GLACIAL LAKE SHORELINES

IN BRANT COUNTY

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By

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SCOPE AND CONTENTS: The glacial lake shorelines of Brant County were traced and mapped in the field. Their heights were estimated and determined accurately at a number of locations, including some in adjacent Wentworth County. The characteristics of other physiographic features were also noted.

From this information and an analysis of previous literature on the subject, the shorelines are identified. Morainic features are related to the conditions of their formation. Finally a chronology is given for the stages of ice retreat across Brant County.

ACKNOWLEDGMENTS

The author wishes to express her sincere appreciation to Mr. D. C. Ford for his invaluable advice, assistance and encouragement during the preparation of this thesis. She wishes also to thank her fellow graduate students for the help given with field work and for their many helpful criticisms. In addition, thanks are also due to Mr. H. R. J. Neumayer for his assistance with the photographs. Appreciation is also expressed to Miss B. Hagel for her co-operation in the typing of this thesis at short notice.

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INTRODUCTION

The purpose of this thesis is the geomorphological analysis of an area which had previously not been studied in comparable detail. From the results of this analysis, the region is placed within the chronological sequence as established for the Pleistocene Epoch in the Great Lakes basin. Special emphasis has been placed on the study of glacial lake shorelines in the area because these provide the major evidence for the establishment of a chronology.

The area studied is indicated on the accompanying location map (Figure 1), and consists of Brant County excluding Onondaga and Tuscarora townships, and a small section of North Dumfries Township in Waterloo County. This region is somewhat elongated along the terminal moraines of the area and the glacial lake shorelines. An analysis of the glacial lake shorelines of northern Wentworth County is also included.

During the Pleistocene Epoch, Southern Ontario underwent four successive glaciations. The retreat of the final ice mass to occupy the area, the Wisconsin Glacier, with its many halts and minor readvances, moulded the surface of the land, and is reponsible for most landforms of the present day. There has been only slight post-glacial modification. At various stages during ice retreat glacial lakes occupied the basins of the present Great Lakes, and their shorelines may now be traced inland from the lake shores, and hundreds of feet above the present lake surfaces.

Due to post-glacial isostatic rebound, all glacial lake shorelines have been deformed by uplift in their northern sections. The amount of deformation depends upon the relative length of time since the existence of the glacial lake.

In 1961, J. Horton mapped two glacial lake shorelines in northern Wentworth County.[1] He heighted them approximately and calculated their deformation. The original problem, as subject for this thesis, was to trace the continuation of these shorelines southwestwards into Brant County and to follow them across that county. Horton had tentatively identified the Wentworth shorelines. With the larger area of the two counties under study, it was hoped to be able to identify them more conclusively.

The shorelines were traced into, and across Brant County by means of mapping in the field and air photo analysis. As the work progressed, it became apparent that there were more than two shorelines present. Mapping was complicated further by the numerous off-shore islands present in this area, and the resulting great variation in situation and form of shoreline features. The final stage of field work was the accurate heighting of the shoreline features in a number of locations where well defined features were found, including several of Horton's sites in Wentworth County. From a study of the heights, amount of deformation, morphology and location of the shorelines, their probable identity was worked out.

The area of Brant County is of particular interest with regard to the relationship between shorelines and moraines. There exist here the

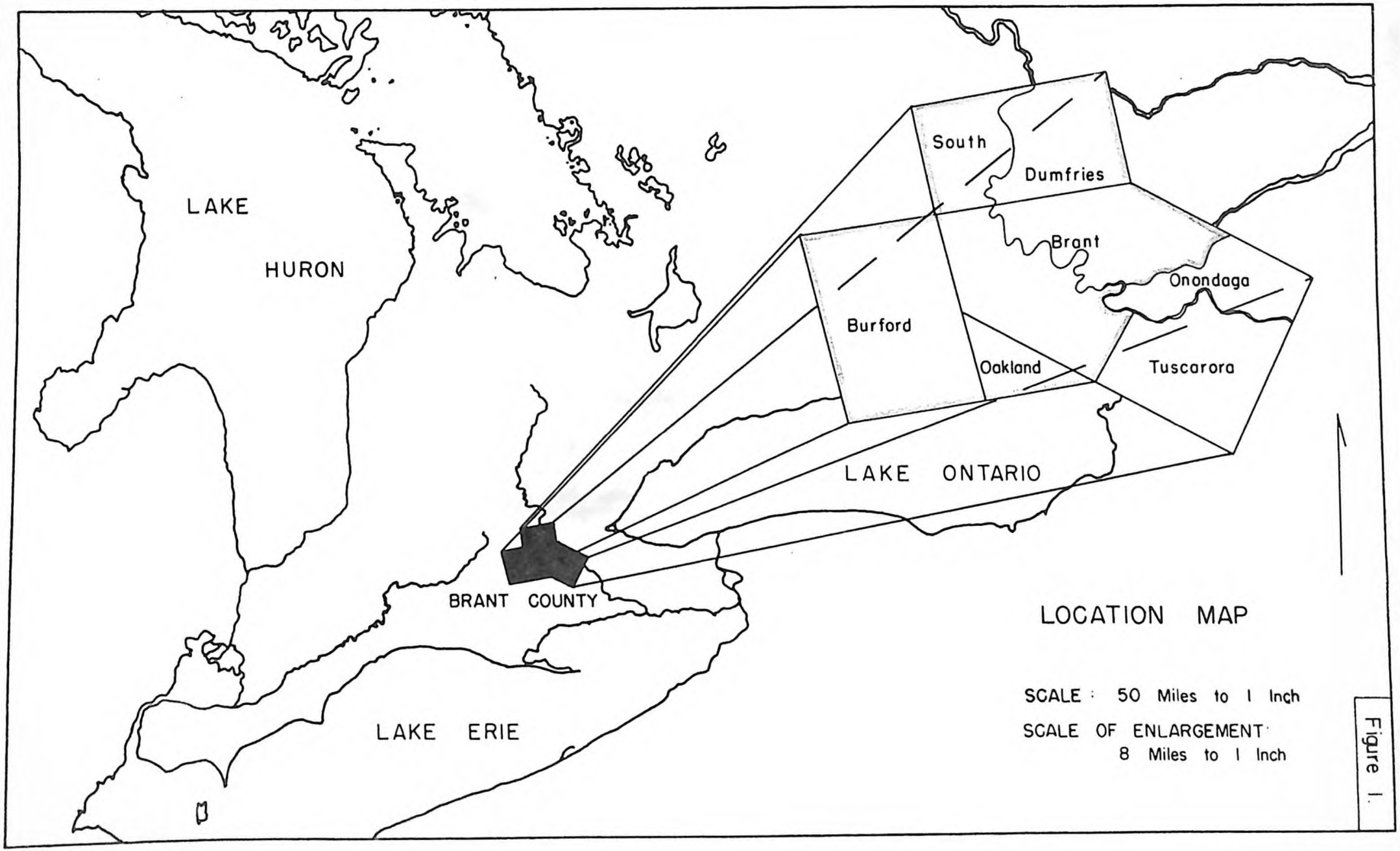

LAKE
HURON
South
Dumfries
Brant
Onondaga
Burford
Oakland
Tuscarora
LAKE ONTARIO
BRANT COUNTY
LAKE ERIE
LOCATION MAP
SCALE : 50 Miles to 1 Inch
SCALE OF ENLARGEMENT
8 Miles to 1 Inch

Figure 1.

contemporary shorelines and moraines for three of the glacial lakes. The north eastern extremities of the lakes were in the northern part of Brant County, thus, in this area, the shorelines are found to grow fainter and fainter, and finally fade out against their respective moraines.

