bars. Ridges parallel with a shore bluff are generally of the submerged type, the top of the ridge 2 to 8 feet below the base of the bluff. 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. All bay-mouth bars and spits are 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 bay-mouth bars of a higher beach where conditions were more favourable for their formation. The paucity of these features may be explained by more protected terrain of the lower stages, which resulted in less violent wave action. No bays are associated with the lower beaches, as the bay-mouth bars of the Algonquin beach effectively sealed pre-existing bays. Bluffs of the lower beaches are less common where the shore was on a boulder-strewn, wave-cut terrace of the Algonquin; they are numerous where the shore was in sandy deposits of a wave-built terrace. The shorter stand of lake level during these lower stages is also an important factor in the poorer development of the shoreline features.

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. Although it is true that the reach of the water was probably more extensive to the north than in other directions, yet the water extended sufficiently far to the east and southeast to permit large waves. Another explanation for the strong development of north-facing beaches may have been the calving of the glacier. As the glacier formed the north shore of Lake Algonquin, large blocks of ice falling from the face of the glacier into the deep water could have produced exceedingly large waves. However, the wave effect produced by calving ice is probably over emphasized because of neglect to consider the damping effect of floating ice. In addition, the Algonquin beach is continuous far to the north of these strong shore cliffs, so that the ice-front had retreated sufficiently far northward beyond the point where wave action due to calving could be effective.

CHAPTER V

HISTORICAL GEOLOGY

PREGLACIAL DRAINAGE SURFACE

Very little is known about the drainage surface prior to the Pleistocene glaciation because of the covering of drift over most of southern Ontario, and only a few oil, gas, or water wells penetrate to bedrock. However, an attempt has been made to contour the bedrock surface in the Lake Simcoe area, using the information collected while making a ground-water survey. Figure 8 shows the bedrock contours. Positive information obtained from outcrops, water wells, and oil wells penetrating bedrock is indicated, and the contours in such places are drawn with confidence. Over large areas such information is lacking, and the depth to bedrock can only be inferred; the information from deeply drilled drift wells indicates that the drift is thick and the bedrock lies somewhere below the elevation given for the bottom of the well.

As an agent of erosion, ice has long been the subject of serious discussion. Moore (19, p. 16) states that it is doubtful whether the average thickness of solid rock removed from the Canadian Shield by the recurring ice-sheet amounts to more than a very few tens of feet at the most. It is suggested that this applies not only to the granitic rocks but also to the softer Palæozoic rocks as well. In places, at the contact of the Precambrian and Palæozoic rocks, the granites outcrop as low, smooth, rounded hummocks, but are devoid of any evidence of glacial erosion; these outcrops represent the original surface when covered by the Palæozoic seas. They resemble their glaciated neighbours to the north in that they exhibit a similar hummocky appearance, but differ from them in that the ice-eroded forms bear chattermarks and grooves, and the surface of the hummocks are often irregular due to ice plucking. If glacial erosion had been deep, the same general hummocky form would not be the same for both, or the outcrops at the contact would show evidence of plucking and abrasion. In all probability the action of the final glacial readvance was to remove the last thin covering of sedimentary rock.

The thin drift on the Canadian Shield also points to shallow erosion. Overloaded ice soon deposits its load, as shown by the increasing thickness of drift immediately south of the Palæozoic contact, yet the glacier in most places continued to scour the soft limestones for some distance after leaving the crystalline rocks, as, for example, south of Uphill.

Two sets of intersecting striæ also favour slight local erosion. Although it is true that of the two sets at Uhthoff the younger set might indicate only a change in direction of ice motion, or at the most a minor readvance, still the final erosion was not sufficient to remove the deeper, older striations.

The flat-lying attitude of the limestone would offer but little resistance to the ice. Erosion was by plucking and abrasion. Scarps show that plucking was an important process, but in many places the scarps are only 3 to 5 feet high, and where higher they might have obstructed the

movement of the ice. Abrasion was no doubt reduced to a minimum by the compact, flat-lying limestone, but this was offset to some extent by the hard granitic boulders in the ice that acted as abrasive tools. However, continued abrasion would load the base of the ice with rock-flour, thus reducing erosion.

Only at one place, 5 miles north of Orillia, have large blocks of limestone, the result of plucking, been seen. This general absence of large limestone blocks indicates that large-scale plucking had only limited application.

Coleman deduced that the erosion is considerable only near the margin of a large ice-sheet; elsewhere it is relatively slight. If so, then erosion was active only during the initial advance of each continental glacier or during any readvance of the ice, thus limiting it to only part of each glacial stage.

Although it is fully realized that the drift between Lake Couchiching and Toronto, which near Thornhill attains a thickness of more than 600 feet, is derived largely from Palæozoic rocks and represents a vast quantity of eroded bedrock, yet this drift was collected from a large area, and it is, in the main, the total drift accumulated during all glacial stages of Pleistocene time. Remnants of the Palæozoic rocks remain a few miles north of the present contact with the sediments, and undoubtedly a thin covering extended far into the Canadian Shield. It is suggested that the thick drift now covering the bedrock south of the Precambrian rocks was derived in part from these few tens rather than hundreds of feet of removed rock. At Uphill, the granitic rocks are now overlain by 100 feet of Ordovician limestone. It cannot be argued, however, that the same, or a greater, thickness of limestone was spread over the Canadian Shield to the north, and was removed during the Pleistocene time, because weathering and erosion from the time these sediments were raised out of the Palæozoic seas up to the end of the Pliocene epoch of Tertiary time must be taken into account. If any formations younger than the Trenton extended into the Shield they were eroded before Glacial times; no detritus younger than Trenton has been found in the drift, even in the deepest exposures, north of Cannington.

In all probability the topography during Pleistocene interglacial periods was not very different from that of today. Lakes, lowlands, highlands, drumlins, and moraines were distributed much as they are now, the main difference being that the thickness of drift was increased northward with each ice invasion. The thick drift of each former glaciation tended to protect the bedrock from further erosion by the succeeding glaciers. In this way the preglacial drainage pattern would be preserved. Such a pattern is indicated by the present bedrock surface. It is certain that no deep stream valleys were present in the granitic basement prior to Pleistocene time in the rock-knob lowlands. The present bedrock surface in the Ordovician strata indicates drainage to the south; therefore, only shallow valleys were present in the northern areas of the Palæozoic rocks within the map-area.

It might be reasoned that the drainage pattern on the bedrock surface is that of the Sangamon interglacial stage. The present drainage generally follows pre-Wisconsin valleys, and, therefore, Sangamon drainage probably followed pre-Illinoian valleys. If the present is the key to

the past, then the Sangamon drainage was not deeply incised. The amount of stream erosion in bedrock since the retreat of the Wisconsin glaciers is almost negligible. In Black and Head Rivers, which flow entirely within the Canadian Shield, the maximum erosion is 3 to 4 feet. In the limestone it is even less; most streams that are still downcutting have a gravel or till stream bed. In the rare places where bedrock is exposed in the stream channels, the maximum amount of rock eroded does not appear to exceed 2 or 3 feet.

Spencer described the route of a great preglacial river, which he called Laurentian River, that existed before the Great Lakes were formed and drained their valleys south past Toronto. The upper part of this river came from Georgian Bay past Barrie, Newmarket, and Richmond Hill. A. K. Watt (personal communication), in his investigations of ground water in the Toronto area, has found several north-south trending valleys, the largest of which extends northward toward Newmarket. Investigation in the Lake Simcoe area and westward to the Niagara escarpment also shows that the large valley in the Toronto area extends northward from Newmarket, and then trends to the west through Bradford, and up into Nottawasaga Valley. Although several holes penetrate to bedrock they are not numerous enough to locate this valley accurately, but they do indicate its presence and support the theory of the Laurentian River.