Along each ice front, certain sections of the moraine stood above lake level, whilst other sections were waterlaid i.e. stood below the level of the lake. This has a significant influence upon the topography of the moraine. The distinction was mapped in the field, and later found to closely correspond to expected morainic topography as calculated from lake height data.

Finally a detailed chronology was worked out for the area, placing in sequence glacial lakes and their associated moraines, the connecting spillways, and related spillway and delta sand and gravel plains. This chronology is placed within the general sequence as established for the Great Lakes basin. Post-glacial modification and the development of the present drainage system are also discussed.

A short appendix has been added dealing with topics closely associated with the geomorphology of the region, such as soil types and agricultural geography.

Reference

1 Horton, J. H. "Glacial Lake Shorelines in Northern Wentworth County, Ontario." Unpublished B.A. thesis, Department of Geography, McMaster University, 1961.

CHAPTER I

THE PHYSIOGRAPHY OF BRANT COUNTY AND A REVIEW OF PREVIOUS LITERATURE

INTRODUCTION

The aim of this chapter is twofold. Firstly, to set the scene before more detailed discussion, the general physiography of the area will be described. The Palaeozoic Geology is dealt with briefly since it plays little part with regard to surface morphology. Surficial landforms are discussed in more detail.

Secondly, an account is given of the previous geomorphological work that has been carried out in this area.

PART A.

SECTION 1. PALAEOZOIC GEOLOGY Figure 2

The bedrock of the area is of significance only with respect to its influence on the composition of the glacial fill. The configuration of the land surface is in no way related to the structure of the underlying rock. Superficial deposits are thin in the extreme north-eastern part of the county, and the bedrock outcrops at the surface in adjacent parts of Beverly Township. Towards the southwest, however, the drift thickens considerably to a maximum of about 300'.

The region is underlain by rocks of Devonian and Silurian age.

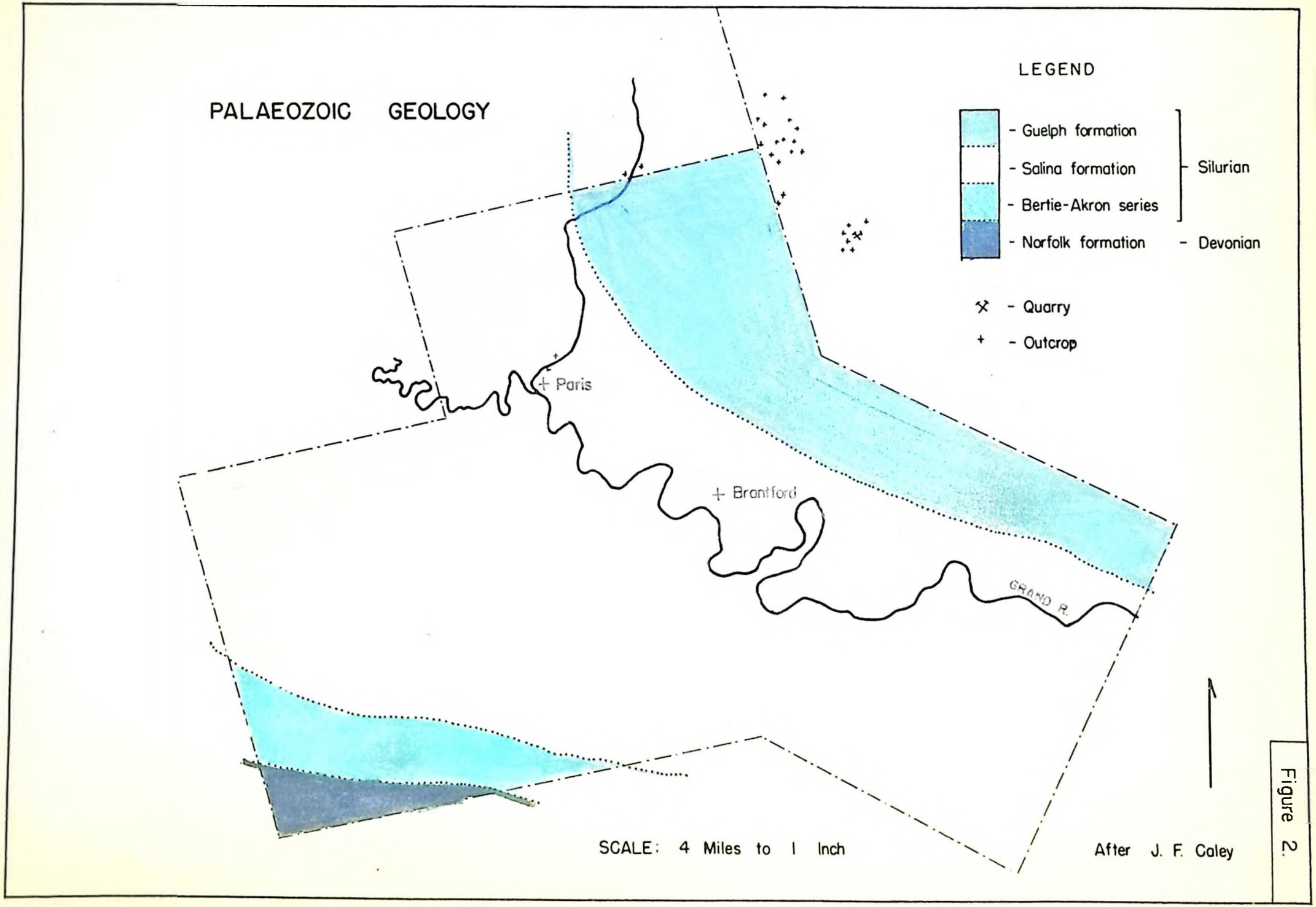

PALAEOZOIC GEOLOGY
LEGEND
- Guelph formation
- Salina formation
- Bertie-Akron series
- Silurian
- Norfolk formation
- Devonian
- Quarry
- Outcrop
Paris
Brantford
GRAND R.
SCALE: 4 Miles to 1 Inch
After J. F. Caley

Figure 2.

Their location is indicated on the accompaying map. Beds of the Norfolk formation represent the Devonian, and consist of grey, bluish, and brown limestones, calcareous sandstone, and chert. The Silurian is represented by three rock series: the Bertie-Akron series, consisting of brown dolomite, and grey and blue argillaceous dolomite; the Salina formation, consisting of brown dolomite, shaly dolomite, and a limy shale with gypsum, and this grades through a transition zone to the Guelph formation, consisting of grey, buff, and brown dolomite.

There are very few outcrops in the area, and those which do occur, are direct results of post-glacial entrenchment by the Grand River. Rocks of the Salina formation are exposed in the river bed at Paris and for 2½ miles to the north, but nowhere does a section occur that is more than 5' in thickness. Small and scattered outcrops of the Guelph Formation occur in the valley of the Grand River between Galt and Glen Morris.

The rocks of the area have undergone only slight deformation. There is a gentle regional dip towards the west or southwest, which is interrupted only by slight variations in its magnitude, and reversals. These variations are not great, but appear to be sufficient for the accumulation of natural gas in certain areas.

SECTION 2. LANDFORMS

Considerable variation of landforms is found within the region. Parts of the south and east are extremely flat, plains regions, whilst further north are areas of highly accentuated topography. The local relief of the area is 450'. The Grand River, flowing approximately north-south, drains the area, but away from the major streams drainage

tends to be very disordered and irregular.

On the basis of landform types, the area has been divided into 12 regions for the purposes of description (fig. 3).

Region 1.

This region is a till plain and occupies the extreme north western part of Burford Township. An area of gently undulating topography, with some shallow blind depressions, rises gradually northwestwards from 825' at the eastern margin to 950' in the extreme north-west. Several streams cross the region, the largest of which is Horner Creek. They flow south-eastwards with the slope of the land, and have undergone slight entrenchment. Some small lakes, of which Colles Lake is an example, and some marshy areas, are found in the larger depression.

Region 2

Trending roughly north-south across the southern half of Brant County are a series of low ridges. From west to east they represent the Norwich, Tillsonburg, Paris and Galt moraines.

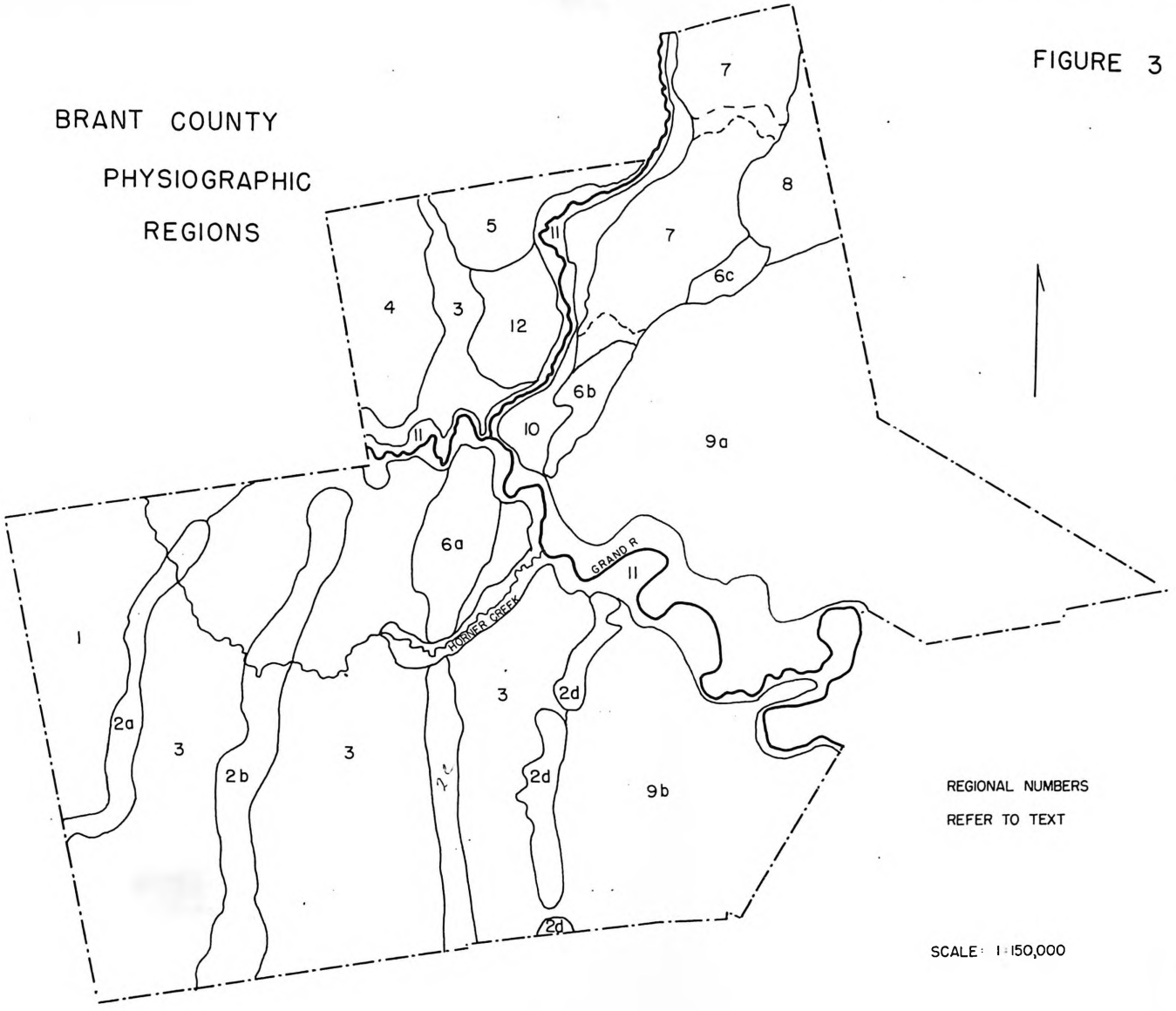
(2a) Adjacent to Region 1 in the extreme west are a number of short ridges and low hills that may be linked together as shown on the map, to form a NNE-SSW trending ridge. This is the Norwich moraine. It is best developed between New Durham and Cathcart where it rises 50' or more above the surrounding area, and is fairly continuous. To the north of Cathcart a number of isolated hills rising up to 925' continue the trend of the ridge. The hills are separated by creeks draining from the rising land to the west, but within the ridge area itself, surface

FIGURE 3

BRANT COUNTY

PHYSIOGRAPHIC

REGIONS



REGIONAL NUMBERS

REFER TO TEXT

SCALE 1:150,000

drainage is absent.

(2b). Two or three miles to the east, lies the second ridge of the series, the Tillsonburg moraine. It runs from slightly east of Northfield Centre northwards to Harley, and then slightly east of north to a mile west of Falkland. It is more continuous than the ridge mentioned above, though it may be best described an an elongated region of higher, undulating land, than a single ridge. Local relief is about 50'. Slopes are generally not steep except in some localized areas around the edges of this feature, in which cases, the east facing slopes tend to be steeper than the west facing slopes. The continuity of the ridge is broken by two eastward flowing creeks: Horner Creek to the west of Burford, and Big Creek a mile south of Harley.

(2c). The next ridge which is the Paris moraine, lies between four and five miles to the east of 2b. It is a continuous though narrow feature, running without a break for seven miles from Scotland in the south to Mount Vernon in the north, where it is broken by Horner Creek. (To the north of the creek, the ridge continues, but differing characteristics have necessitated its distinction as a separate region.) Local relief here is about 100'. The ridge drops steeply at its east-facing slope to a height of 800', whilst in contrast, the western side slopes gently, and almost imperceptibly, and merges into the adjacent plain area at 850'. The crest line of the ridge is gently undulating, but in detail, there are many sharp undulations with numerous blind depressions.