The present streams of the Lake Simcoe district generally follow preglacial valleys that were tributaries of Laurentian River. A small tributary flowed southward from Uphill, through Dalrymple Lake, and into Lake Simcoe where it was joined by another stream flowing southwest from Canal Lake. Two other streams joined those from the north in the lake Simcoe basin; both flowed northward, the one in the valley now occupied by Beaverton River and the other in the valley of Pefferlaw Brook. The steep, 100-foot bluff now forming the south bank of Head River just south of Uphill may be the edge of the preglacial escarpment. The bluff stands at right angles to the general direction of ice movement, and it is very doubtful if Pleistocene or Recent stream erosion or glacial erosion could have formed this escarpment.

The course of Laurentian River west and south of Lake Simcoe is a matter of speculation. Whether the river flowed southeast between Alliston and Cookstown to just south of Newmarket, or whether it turned eastward near Minesing Swamp to flow through Kempenfelt Bay and then turned abruptly south into Cook Bay, is unknown. The latter course is preferred by the writer, because it coincides with the deep valleys of Kempenfelt and Cook Bays.

Little is known about the bedrock surface between Barrie and Coldwater because of the great thickness of drift and the absence of wells penetrating to bedrock. Bedrock outcrops along most of the shore of Georgian Bay around Waubaushene. A preglacial tributary of Laurentian River flowed south from Matchedash Bay or Sturgeon Bay, or both. Coldwater River now flows north into Matchedash Bay, but the slope of the bedrock surface in the valley is to the south. This preglacial valley may have extended south to join Laurentian River Valley near Kempenfelt Bay, or it may have turned westward along a course now followed by Coldwater Valley. Little is known about Sturgeon Valley.

The generalized map of the bedrock surface is not intended to portray the erosion surface of the late Tertiary time. Many of the small, flat, plateau-like 'islands', similar to Georgina and Thorah Islands in Lake Simcoe, are, in part, the result of glacial erosion. They are remnants of a Tertiary peneplain that extended south to the Niagara escarpment. Northeast of Lake Simcoe, the peneplain was slightly dissected by tributaries of the preglacial Laurentian River; to the southwest it was deeply incised by Laurentian River Valley, so that the general slope of the erosion surface was to the southwest.

EFFECT OF GLACIATION ON PREGLACIAL VALLEYS

The probable results of Nebraskan glaciation would be the general interruption of the Pliocene drainage system. Valleys transverse to the direction of ice movement would become choked with drift; valleys parallel with this direction would be preserved, for in them the ice advanced as lobes that may have deepened some valleys or become stagnated in others, serving to preserve the valley while the surrounding ice advanced and deposited material on the highlands. This preservation of valleys parallel with the direction of ice movement is well illustrated in the Lake Simcoe and Georgian Bay areas. South and west of Lake Simcoe, several of these finger-like valleys extend from the lake basin. At present they are occupied by misfit streams that are too small to have eroded the valley. Schomberg River, flowing northward into Cook Bay, is a good example of such a stream. Coldwater and Sturgeon Rivers occupy valleys that were filled with ice from the Georgian Bay area. Not only did the ice advance and readvance as lobes but during its retreat the ice remained in the valleys after it had disappeared from the highlands. The steep sides in Sturgeon and Coldwater valleys are not the result of wave action from glacial Lake Algonquin, but must have been eroded, or retained, by ice filling the valley. Ice-contact deposits are found at the tops of these valley walls and represent kame terraces. In the Holland Marsh, 3 miles south of Bradford, deltaic deposits of sand and gravel are exposed on both sides of the marsh, and represent outwash from a valley ice-lobe. The sand and gravel are overlain by 6 to 8 feet of interbedded till and varved clay laid down during a slight readvance of the lobe.

Innisfil Creek, which flows south of Cookstown and joins Nottawasaga River, occupies a valley that was filled with an ice-lobe. In addition to ice-contact deposits overlain by till, kame and terminal moraines mark readvances of the lobe in this valley. 'The Hollows', 4 miles southeast of Cookstown, is a large amphitheatre thought by some to result from melting of a huge block of stranded ice. However, the high ridge that separates the amphitheatre from the valley is a terminal moraine formed by an ice-lobe that advanced down the valley. The amphitheatre was formed, not by the melting of a stranded block of ice, but by a morainic ridge that partly closed off an embayment in the valley.

In all probability each new advance of a glacier did not materially change the pre-existing topography.

SEQUENCE OF EVENTS DURING DEGLACIATION

Figure 9 (in pocket) depicts the sequence of events from the time the glaciers withdrew from the Niagara escarpment, through the period of growth of the various stages of Lake Algonquin, and up to the time the ice-front had retreated from the Lake Simcoe area. The position of the ice-lobe fronts and the direction of movement in the lobes have, in part, been adapted from Putnam and Chapman (2, p. 459).

NIAGARA ESCARPMENT SPILLWAY AND KAME TERRACE STAGE

Figure 9A represents the stage when the ice in the two lobes, the northern lobe occupying the Georgian Bay and Lake Simcoe basins, and the southern, or Ontario, lobe occupying the Lake Ontario basin, fronted the Niagara escarpment. At some time prior to this stage the two lobes were united as a continuous ice-sheet, and only Ontario Island was free of ice. It was at this time that the spillways, some of which are shown in Figure 9A, functioned as outlets for the meltwater. They generally followed depressions on the glacier side of terminal moraines that were deposited earlier. These spillways are now occupied, in part, by misfit streams of the present drainage system; they were contemporaneous with glacial Lake Lundy or even glacial Lake Warren in the Lake Erie basin.

The spillway through Feversham (No. 1) is at an elevation of about 1,550 feet, and was effective when the ice lay above the Niagara escarpment. The spillway south from Dunedin (No. 2) follows along the top of the escarpment, crosses Pine River 4 miles east of Horning Mills, and passes through Mono Centre and Orangeville. At Dunedin, the elevation is about 1,450 feet and at Orangeville about 1,350 feet. A lower spillway (No. 3), starting just east of Dunedin at an elevation of about 1,375 feet, can be traced southward and probably joins the higher spillway south of Mono Centre at an elevation of 1,350 feet, or it may have found depressions at slightly lower elevations.

Everywhere associated with these, and lower, spillways are flat-topped remnants of kame terraces that were formed between terminal moraines or the escarpment and the ice-front, in narrow ice-border streams. The terraces are found mainly between Dunedin and Orangeville at elevations from about 1,500 feet to about 800 feet. The material is sand and gravel, varying in thickness from a few feet to more than 200 feet. Where the deposits are thin, terminal moraine commonly rises above the terraces, and in deeply eroded valleys the underlying till is commonly exposed. The streams, finding their original channels indented in the escarpment, incised the drift and kame terraces choking the valley as they followed the retreating glacier down the escarpment slopes, carrying the material first to lower terraces and finally into Lake Algonquin basin.

As these terraces, and other evidence of glacio-fluvial deposits, are absent from the face of the escarpment at the higher altitudes from a point a little north of Dunedin, it is probable that the glacier abutted the escarpment in the Georgian Bay area and prevented escape of the meltwaters to the north. The discharge was to the south into Lake Lundy.

The Oak Ridges interlobate moraine was being formed at this time, probably during the later part of this stage. It was certainly formed before the succeeding Lake Schomberg stage.