(2d). The Galt moraine which forms the easternmost ridge lies at a distance of two to three miles from the adjacent feature, and runs northward from Oakland to the Grand River. It has a local relief of about

80', and in most respects is similar to the feature 2c. It is however, slightly lower in elevation and has a comparatively smooth surface. It is broken in two places by small creeks flowing eastwards.

Region 3.

This region is characterized by its lack of relief. It consists of a series of plain areas lying between the morainic ridges of Region 2. An outlying part of this region extends northwards from Paris to the county boundary. Over approximately 50% of this area, drainage of the soil (by percolation since there are no surface streams) is good. Farm pits dug here reveal the sandy nature of the soil and subsoil, and also show that the water table is only two or three feet below the surface. The lower lying sections of these areas are adjacent to the moraines and here, drainage is frequently imperfect. Large areas are occupied by cedar swamps. Small streams which drain these areas are tributary to the larger east-west flowing streams. Other surface drainage is absent.

In places low terraces may be traced running across the sandplains. In the area around Brantford Airfield are several large enclosed depressions, but no ill-drained areas. This is because of the permeability of the sand and gravel subsoil and the ready discharge to the adjacent lower lying valleys of the Nith and Grand Rivers.

Region 4

This is a comparatively large area of gently, undulating land and comprises the northern section of the Tillsonburg moraine. Local relief is unusually great, being 225'. The highest point is above 1075', and this is the highest point in Brant County. Slopes are steep only

in small, localized areas, the topography generally being gentle and rounded. Surface drainage and stream dissection are rare, although streams are found along the immediate borders of the region on the adjacent sand plain.

Region 5

This is the most northerly part of the Paris moraine within Brant County. The topography here is somewhat similar to that of Region 4. Local relief is slightly more than 125'. The land surface rises abruptly from 900' on the sand plain to the west, and slopes steeply to the valley of the Grand River to the east. There are many blind depressions, several of which are occupied by large lakes. Immediately to the north of Spottiswood Lakes is a prominent, arcuate ridge which is over a mile in length and flanked on either side by similarly trending elongated lakes.

Region 6

This is a continuation of the ridges of Region 2c and 2d, namely the Paris and Galt moraines.

(6a). The ridge here is considerably broader than in the southern section and reaches a maximum width of two miles. Local relief decreases slightly to approximately 80', and the steepness of the east facing slope decreases northwards. The surface of the ridge shows broad undulations rising to over 925' and there are some small, blind depressions. Permanent surface drainage is absent.

(6b). This region is similar in most respects to 6a. It is a broad ridge-like section of the Galt moraine, trending from southwest to northeast and having local relief of slightly more than 75'.

(6c). This region, although peripheral to a larger region of higher land (Region 7) shows similar characteristics to the sub-regions just described. It is part of the Galt moraine. Topography is gently undulating and there are scattered blind depressions, some with permanent lakes, but there is no surface drainage. Local relief is slightly more than 80'.

Region 7

This region is a continuation of the ridge of 6b, but surficial characteristics differ considerably. Here, the Galt moraine reaches its greatest strength. The upland area increases in breadth to a maximum of five miles, and extends in a northeast-southwest direction for eight miles from Blue Lakes to the boundary of the area studied, (beyond the county boundary). The main ridge is broken at Blue Lakes and at Branchton by broad, flat-floored channels.

Topographically, this region is distinct in having extremely well developped knob and kettle topography. Local relief is over 125'. There are blind depressions, many of which contain lakes are up to 50' deep. There is surface drainage related to these lakes but it is very limited.

Region 8

This may be broadly termed a plain region, but relief increases towards Region 7 to the west, giving a local relief of up to 75'. Several streams cross the area and have dissected the plain surface, and the underlying limestone bedrock is frequently exposed in their beds, especially in the adjacent regions of Wentworth County.

Region 9

This is an extensive area of highly dissected plain. It has a veneer of sandy soil, and sands and fine gravels are exposed frequently in stream beds. The original plain surface slopes gently eastwards and southeastwards from 800' at its western margin to 700' in the south-east. Dissection has lowered stream channels to a maximum depth of 75' below the plain surface. Over most of this region drainage densities are comparatively high, although there are some marginal, undissected areas.

In the northern section a dendritic network of streams has developed to the trunk stream of Fairchild Creek, which displays large ingrown meanders. In the southern section, the plain is dissected by many small tributaries of the Grand River. Base level for the whole area is 640'.

Region 10

This region is composed of several small separate areas of a distinct topographic type. They lie along the edges of the major river valleys, and are areas of gently undulating land with a local relief of no more than 40'. The slope, in a series of irregular, terrace-like features, is towards the adjacent valleys. They represent the remnants of spillway plains and terraces, which have undergone post-glacial dissection.

Region 11

The main 'trenches' of the larger river valleys have been grouped to form this region. These are the Nith, the Grand , and the lower sections of Horner Creek. To the north of Paris, the Grand River is

entrenched in a narrow, steep-sided valley, averaging 100' in depth. There is only slight flood plain development, and minor terraces can be recognized in certain areas.

The Nith Valley to the east of Paris and the valley of the Grand River to the south of Paris show similar characteristics. The valleys are wide and the river winds in a series of ingrown meanders. Meander terraces are widespread, and for most of their courses there is a broad floodplain. The rivers appear to have reached Grade in this section, but not to the north of Paris.

Horner Creek valley is similar in form to those just described although on a much smaller scale. Upstream, this valley broadens and becomes shallower as it crosses the plain area around Burford.

Region 12

This region consists of a northeast-southwest trending series of terraces with a gently undulating surface between. These terraces rise from a height of 800' in extreme southeast, to 900' in northwestern part of the region. There are frequent blind depressions, and these are generally quite shallow.

PART B. PREVIOUS GEOMORPHOLOGICAL WORK IN BRANT COUNTY

There has been no previous detailed geomorphological work in the greater part of this area. Karrow, in 1961, published the results of his geomorphological mapping in the area of the Galt topographic sheet, which includes the extreme northern part of Brant County.(1)

Prior to this, Putnam and Chapman had mapped the area on a scale of 4 miles to 1 inch in conjunction with their published work of 1951.(2)

In this a brief description of the moraines and various physiographic regions of Brant County is included. It is their identification of the moraines which is given in the previous part of this chapter. The account given of the chronology of Southern Ontario during the final glacial retreat, has been altered and added to by more recent writers.

Leverett and Taylor are most prominent among the earlier writers on the Southern Ontario region as a whole.(3) In 1913, Taylor mapped the moraines of Brant County, but this was only a minor section of his work which included all of Southern Ontario.(4)

The most recently published work on the formation of the Great Lakes is by Hough.(5) Brant County is included within the area discussed, but no mention is made of this area in any detail.