LAKE SCHOMBERG STAGE

With the further retreat of the glacier of the first stage, the meltwater formed a narrow marginal lake between the ice-front and the highlands of the moraines to the south and the escarpment to the east (Figure 9B). The marginal lake, called glacial Lake Schomberg by Putnam and Chapman (2, p. 466), was of short duration; it has no recognizable shoreline features common to the well known glacial lakes; and its extent is determined by the occurrence of varved clays and silts on the bed of the lake. The position of the eastern area of Lake Schomberg clays is adapted from the map by Putnam and Chapman (2, p. 461). Numerous islands dotted the marginal lake. Putnam and Chapman describe the lake as a series of temporary lakes, but they must have been joined to give escape to the meltwater. In places the narrows connecting the larger bodies of water must have resembled spillways (*See* Plate XII B).

The outlet for Lake Schomberg is not known. Varved sediments occur up to an elevation of about 875 feet in the vicinity of Schomberg, and in all probability the lake level was not much more than 900 feet above sea-level. Three possible spillways (Nos. 4, 5, and 6, Figure 9B), may have served as temporary outlets at an early stage of this lake. The Canadian National and Canadian Pacific railways follow a valley (Spillway No. 4) through Palgrave that may have carried the discharge, although near the present height of land spillway features are generally lacking. The elevation of this valley is about 950 feet. The spillway south of Schomberg (No. 5) joins Humber River at Bolton; its elevation is about 950 feet. The lowest spillway (No. 6), with an elevation of 925 feet, joins the Humber at Kleinberg. In all three of these spillways, the characteristics of channels carrying a large volume of water are obscure near the crests of the valleys, which are now occupied by streams flowing to the north and south. These streams are all misfits, thus lending support to the possibility of the valleys being spillways. The most plausible outlet (No. 7) was to the northeast between the ice-front and the Niagara escarpment. A well-established spillway cannot be found, but here and there is evidence of water action up to about 100 feet above the Algonquin shoreline. This evidence is in the form of strong boulder pavements and modified bluffs. A final alternative outlet (No. 8) was to the east around the ice-front to join the meltwaters of the Ontario lobe, but the writer lacks sufficient knowledge of this area to support this possibility.

The elevation of the water-plane of Lake Schomberg has been taken as about 100 feet above the Algonquin shoreline. However, as will be discussed below, there was considerable uplift before the main Algonquin shoreline was formed, so that the area at the time of Lake Schomberg may have been as much as 100 feet lower than the water-plane of Lake Algonquin, thus giving Lake Schomberg about the same elevation as Early Lake Algonquin[1] in the Huron basin.

Lake Schomberg existed for only a short time and under conditions of a fluctuating ice-front. Just west of Bradford, the section of varved clay, showing about 100 varves, is not more than 4 feet thick. Along the southern borders of the lake the section is nearly 50 feet thick, as shown

[1] Early Lake Algonquin, the first stage of Lake Algonquin, was confined to the southern part of the Lake Huron basin, and did not cover any part of the present Georgian Bay basin. The discharge was southward into Lake Erie through the Port Huron outlet.

by Putnam and Chapman (2, p. 466). Two miles west of Tottenham, a well dug 30 feet in varved clays had not reached the base of the section. Individual varves along the southern borders are generally thick, with a maximum of 20 inches (*See* Plate XIII A) and averaging 7 or 8 inches. Cuts along the new highway north of Schomberg indicate a readvance of the ice-sheet during the Lake Schomberg stage. One exposure showed 5 feet of brown, sandy till, underlain by 6 feet of varved clay, and overlain by 5 feet of varved clay. Another cut showed boulders of till folded into varved clays. Some of the varves were vertical, and could not have resulted from depression by ice-rafted blocks of frozen till. Plate XIII B shows contorted and folded varves overlain and underlain by till in a road-cut just south of Holland Marsh on the new highway. The ice-front was lobate in form, with ice filling the finger-like depressions. The varved sediments are absent in many places below 875 feet, showing that ice occupied these lower elevations at the time of Lake Schomberg.

Between Barrie and Schomberg several deposits of stratified sand and gravel resemble shore features, and have been included in the Lake Schomberg deposits by some investigators although not considered so by the writer. Four localities will be mentioned: the first is the flat sandy plain between Allandale and Thornton; the second is the gravel and sand ridges and bluff just south of 'The Hollows'; the third, the sand and gravel bluff and ridges 2 miles south of Beeton; and the fourth, the sand and gravel ridges and bluff 2 miles west of Schomberg. The elevation of the deposits at these four localities is slightly more than 1,000 feet.

If these were Lake Schomberg sediments, then glacio-lacustrine deposits should be exposed between this elevation, 1,000 feet, and that of the varved clays, 875 feet. However, the sand and gravel ends rather abruptly within a short distance of the ridges, and till is exposed at the surface between the two elevations. In addition, lacustrine deposits are lacking between these elevations above the Lake Schomberg limits to the south. The first deposit is mapped as outwash. The other three are mapped as kame moraine deposits, because stratified sand and gravel comprises the bluff that rises 25 to 50 feet above the terrace-like base and the topography in places is that of kame moraine. Slumping of the material that abutted the ice-front may have resulted in the present steep faces that resemble lake bluffs.

The Schomberg Lake plain is unlike the Algonquin Lake plain in that the area is generally undulating to rolling. This is due in part to the topographic expression of the underlying material and in part to erosion. Till ridges, drumlins, and hills of ground moraine rise above the clay deposits in many places, and where the hills are only thinly covered the topography of the underlying material is reflected by the initial dip of the sediments. Erosion has been extensive, particularly in the silty deposits. Around Newmarket, in the Schomberg silts, erosion has produced a topography not unlike terminal moraine.

FENELON FALLS OUTLET STAGE

At its third stage, the glacier had retreated far enough to the north to open the outlet through Kirkfield, Fenelon Falls, and Trent Valley into glacial Lake Iroquois. Taylor and Johnston had found evidence that the level of Lake Algonquin was lowered from 50 to 100 feet by the original

opening of the Fenelon Falls outlet. Additional evidence is given here in support of this idea.

The retreat of the glacier between the Lake Schomberg and Fenelon Falls outlet stages must have been fairly rapid if the discharge followed the route through Fenelon Falls, as shown in Figure 9C, because this area was depressed sufficiently to receive the water from the Huron basin, and there is no evidence to show a ponding of water between the Algonquin shoreline and Schomberg clays. The other alternative is that another outlet south of Fenelon Falls was open but later closed by the readvance of the ice to the succeeding, or Lake Simcoe moraine, stage shown in Figure 9D. The ice-front between Lake Simcoe and Georgian Bay is placed as in Figure 9C, because a long stand of the ice there is necessary for the formation of the Bass Lake kame moraine.

Johnston (14, p. 16) estimated a rise in the lake level of at least 50 feet between the Fenelon Falls and the fifth or 'two-outlet' stages, based on evidence of a distinct disconformity in lacustrine sediments. The same evidence was found by the writer in Nottawasaga Valley near Alliston. In several localities the top 6 to 8 feet of lacustrine sands of main Lake Algonquin contained numerous fossil freshwater shells of several species; below 8 feet no fossil shells were found. In one place the base of the fossil zone was marked by a disconformity (*See* Plate XIV A), the elevation of which is 700 feet, 50 feet below the Algonquin water-plane. In the Boyne River banks, 2 miles east of Alliston, the top of the unfossiliferous sands is at an elevation of 695 feet, and their base was not exposed at 645 feet, or 90 feet below the Algonquin water-plane. These sands are well stratified and crossbedded, and in places are interbedded with gravel, indicating general shallow water deposition. The material was undoubtedly brought in by Boyne and Nottawasaga Rivers, as they cut down through the kame terraces along the base of the Niagara escarpment. It is suggested that these deposits accumulated during the low-water level of Lake Algonquin when Fenelon Falls was the sole outlet, or during the rising stages of Lake Algonquin when the readvancing glacier again closed the Fenelon Falls outlet.

The valleys now occupied by Sturgeon and Coldwater Rivers may, in part, be due to stream erosion during the Fenelon Falls stage as the glacier retreated to the north. Also, the valley leading into Kempenfelt Bay from the west may have been occupied by a large river carrying the meltwater from the glacier, and the discharge from Lake Algonquin in the Huron basin, into the Lake Simcoe basin and out the Fenelon Falls outlet; no other escape for the waters seems possible at the time when the Bass Lake moraine was forming.

The valley 2 miles north of Kempenfelt Bay, now occupied by Little Lake and Willow Creek, was probably formed at this time through erosion by meltwaters off the Bass Lake moraine. At the mouth of this valley is an extensive deltaic sand and gravel deposit showing the forest beds dipping consistently to the west (*See* Plate XIV B). The beds would dip to the south or to the east and west if this deposit was a bay-mouth bar of Lake Algonquin. The top of the deposit is at an elevation of 770 feet, or 30 feet below the Algonquin shoreline; the total depth is unknown, although 20 feet are exposed in the gravel pit. The elevation, attitude, and material of this deposit suggest a deltaic origin from a stream flowing

from the east and depositing the material in a lake at a lower level than that of the main Lake Algonquin, again the early low-water level of Lake Algonquin. The only stream competent to erode the valley and form the delta flowed when the kame moraine was being formed and the volume of meltwater was large. Deposition of lacustrine material in this and other valleys during the high-water level of Lake Algonquin covered the earlier stream gullies and left the flat sandy floors as seen today.

It is more difficult to trace the discharge channels east of Lake Simcoe. The elevation of the Algonquin shoreline at Kirkfield is 870 feet; the elevation of the low ground is 840 feet. This allows a lowering of Early Lake Algonquin by only 30 feet. However, a deeper channel, now filled with sediments, may exist, or an advance of the ice may have obliterated the earlier channel. Johnston (14, p. 7) states that there are two channels, with depths of 40 feet, on either side of the island in Mitchell Lake just east of Kirkfield. In order to have the water level lowered by 50 to 100 feet it is necessary to postulate a greater depression of the Fenelon Falls area than the Kempenfelt Bay area, a not unlikely possibility as initial uplift would first affect the land to the south. The difference of 30 feet between the Algonquin shoreline and the ground level at Kirkfield, together with the additional lowering supplied by a concealed channel, even if only 15 or 20 feet, and the few feet prior to the initial uplift at Fenelon Falls would be enough to give a low-water level of Lake Algonquin that would explain the valleys and stratified sediments mentioned above.

LAKE SIMCOE MORAINE STAGE

Subsequent to the Fenelon Falls outlet stage, the glacier again advanced to close off the Fenelon Falls outlet and divert the discharge water to the Port Huron and Chicago outlets. At the same time the ice-front advanced beyond the line shown in Figure 9D and into the Lake Simcoe basin. The drumlins along the north side of Kempenfelt Bay, particularly those in Little Lake valley, and the till overlying deltaic and ice-contact deposits in the finger-like valleys leading from Lake Simcoe, all indicate such a readvance. The drumlins in Little Lake Valley were formed after the valley was made, and if the origin of the valley, as suggested, is correct, then the drumlins were formed after the Bass Lake moraine of the Fenelon Falls outlet stage. In addition, the stagnant ice-fields, as indicated by the ice-block ridges, would require an advance of ice after the valley was carved. This readvance left no recognizable terminal moraine, and withdrew northeast of Lake Simcoe before pausing or slightly readvancing to form the Lake Simcoe moraine. This moraine, indicating that the pause of the ice-front was of short duration and that the deposits were laid down in water, has been traced from northwest of Lake St. John to just south of Lindsay. The position of the front east of Lindsay is conjectural.

THE 'TWO-OUTLET' STAGE

With the retreat of the northern lobe from the position as indicated in the preceding stage, the Fenelon Falls outlet was again in operation, together with that at Port Huron. The Chicago outlet may or may not have functioned at this time. This stage was indeed long compared with later stages as indicated by the strength of the Algonquin shoreline developed at this time. The ice withdrew far onto the Canadian Shield, and

if all the beaches as far north as North Bay belong to this stage then it withdrew at least to Mattawa Valley. As Goldthwait (10, p. 35) suggests, these highest beaches probably belong to some of the later stages of Lake Algonquin, as the tilt rate is not uniform, and, in fact, decreases to the north. A more detailed description of this and subsequent stages has been given in Chapter IV.

SUMMARY OF EVENTS IN THE HISTORY OF LAKE ALGONQUIN

The succession of the various stages of Lake Algonquin in the Lake Simcoe-Georgian Bay area may be enumerated as follows.

(1) In the initial stages the glacier covered the area and stood high up on the Niagara escarpment. Drainage was to the south through spillways into glacial Lakes Lundy or Warren. Kame terraces formed along the front of the escarpment.

(2) When the meltwaters were no longer able to find outlets over the highlands to the south the water ponded in front of the ice to form Lake Schomberg. Discharge was mainly around the north of the Niagara escarpment into Early Lake Algonquin or eastward into Lake Iroquois.

(3) As the northern lobe retreated to the northeast of Lake Simcoe the Fenelon Falls outlet was opened, permitting discharge through Trent Valley into glacial Lake Iroquois. The Lake Algonquin waters were lowered from 50 to 100 feet, thus leaving the Port Huron and Chicago outlets dry. The Bass Lake moraine was formed at this time.

(4) A readvance of the ice into the Lake Simcoe basin followed by a retreat and halt to form the Lake Simcoe moraine cut off the Fenelon Falls outlet and again diverted the waters of Lake Algonquin to the south through the Port Huron and Chicago outlets. This diversion was probably of short duration.

(5) The Fenelon Falls outlet was again reopened as the ice-front retreated. Differential uplift had raised the outlet area so that its relative position to the Algonquin shoreline was the same then as it is today. The discharge of Lake Algonquin was probably equally distributed between Trent Valley and St. Clair River (the 'two-outlet' stage). At this stage the main Algonquin beach was formed, and it represents the longest stand of the water at a constant level in the history of the lake. Fenelon Falls received the greater volume of discharge as it marked the site of a channel at least 30 feet deep.

(6) 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. Discharge was mainly through the Port Huron outlet, with diminishing volume through Fenelon Falls outlet.

(7) The upper Orillia beach marks a longer resting period in uplift, when discharge had been diverted to the Port Huron outlet.

(8) A drop in lake level of 20 feet resulted in the formation of the Lower Orillia beach, when in all probability the Port Huron outlet was closed. The drainage of the lake was probably due to the opening of a lower outlet to the north.

(9) A further drop in lake level of 20 feet, when still a lower outlet was 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.

(10) Forty feet below the Wyebridge beach the lake again remained constant to form the Penetang beach, the strongest of the beaches since the Algonquin. The existence of Simcoe and Couchiching as independent lakes follows this stage.

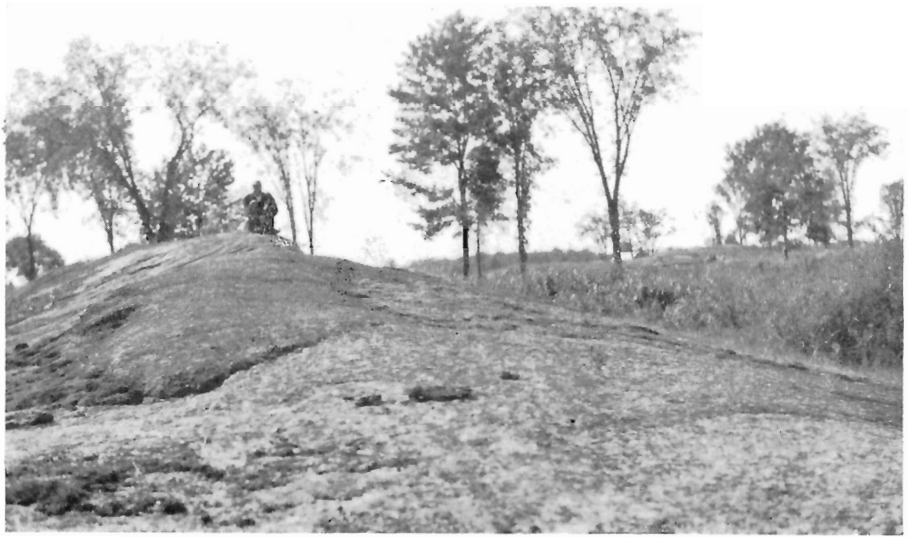
(11) Another drop of 25 feet in lake level resulted in the Cedar Point beach, which represents a stage equal to or longer than the Penetang.