With more specific regard to shorelines, this area has been included in many generalized discussions, but there has been no previous large scale mapping of shorelines. In 1891 Spencer worked on the Warren and Whittlesey shorelines in the eastern part of Southern Ontario.(6) He traced the shoreline of "Lake Warren" and identified it accurately from place to place as far north as Brantford. He traced the Whittlesey shoreline eastwards and northwards from London towards Brant County. A.P. Coleman in 1901, published the results of his work in which he gives a short survey of the beaches which had been identified in Ontario at that time.(7) He briefly alludes to the "well developed Warren beach" in the southern part of the Ontario peninsula but gives no details.

In 1915, Leverett and Taylor published their monograph on the history of the Great Lakes.(8) They base most of their interpretations, however, on features found in the United States, and make only slight

reference to the occurrences of beaches and moraines in Ontario. Lake stage maps are given for Whittlesey, Warren and Wayne, but shorelines are plotted only tentatively with regard to the area under discussion. The position of the ice barriers as indicated are now known to be erroneous.

In 1939, Leverett published his paper on the correlation of beaches with moraines in the Huron and Erie basins.(9) Once again, emphasis is on development within the United States, but more detail is given regarding Ontario. The Lake Whittlesey beach in Ontario is not mentioned but two Warren beaches are differentiated and described. The lower of these is stated as showing "strong development as a gravel ridge on the inner slope of the Fort Huron morainic system", and being present "clear up to the ice barrier". 'From Simcoe northwards the beach is finely developed on the inner border of the Galt Moraine past Waterford, Brantford, and St. George, to Sheffield. From there the course is eastwards to a moraine on the Niagara Escarpment near Carlisle which appears to mark the ice barrier of the lake." The Upper Warren beach is mapped at 800' at Brantford and rising 50' between here and the ice barrier. The Wayne beach is not described.

Also in 1939 D.C. MacLachlan traced the Whittlesey and Warren beaches at three or four locations within the county and describes their locations and features very generally.(10)

Putnam and Chapman, writing in 1957, describe briefly the beaches within Brant County.(11) Of the Whittlesey beach ... "... it serves as a boundary between till plain and lake plain from Brantford to Exeter". They recognize the twin Warren strandlines and map them as encircling

the islands of the Galt moraine between Brantford and Simcoe, and the main shoreline running along the inner slope of the Paris moraine. No further details are given.

Thus these writers agree with regard to the presence of beaches within Brant County, but reach no agreement concerning the number and height of these beaches.

The only detailed mapping of beaches was done by Karrow and Horton. Horton's work has already been mentioned.(12) He traced two shorelines continuously across northern Wentworth County. He found the upper beach rose from 905' in the west to slightly over 925' in the east, giving a warp of 1.25' per mile, whilst the lower beach rises from 870' in the west to 880' in the east, having a tilt of .75' per mile. The water planes thus converge westwards at a rate of .50' per mile. The line of maximum tilt trends northeastwards.

Horton gives a tentative identification of these shorelines. He states "... the upper shoreline is probably related to one of the earlier glacial lakes in the Erie basin such as Whittlesey or Arkona. The lower shoreline on the other hand is probably related to Lake Warren. An alternative explanation would be that both shorelines represent the extreme northern divergence of the warped water planes of upper and lower Lake Warren."

In 1961, Karrow found a prominent raised shoreline at 905' on the Galt moraine in the extreme north of Brant County, with others at various elevations below this.(13) In the adjacent parts of Wentworth County, two years previously, he reported finding two water levels - at 925' and at 875' on the drumlins south of Carlisle, and an indication

of a beach, again at 875', on the southwestern 'nose' of a moraine near Millgrove.(14)

From Hough's work on the geology of the Great Lakes it can be surmised that five beaches may exist in the area of Brant County related to moraines there, and also to moraines further east.(15) This will be discussed more fully in Chapter 3.

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CHAPTER 2

A DESCRIPTION OF THE BRANT COUNTY SHORELINES

INTRODUCTION

This chapter describes the five shorelines identified in Brant County. They are named, for ease of distinction, according to the analysis of Chapter 4. First of all, field methods and mapping techniques are discussed. A classification of shoreline types is given on the accompanying map (figure 4).

PART A. FIELD METHODS AND MAPPING TECHNIQUES

From Horton's work in Wentworth County the approximate elevations of the Wayne and Lower Warren shorelines at the western boundary of that county were known. Thus the initial identification of the shorelines was quite straightforward.

Mapping of the shoreline features was started at the Wentworth County boundary and the shorelines were traced southwestwards across a small area of North Dumfries Township (Waterloo County), and into Brant County. Originally the mapping was done on large scale maps at 1:12,500, produced by hand copying from aerial photographs. As mapping progressed, it became possible to estimate approximately the location of shorelines in the remainder of Brant County. The great amount of work involved in

mapping such a length of shoreline on the large scale was realized and subsequent mapping done on the topographic sheets at a scale of 1:50,000. The length of the Middle Lake Warren shoreline alone is over 70 miles, almost 50 miles of this being the shorelines of offshore islands.

Areas where shoreline features were mapped accurately on the 1:12,500 scale, are the Galt moraine north of the Grand River, the Paris and Tillsonburg moraines north of the River Nith, and the Paris moraine between the River Nith and Horner Creek. From this larger scale mapping, valuable information was gained on the varying characteristics of the shorelines to be found throughout the whole area.

As the mapping progressed southwestwards it became evident from the variety of altitudes at which shoreline features were found, that there were more than two shorelines within the range of altitude being considered. All shoreline type features within appropriate height limits were mapped.

CRITERIA USED FOR IDENTIFICATION AND MAPPING

The criteria used for mapping shorelines in the field may be divided into two categories:

(i) topographic characteristics, used primarily for identifying erosional features

(ii) characteristics of superficial materials which occur in conjunction with the shorelines.

(i) Topographic Characteristics

The most common of all shoreline features are wave-cut bluffs. The degree of development reached by the bluffs is dependent upon several factors:

(a) depth of water offshore; a large area of shallow water offshore will hinder the development of erosive waves, and thus minimize bluff development.

(b) exposure of the shoreline; the length of available fetch will influence wave strength and thus play an important part in the nature of bluff development.

(c) steepness of slope; a steep slope will lend itself more readily to the development of steep and high bluffs than a more shallow slope.

(d) nature of the material being eroded; bluffs which have retained maximum steepness to the present day are those cut in the most resistant materials, namely, the loams and clays of the more northerly moraines.

Development of wave cut benches is closely associated with bluff development. The best examples of bench development occur, as with bluffs, in the more exposed locations where other factors are favourable. The form of the bench varies from a smooth, wave cut platform with a veneer of fine sand or fine gravel, to a series of beach ridges. In the latter cases, the height of the crests of the ridges correspond to the height of the break of slope at the foot of the bluff, which is taken as representing the lake level.

In certain localities, the evidence for a former lake level appears as a break of slope or a small terrace on the face of a previously formed steep slope. This slope is usually a constructional morainic feature.

Gravel beaches, spits, and bayhead beaches frequently show distinct topographic form. This factor, coupled with features of location and alignment, is the basis of the initial tentative identification of such

features.