(12) The last beach above the Nipissing in this area is the Payette, 25 feet below the Cedar Point. This beach is transgressed and impounded by the Nipissing farther south. Additional beaches of the lower Algonquin group may be found farther north.

(13) The Nipissing Great Lakes resulted from the opening of the Mattawa-Ottawa outlet. Prior to this last event differential regional uplift involving all of the area from just north of Port Huron to at least North Bay, occurred on a major scale, raising all Algonquin Lake beaches to nearly their present elevations. Lower stages of the Nipissing Great Lakes are indicated by the Waubaushene beach 20 feet below the Nipissing beach. If this beach is parallel with the Nipissing, it further complicates the history of the Great Lakes, marking still another period during which the Port Huron outlet was closed. If the two beaches converge, then they result from differential uplift rather than lower outlets. Still another beach, 11 feet above Georgian Bay at Waubaushene, may, together with the Waubaushene, constitute members of a group of beaches that bear the same relation to the Nipissing as the 'upper group' of Algonquin beaches bear to the Algonquin.

(14) The present Great Lakes date from the closing of the Mattawa-Ottawa outlet by differential regional uplift and final diversion of water to the Port Huron outlet.

PLATE II



A. *Roche moutonnée* of granite in the Canadian Shield, showing the gently sloping stoss end. Rama tp. (99026). (Pages 5, 9.)

B. A 5-foot escarpment in the limestone plains. Orillia N tp. (12-6, 1946). (Pages 5, 9.)

PLATE III

A. Gravelly till of ablation moraine overlying a sandy till of ground moraine. Note the layer of gravel at the base of the ablation moraine. Innisfil tp. (13-4, 1946). (Page 11.)

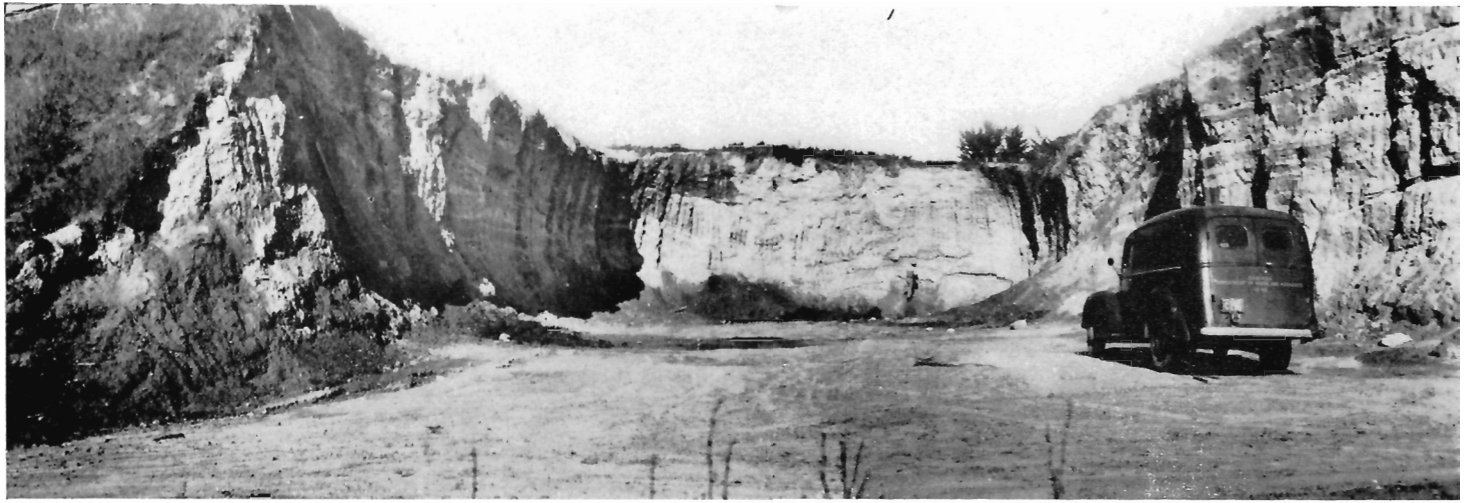
B. A small drumlin rising above sand and clay flat of Lake Algonquin. Shoreline not well developed on the drumlin. Georgina tp. (8-5, 1946). (Page 12.)

PLATE IV

A. A large drumlin partly composed of sand and gravel. Excavation shows a maximum thickness of 30 feet of stratified material. Brock tp. (1-5, 1947). (Page 13.)

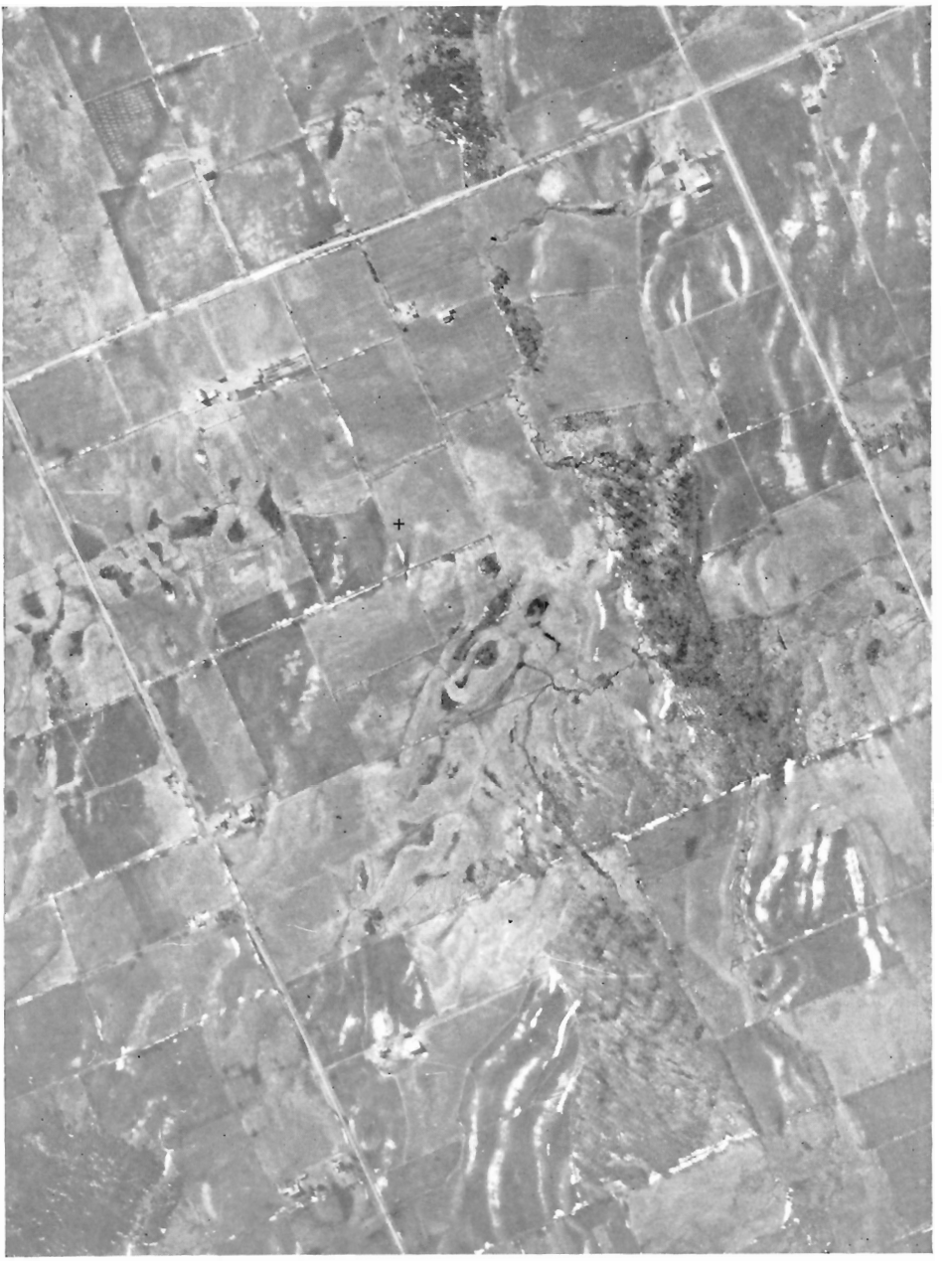
B. A road-cut in the side of a large drumlin showing two beds of sand and silt. Tecumseh tp. (4-3, 1947). (Page 13.)