(ii) Characteristics of Superficial Materials

Diagnostic materials are beach sand, gravel, cobbles, and to a lesser extent, partially exhumed limestone boulders. Beach sand is usually found as a veneer over the wave cut bench and lower parts of the bluffs. It is exposed in the soil and the degree of sandiness varies from slightly sandy soil to almost pure sand. Beach gravels vary from coarse sand to coarse gravel with pebbles up to 2" in diameter, and gravels are found both on the wave cut bench and also on the beach bluffs. There is a distinct boundary between beach and underlying materials.

Constructional forms consist chiefly of bedded gravel with cobbles. Cobbles are more limited in distribution than either sands or gravels. Their occurrence is determined by the nature of the material into which the beach bluffs are cut. In stoney moranic areas, chiefly areas of landlaid moraine, there are many cobbles. These are composed mainly of limestone, but there are some of gneissic and granitic erratics. In regions of sandy, water-laid moraine, cobbles are very rarely found. The shape of the cobbles varies from the roughly spherical form to the flattened or "hammered" forms, both forms being found in the same localities.

In certain highly localized areas of landlaid moraines large limestone boulders occur. These may be up to 12' in diameter and are subangular, still clearly showing bedding and joints. They stand on the wave cut bench, at the break of slope, or on the lower slope of the bluffs. They would appear to have been exhumed from the morainic till by wave action. Some are almost completely buried, whilst others

are completely exposed, varying according to location with respect to wave action.

Whilst carrying out field mapping, a number of difficulties regarding the identification of shoreline features became apparent, and a number of somewhat similar features with which it was possible to confuse shoreline features, were recognized. These will now be discussed.

The most common feature mistaken for a shoreline is the break of slope at the boundary between a moraine and the adjacent sand plain. This boundary does, very often coincide approximately with the height of the shoreline. It would appear that in the past, some writers may have mistaken this break of slope for a shoreline. For example, in 1939 MacLachlan writes - "From beyond Brantford to east of Galt, the general location of the shoreline is indicated by the change in slope from the flat land of the lake plain to the more uneven topography of the Galt moraine."[1] This confusion was overcome by a consideration of the location of shoreline features in relation to other geomorphological features and the likely occurrence of other breaks of slope. Also, breaks of slope, such as that between a moraine and an adjacent sand plain, are generally on a much larger scale than shoreline breaks of slope.

It is also possible to confuse spillway terraces cut in sand and delta plains with shorelines. These features are usually fairly well defined and continuous, whereas shoreline features in such locations,

[1] MacLachlan 1939.

with large areas of extremely shallow water offshore, would show only weak development.

Evidence given by the sand or gravel content of the soil is not a valid indication of a shoreline in areas of waterlaid moraine or in areas of sand plain since soils in such areas are invariably sandy. In some places, strips of almost pure sand mark the location of former beaches, but soil sandiness is no good as a general criteria in such areas.

In places where 'islands' of landlaid moraine occurred along an ice front, the altitudes of shoreline features are seen to vary considerably towards the ice front. It is believed that the break of slope between the landlaid and waterlaid moraine, which is theoretically a shoreline, is complicated by areas of outwash and minor, ice-front spillways which are above lake level. This would account for the rapid rise in altitude of the supposed shoreline towards the ice front.

The analysis of some features was not carried out until accurate shoreline heights had been finally determined. Whilst working in the field, all doubtful features were mapped within reasonable height limits.

Air photo coverage at scales of 1;36,000 and 1:42,000 was obtained for most of the area under study. Analysis of the photographs revealed that shoreline features were difficult to identify, and frequently good features which were known from field work were not visible on the photographs. Shorelines were visible however, in locations where much sandy beach material was present, but it is possible to confuse this feature with similar 'streaky' features found on the spillway-sand plains. Generally, air photos were of no great value with regard to shoreline identification, but they were used for mapping all

other geomorphic features and physiographic regions.

Whilst the main purpose of the field work was the mapping of the shorelines, the topographic characteristics of the morainic areas and the sand plain areas were also noted and mapped. Major spillway terraces, the boundary between sand plain and morainic areas, and boundaries between areas of varying morainic topography were identified and mapped.

When mapping of the shorelines was completed a representative selection of locations was chosen over as wide a range of altitude and as broad an area as possible, for the purpose of establishing the height of the shorelines accurately. The Wentworth County shorelines were also taken into consideration at this stage thus giving a much greater length of shoreline for the two lowest lakes, and enabling a more accurate determination of their height and deformation. To height a shoreline it was necessary to find a good feature within reasonable distance of a spot height. Spot heights at cross roads were used, and traverses made across the one or more adjacent shoreline features. The height of the break of slope at the foot of the bluff was determined for at least two locations on each feature. The crests of any beach ridges present were also heighted. Estimated error was within one foot.

The analysis of the results of the above work led to the identification of five shorelines in Brant and Wentworth Counties. They are shorelines of the glacial lakes Whittlesey, Upper Warren, Middle Warren, Lower Warren and Wayne, and their shoreline features are described in the latter part of this chapter. Features, as mapped in the field are shown on the map (fig.4). The position of the shorelines

in some areas have been interpolated from projection of profiles. In most of these cases shoreline features are not present since conditions here were adverse to their development. Such areas are indicated on Figure 4.

PART B. SHORELINE DESCRIPTION

THE SHORELINE OF LAKE WHITTLESEY

The main shoreline of Lake Whittlesey runs along the gentle east-facing slope of the till plain which occupies the extreme western part of Burford Township. The dissected Norwich moraine runs roughly parallel to this shoreline to form a series of islands never at a distance of more than a mile from the shore.

This shoreline is found at an elevation of slightly more than 880' at its southern limit within Brant County, and rises gradually northwards to a maximum elevation of 903' at its northern limit.

The northeastern arm of Lake Whittlesey which occupied this part of Brant County gradually decreased in width northwards, until the shoreline abutted against the ice front just beyond the county boundary (i.e. in Oxford County). Thus the whole length of this shoreline in Brant County was comparatively sheltered, compared with sections of shoreline further to the southeast, accounting for its relatively weak development in this area. Many writers describe the Whittlesey shoreline as being the most prominent of the earlier shorelines in Southern Ontario. However, in this region, strong features are found only in exposed locations and there is some minor development of constructional forms cutting across embayments.

The main shoreline crosses the boundary from Oxford County four miles to the north of New Durham, and runs for two miles along a fairly steep and south facing slope. Quite a strong feature is found here with bluffs cut into the till plain and a well developed bench in the erosional locations. At the eastern limit of this section of shoreline, a small sand spit has developed, continuing the eastward trend, and cutting across a small valley. The sandy soil of the spit is well exposed, and contrasts with the surrounding dark humic soils of the valley bottom (photos 1 and 2).

From here the shoreline turns northwards and runs towards Colles Lake. There is only weak bluff development in a few scattered locations. Northeastwards from Colles Lake the continuity of the shoreline is broken by a number of valleys - the largest of which contains the headwaters of Horner Creek. Some bluff development is found on the south and southeastward projecting spurs between the creeks, but strength of features decreases rapidly northward.