PLATE V



A drumlin partly composed of stratified sand. Note horizontal beds of sand in the sides and the irregular pockets in the end of the excavation. One mile south of Bradford, Gwillimbury W. tp. (3-1, 3-2; 1948). (Page 13.)

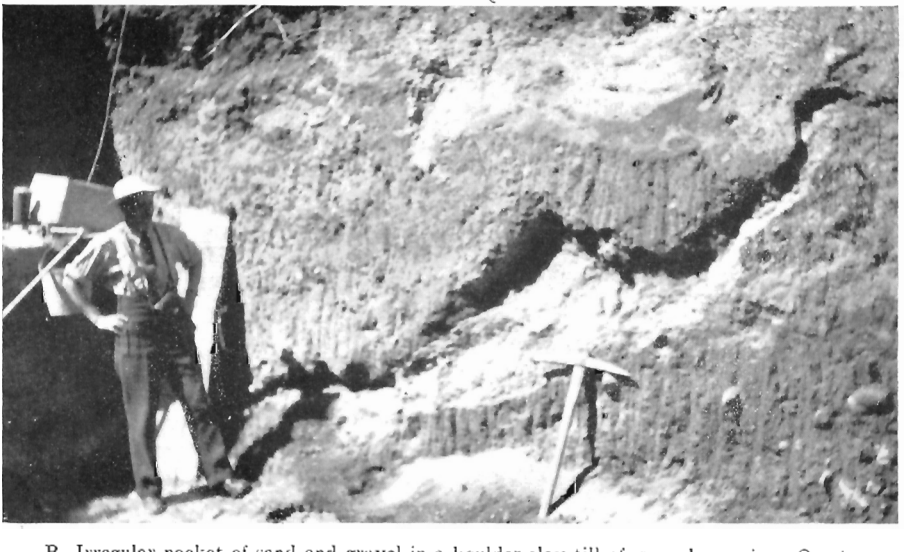
PLATE VI



Aerial photograph of ice-block ridges, showing both elongated and elliptical types. Oro tp.
(*Royal Canadian Air Force* A3243-12.) (Page 14.)

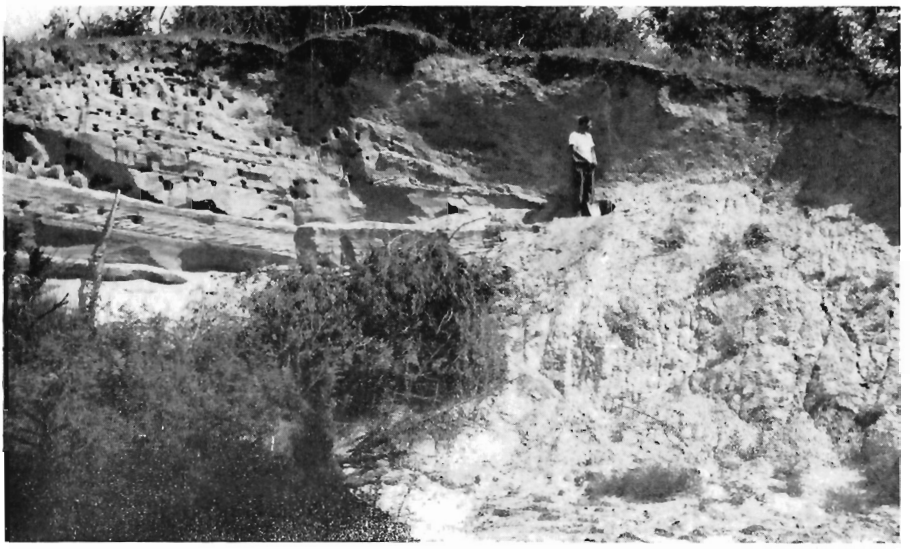
PLATE VII

A. Side view of elongated type of ice-block ridge. Oro tp. (3-2, 1946). (Page 14.)



B. Irregular pocket of sand and gravel in a boulder-clay till of ground moraine. Oro tp. (2-1, 1946). (Page 25.)

PLATE VIII



A. Stratified sand of ice-contact deposit overlain by a compact sandy till. One mile south of Cookstown. Gwillimbury W. tp. (9-4, 1948). (Page 32.)

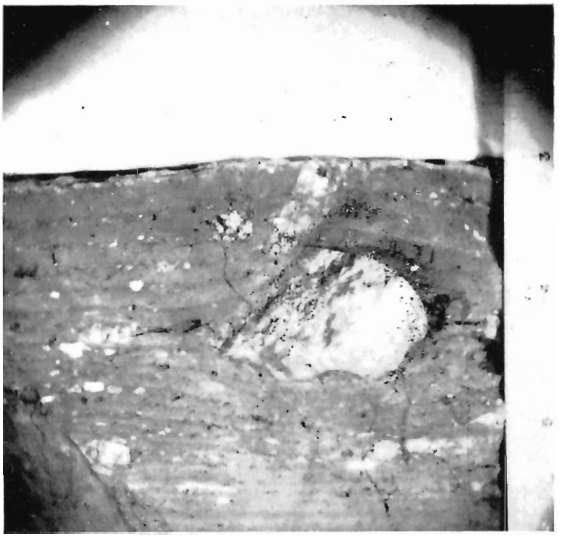
B. A single bluff of a constriction or spillway. Ice formed the other bank of the channel. Oro tp. (7-3, 1946). (Page 33.)

PLATE IX

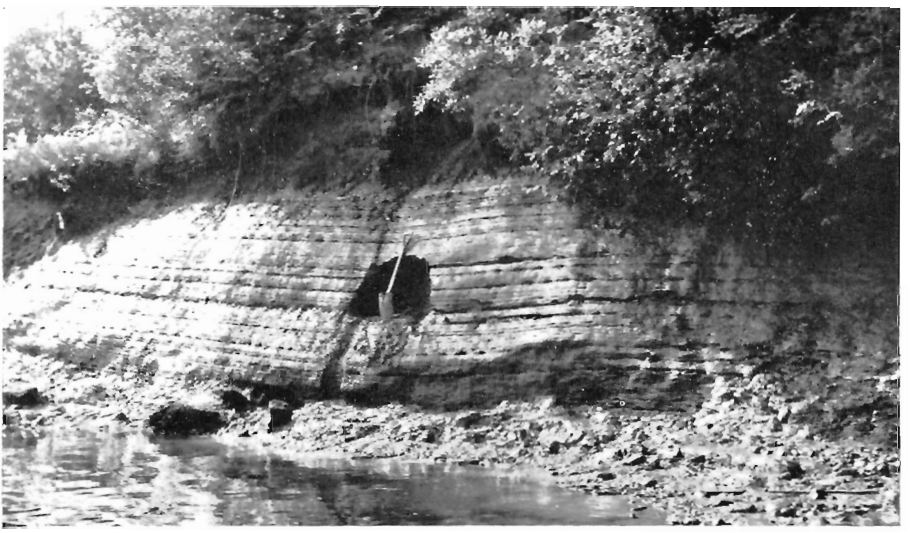
A. Cross-section near the head (north) end of an esker. Note coarseness of material and lack of stratification in contrast with B below. Two miles northeast of Cannington. Mariposa tp. (1-3, 1947). (Page 33.)

B. Excellent sorting and stratification near the south end of the esker shown in A above. One mile south of Sunderland. Brock tp. (15-1, 1948). (Page 33.)

PLATE X



A. Stones in varved clay. *(Photo by J. A. Elson.)* (Page 37.)



B. Ripple-marked varved sand and silt. Willow Creek and No. 26 highway. Vespra tp. (5-1, 1946). (Page 37.)

PLATE XI

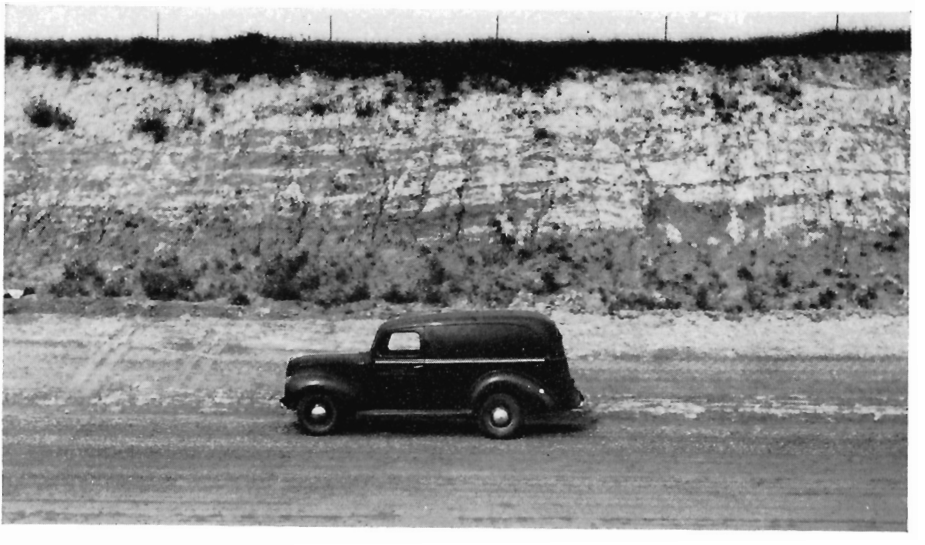
A. Truncated varved clay. Nottawasaga River. Essa tp. (13-4, 1948). (Page 37.)

B. Algonquin bluff and heavily boulder strewn terrace. Orillia tp. (99015). (Page 72.)

PLATE XII

A. Algonquin bluff and sandy terrace. Orillia S. tp. (99018). (Page 72.)

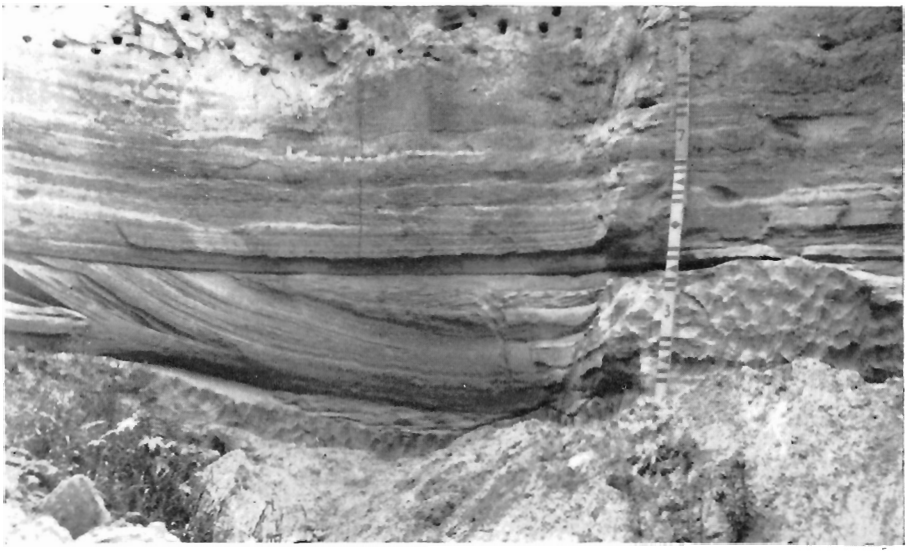
B. A narrow connecting channel or spillway of Lake Schomberg. Two miles north of Mount Albert. Gwillimbury tp. (16-3, 1948). (Page 86.)



A. Varved silt and clay of Lake Schomberg. Varves vary from 12 to 20 inches in thickness. One mile east of Newmarket. Whitchurch tp. (1-2, 1948). (Page 87.)

B. Contorted and folded varved clay overlain and underlain by a compact sandy till. King tp. (3-6, 1947). (Page 87.)

PLATE XIV



A. Eight feet of fossiliferous sand and clay beds of main Lake Algonquin overlying unfossiliferous sands of an earlier stage of Lake Algonquin. Nottawasaga River. Essa tp. (14-1, 1948). (Page 88.)

B. Deltaic sand and gravel deposit at the entrance of Little Lake Valley. Beds dip 0 to 5 degrees to the west. Canadian Pacific Railway gravel pit at Minesing. Vespra tp. (5-5, 1946). (Page 88.)

INDEX

PAGE

Ablation moraine..... 11
Acknowledgments..... 2
Aftonian interglacial stage..... 8
Algonquin beach..... 45-72
Algonquin Lake plain..... 5
Allandale, Ont..... 74, 87
Alliston, Ont..... 83, 88
  Drumlins near..... 13
Antevs, E..... 39
Ardtrea beach.....43, 45-71, 73, 90
Ardtrea Island.....73, 74, 76
Argyle, Ont., drumlins near..... 42

Barrie, Ont.....41, 74, 83, 87
  Algonquin beaches near..... 72
  Ardtrea beach near..... 73
  Outwash near..... 34
Bass Lake.....7, 37, 72
Bass Lake kame moraine.....31, 34, 88
Bay-mouth bars.....5, 35, 79
Beach bars..... 79
Beach ridges.....5, 35, 79
Beaches, Algonquin..... 72
  Ardtrea..... 73
  Cedar Point..... 75
  Convergence of..... 73, 78
  Development of..... 79
  Impounded..... 76
  Lower Orillia..... 74
  Nipissing..... 75
  Other..... 75
  Parallelism of..... 78
  Payette..... 75
  Penetang..... 74
  Upper Orillia..... 74
  Waubaushene..... 75
  Wyebridge..... 74
Beaverton, Ont..... 32
  Algonquin beaches near..... 73
Beaverton River.....6, 36, 83
Beeton, Ont..... 87
Bell Ewart, Ont..... 32
Bibliography..... 3
Black River..... 6
Black River sub-epoch..... 8
Bolton, Ont..... 86
Boyne River..... 88
Bradford, Ont.....83, 84, 86
  Drumlins near..... 13
Brechin, Ont., drumlins and striæ near..... 42