The most southern island of the Norwich moraine archipelago is at New Durham. It stands at a considerable distance from the main shoreline and good bluff and bench features are found on all sides, and on all sides of the adjacent islands. Between New Durham and Cathcart a ridge-like section of moraine shows features of the Whittlesey shoreline on spurs and in exposed locations on both east and west sides. Sandy soil is associated with the bench at the foot of these features. To the northwest of Cathcart is a small but well defined island, and shoreline features are developed on all but the northern, more shelterdd side (photo 3).

Photo 1. The Whittlesey sand spit east of Cathcart. The sandspit is indicated by the strip of light coloured sandy soil running across the mouth of the embayment. See also photo 2 below.

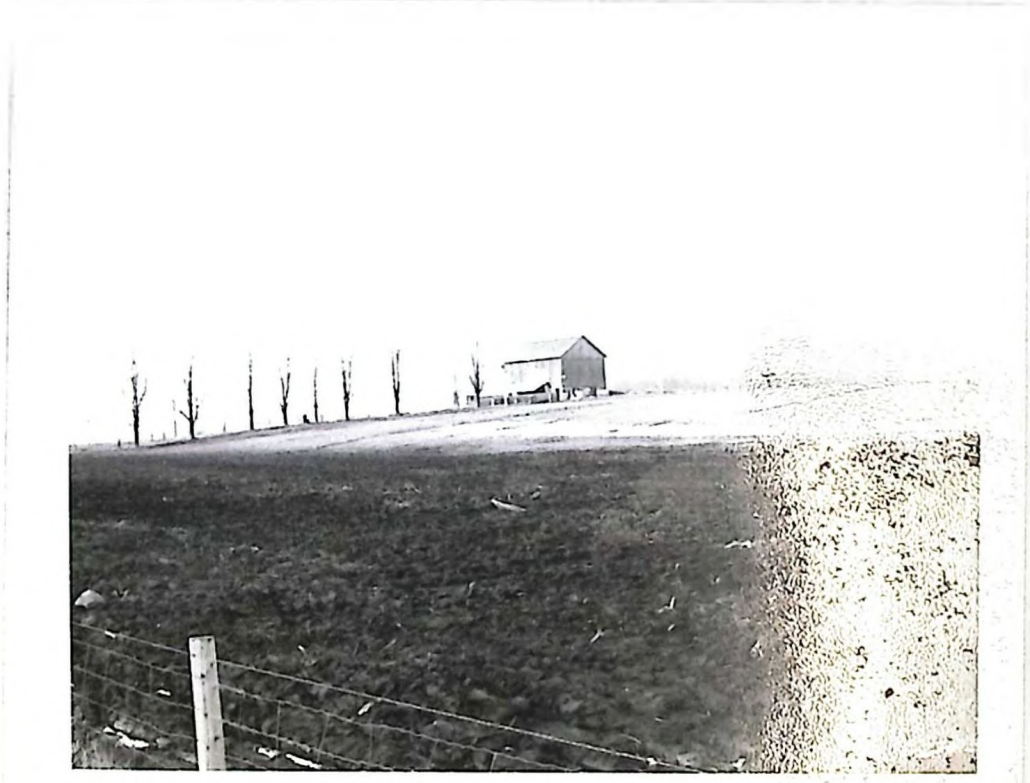


Photo 2.

Photo 3. A southeast facing shoreline feature on an island in the Norwich moraine to the northwest of Cathcart.

THE SHORELINE OF UPPER LAKE WARREN

At the time of Upper Lake Warren the ice front stood at the Paris moraine. The northeastern arm of the glacial lake was too confined to allow strong shoreline features to develop. The main shoreline runs along the eastern slope of the Norwich moraine to the northern boundary of Burford Township, and then runs northeastwards towards the Paris moraine. There are numerous islands formed by the Tillsonburg moraine, and several islands adjacent to the ice front formed by the Paris moraine.

The elevation of this shoreline increases from approximately 858' at the southern county boundary, to slightly more than 900' where it crosses the Tillsonburg moraine in the north.

(a) <u>The Shoreline of Upper Lake Warren on the Tillsonburg Moraine to the north of the River Nith.</u>

The shoreline first becomes apparent, when tracing it away from the ice front, at a height of just over 900', slightly more than two miles to the north of Paris, immediately west of Highway 24A. Here there is a fairly well defined bluff cut in the side of a remnant of a high level spillway terrace. It has been modified however, and the bench reduced in area by a stream flowing at the foot of the slope. As a result the shore bluff and associated bench are now occupying the position of a stream terrace. But the shoreline feature is continuous to the south, then it tends westwards around this spillway terrace remnant. To the west is an embayment formed by a lower spillway terrace, and the shoreline appears on the western side of the embayment as an indefinite southeastward facing feature cut into the hill of the Tillsonburg moraine. The morainic topography, giving rise to shoals and shallow water offshore and numerous embayments, prevents the development

of continuous shoreline features here. As with the Middle Warren shoreline in this area, well defined features are restricted to bluffs and associated benches cut on the ends of exposed spurs and south facing slopes. These features all occur at slightly more than 900', and they can be linked together, and the shoreline traced to the county boundary.

(b) The Shoreline of Upper Lake Warren in front of the Norwich Moraine

The height of this shoreline is such that it corresponds approximately to the height of the boundary between the Norwich moraine and the adjacent sand plain at approximately 865'. Thus it runs around the 'base' of the morainic islands, and elsewhere crosses areas of sand plain. Consequently, there were large areas of shallow water offshore, and this, coupled with the fact that this stretch of shoreline occupies a sheltered location behind the archipelago formed by the Tillsonburg moraine, has severely limited the development of shoreline features.

Between New Durham and Cathcart, bluffs belonging to this lake stage are found truncating exposed spurs of the Norwich Moraine. This shoreline shows relationship to the nature of soil materials here, and there is a narrow strip of sandy soil indicating the former beach position. To the north of Cathcart, isolated shore bluffs are found in the most exposed locations.

(c) The Shoreline of Upper Lake Warren on the Tillsonburg Moraine to South of River Nith.

The Tillsonburg Moraine consists of a series of morainic 'islands' separated by areas of sand plain. The level of Upper Lake Warren was such that these islands stood above lake level whilst the sand plain areas were submerged.

The northernmost morainic island, to the southwest of Falkland,

was just awash in the waters of Upper Lake Warren. Its surface at an average elevation of 880' is unusually flat compared with other morainic surfaces in the Tillsonburg moraine, the local relief being only 10' and there is very gentle sag and swell topography. This modified form is the result of the planing action of the waves of this glacial lake. Soils here are patchy but tend to be sandy in the better drained ares.

About 1½ miles to the north of Highway 53 is the northern most island of the archipelago. There is a good feature on its eastern side where bluffs and a narrow bench have been cut in the morainic material above the junction of moraine and sand plain, which forms a second, more rounded break of slope.