Canal Lake.....7, 32, 83
Cannington, Ont., drumlins near... 5, 42
  Eskers near..... 33
Cary substage..... 8, 29
Cedar Point beach.....44-71, 75, 91

PAGE

Chapman, L. J..... 4, 86
Chicago outlet..... 89, 90
Clay.....11, 16, 35
Cobourg formation..... 8, 9
Coldwater River.....6, 37, 72, 83, 84, 88
Cook Bay.....5, 14, 83
Cookstown, Ont..... 83, 84

Dalrymple Lake.....7, 15, 83
Drainage, preglacial.....7, 81, 83, 84
  Present..... 6
Drift, composition of..... 10
  Thickness of.....4, 11, 82
Drumlins.....6, 10, 12, 42
  Composition of..... 12
  Description of..... 12
  Fields..... 5, 12
  Near Little Lake..... 89
  Origin of..... 13
  Stratified material in..... 12
Dunedin, Ont..... 85
Dunes..... 41

Eady, Ont..... 75
Eldon tp..... 15
Erosion, glacial.....4, 9, 10, 81, 82
  Stream.....7, 83, 88
Escarpments, limestone..... 9
Eskers.....10, 15, 33

Feversham, Ont..... 85
Fenelon Falls, Ont..... 15
Fenelon Falls outlet.15, 74, 76, 78, 87, 88, 90
Flint, R. F..... 4, 11

Geology, general..... 8
  Historical..... 81
Georgina Island..... 5, 84
Glacial deposits..... 10
Glacio-fluvial deposits..... 31
Glacio-lacustrine deposits..... 34
Glint Lakes..... 7
Goldthwait, J. W..... 44, 90
Goldthwaite, L..... 27
Ground moraine.....6, 10, 11
  Area covered by..... 11
  Composition of..... 11

Hawkestone, Ont..... 73
Head River.....6, 9, 83
Hobbs, W. H..... 41
Holland Marsh..... 84, 87
Horning Mills, Ont..... 85
Humber River..... 86

PAGE

Ice-block ridges.....10, 14, 89
Ice-contact deposits.....10, 31, 84
Ice-lobes.....32, 84, 85
Illinoian stage..... 8
Innisfil Creek..... 84
Interglacial deposits..... 29
Investigations, scope of..... 1
Iowan substage..... 8, 29

Johnston, W. A.....39, 44, 87, 89

Kames.....10, 15, 31, 32
Kame moraines..... 10, 87
Kame terraces.....10, 32, 85
Kansan stage..... 8
Kempenfelt Bay.....7, 33, 74, 83, 88
Keswick, Ont..... 74
Kirkfield, Ont..... 15, 89
Kleinberg, Ont..... 86
Krumbein, W. C..... 24

Lake Algonquin, deposits..... 5, 35
  Erosion by..... 6
  History of..... 85, 90
  Rising stages of..... 88
  Shorelines.....44, 45-72
  Varved clay..... 39
  Water-planes..... 43
Lake Couchiching.....7, 44, 79
Lake Iroquois..... 90
Lake Louise, Alta..... 39
Lake Lundy..... 85, 90
Lake St. John.....7, 15, 32
Lake Schomberg..... 86
  Varved clay..... 39, 86
Lake Simcoe..... 7, 44
Lake Simcoe moraine.....14, 15, 89
Lake Simcoe moraine stage..... 89
Lake Simcoe till plains..... 6
Lake Warren..... 85, 90
Laurentian River..... 83
Legget, R. F..... 22, 24
Leray formation..... 8, 9
Limestone, plains..... 5
  Erosion of..... 4
  Escarpments..... 5, 9
Lindsay, Ont..... 15, 89
Little Lake.....7, 33, 72, 88
Loess..... 41
Logans Hill..... 15
Lower Orillia beach.....43, 45-71, 74, 90
Lowville formation..... 8, 9

Mankato substage..... 8, 29
Mara tp.....5, 15, 40
Marl..... 41
Mattawa Valley..... 90

PAGE

Mechanical analyses..... 16
  Of stratified material..... 16
  Of tills.....16, 27, 29
  Of varved clay..... 38
Mitchell Lake..... 89
Mono Centre, Ont..... 85

Nebraskan stage..... 8
Newmarket, Ont..... 83, 87
Niagara escarpment..... 85
Nipissing beach.....45-71, 75, 91
North Creek..... 36
North River..... 6
Nottawasaga River..... 84, 88

Oak Ridges moraine.....14, 29, 85
Orangeville, Ont..... 85
Orillia, Ont., Ardtrea beach at..... 73
  Algonquin beach at..... 72
  Drumlins near.....5, 12, 42
Oro, Ont..... 73
Outwash..... 10, 34
Palgrave, Ont..... 86
Pamelia formation..... 8, 9
Payette beach.....44, 45-71, 75, 91
Pefferlaw Brook.....6, 9, 83
Penetang beach.....44, 45-71, 74, 91
Physical features..... 4
Physiographic divisions..... 4
Port Huron outlet.....78, 89, 90
Precambrian rocks..... 9, 81
  Erosion of..... 4
Putnam, D. F..... 4, 86

Rama tp.....5, 15, 40
Recent deposits..... 41
Richmond Hill, Ont..... 83
Roches moutonnées.....5, 6, 9, 10, 42

Sand.....11, 16, 35
Sand and gravel, beach..... 35
  In drumlins..... 12
  In eskers..... 33
  In kame moraines..... 32
  In kames..... 32
  In outwash..... 34
Sangamon interglacial stage..... 8, 82
Schomberg, Ont..... 87
Schomberg River..... 84
Severn River..... 7, 40
Shorelines, development of..... 72
Silt.....11, 16, 35
Soil, analyses charts of..... 22
  Formation of..... 10
  Specific gravity of..... 24
Spillways.....32, 85, 86
Spits.....5, 35, 79

PAGE

Stanley, G. M. 43, 76
Striæ 10, 42, 81
Sturgeon River 6, 72, 84, 88
Sunderland, Ont., drumlins near 12, 13
  Eskers near 33
Sutton, Ont. 41, 74
  Algonquin beach near 73
  Drumlins near 13

Taylor, F. B. 87
Tazewell substage 8, 29
Terminal moraines 10, 15
The Hollows 84, 87
Thorah Island 5, 84
Thornhill, Ont. 82
Thornton, Ont. 87
Thwaites, F. T. 14
Till, colour of 26
  Composition of 16
  Differences in 29
  In ablation moraine 11
  In drumlins 12
  In ground moraine 6, 11
  In ice-block ridges 14
  In terminal moraine 15
  Kinds of 25
  Mechanical analyses of 16, 27
  Oxidation of 26
  Types of 16
Toronto, Ont. 10, 17, 83
Tottenham, Ont. 87

PAGE

Trask, P. D. 16
Trenton formation 8, 9, 82
Trenton sub-epoch 8
Two-outlet stage 89, 90

Uhthoff, Ont., Drumlins and striæ near 42, 81
Uphill, Ont. 73, 74, 76, 82, 83
Upper Orillia beach 43, 45-71, 74, 90

Varved clay 36, 87
  Colour of 38
  Description of 37
  Location of deposits 36, 37
  Mechanical analyses of 38
  Origin of 40

Washago, Ont. 7, 15
Water-planes, convergence of 73
  Deformation of 78
  Direction of tilt 44
  Table of 77
Waubaushene, Ont. 39, 74, 75, 83
  Striæ near 42
Waubaushene beach 44-71, 75, 91
Wisconsin stage 8, 10, 29
Wyebridge beach 44-71, 74, 91

Yarmouth interglacial stage 8