Highway 53 traverses a small island 2½ miles to the west of Burford. To the south of this island are 14 more islands ranging in size from over a mile to 100 yards in length. Comparatively well defined features are found on all east and southeast facing slopes in the more exposed locations, and where deep water existed offshore. Bluffs are cut in the morainic till and are rounded with fairly narrow sloping benches in front, and associated cobbles (photo 4). Soil sandiness is widespread and thus of no use in shoreline identification. On sheltered shores, between the islands and facing westwards, there are frequently no shoreline features to be found. On the western slopes, the height of the shoreline frequently corresponds to the height of the break of slope between the moraine and adjacent sand plain.

(d) <u>The Shoreline of Upper Lake Warren on the Paris Moraine between the River Nith and Horner Creek</u>

These are some unusual features associated with the development of the shoreline of Upper Lake Warren in this section of the Paris moraine.

The ice front was standing at this moraine during the existence of Upper Warren and shorelines developed around the morainic areas which were adjacent to the ice front and standing above lake level. Thus the shoreline separates the landlaid areas of moraine from those areas of moraine which were submerged by the lake and deposited beneath its surface. Surprisingly well defined features are found in close proximity to the ice front, in locations where, because of their enclosed nature only poorly developed features would be expected, or none at all. These shorelines rise rapidly in altitude upon approaching supposed position of ice front. As noted, it is thought that these breaks of slope mark the boundaries of local spillway and outwash areas. The 'bluffs' at the edges of these features merge imperceptibly with the shoreline bluffs. The deposition of outwash materials in these channels and over the areas of waterlaid moraine forms a veneer of bedded sands and gravels, typical of such areas.

The shoreline as mapped outlines several large and irregular islands with several characteristic features. In the extreme south, immediately to the north of Horner Creek is a ridge of high land bounded on the west by a line of well defined bluffs cut into sandy fill. The southern tip of the feature has been truncated by the post glacial erosion of Horner Creek; to the north, the land surface becomes lower and the shoreline is indefinite. There are no shoreline type features to be found on the steep east facing slope. It is believed that this was the ice contact face at the time.

To the north the larger islands exhibit the same characteristics. The best defined bluffs and benches occur on the western sides, a weaker feature elsewhere, whilst the eastern slopes show the characteristics of

an ice contact slope. Soils are sandy over the area of waterlaid moraine whilst almost pure sand or fine gravel is found along the beach strands. Cobbles are generally absent.

THE SHORELINE OF MIDDLE LAKE WARREN

This shoreline is located throughout its length, some 10' to 15' below the shoreline of Upper Lake Warren. Consequently, in most locations it is in a less favourable position for the development of shoreline features due to the presence of extremely shallow water offshore.

Within Brant County, Middle Lake Warren was divided into three sections by island archipelagos of the Tillsonburg and Paris moraines. Thus nowhere is there a great length of fetch, and there is a great variety of shoreline situations.

The shoreline rises from 845' in the south to 895' in the north where it occupies a position on the Galt moraine to the north of Blue Lakes.

(a) <u>The main shoreline of Middle Lake Warren in front of the Norwich moraine</u>

The arm of the lake between the main shoreline and the Tillsonburg moraine was nowhere more than 10' deep. This shoreline was also sheltered by the islands of the Tillsonburg moraine, and consequently the development of shoreline features here must have been limited. There are no shore features in this area which have been definitely identified.

(b) <u>The shoreline of Middle Lake Warren on the Paris and Tillsonburg Moraines to the north of the River Nith.</u>

In the northeastern extremity of this area the Grand River spillway was flowing southwards along the ice front (at Galt moraine) and discharging into this lake. The shoreline runs southwestwards from the

point of entry of the spillway into the lake, the feature increasing in strength as its distance from the spillway increases. There was a broad area of shallow water offshore for most of the length of this shoreline, consequently poorly developed features might be expected. In actual fact, quite well developed features are found, and this is probably due to the soft and easily erodible materials (chiefly water laid moraine) into which shore features have been cut. There are associated sands and gravels and the broad sloping bench in front of the bluffs. The nature of the topography lends itself well to bench development.

The shoreline feature runs southwestwards for about a mile from the Grand River spillway and consists in this section of a gently sloping bluff, averaging 15' in height and a 10 to 20 yards wide bench. There are some weakly developed beach ridges offshore. The shoreline then turns and runs northwestwards and reaches its maximum development in this section. There is a steep bluff but it is quite low - about 10', which is continuous and has a broad, exceptionally sandy bench in front with scattered cobbles up to 4" in diameter. This line of bluffs continues northwards along the western side of the Paris moraine gradually becoming indistinct towards northern limits of the lake.

Several low islands are located across the mouth of this embayment. Good bluff and bench features are found on their exposed southern sides and there are associated sands, gravels and small cobbles.

On the eastern side of the Tillsonburg moraine, i.e. the western side of the embayment, shoreline features are absent due to either one, or possibly both of two factors. Post glacial stream erosion is active

here and may have removed the features, and also the area is sheltered by the above mentioned islands. To the west of the islands shore features are again found cut in the till of the moraine. Stepped profiles on spurs between gullies are characteristic of this area.

The Middle Warren shoreline runs parallel here to the shoreline of Lower Warren and tends to be better developed due to a more favourable location further up the morainic slopes. Both shorelines are discontinuous due to post glacial gully and stream development, but it is possible to trace the Middle Warren shoreline around the southern end of this section of the Tillsonburg moraine to the county boundary.

(c) <u>The shoreline of Middle Lake Warren on the Paris Moraine between the River Nith and Horner Creek.</u>

This section of the Paris moraine formed two large islands in Middle Warren separated only by a narrow, shallow channel. The Middle Warren beach runs parallel to the High Warren beach along the eastern side of this moraine and 10' to 15' vertically below it. In some extreme cases, in exposed locations on steep slopes the two beaches merge into one broad feature, whilst on the western, more gentle slope of the moraine, the two features are up to 600 yards apart.

The Middle Warren shoreline is generally less well defined than the shoreline of Upper Warren, as was the case in the area of the main shorelines on the Norwich moraine. Along the eastern side of the islands well defined features of the Middle Warren beach are found in the more exposed east and south-east facing locations. Bluffs cut into sandy till are generally weak and not well developed, but the wave cut benches often reach widths of over 100 yards (photo 5). These broad level areas of sandy soil are frequently the sites of orchards. At the southern tip

Photo 4. The Upper Warren beach on the Tillsonburg moraine to the west of Northfield Centre. This is a fairly well defined feature facing southeastwards. Note the second and lower break of slope between the moraine and the adjacent sandplain.

Photo 5. The Middle Warren shoreline. The rounded feature represents this shoreline on the northeastern side of the more southerly of the two islands.

of this section of moraine, shoreline features have been eroded by the post-glacial development of Horner Creek.

The shoreline along the western side of the moraine is indicated by discontinuous weak features. Poorly defined bluffs, an intermittent bench and a narrow strip of stoney or sandy soil can be traced with difficulty.

The northwestern boundary of this morainic area, which crosses Highway 2 a mile to the west of Paris, is marked by an exceptionally fine feature which is the result of a combination of factors (photo 6). This is the boundary between moraine and sand plain at the point where a spillway channel impinged upon the moraine, and eroded the present feature. The shoreline features, which pre-date the spillway have been almost completely eroded, and the only remaining evidence is a slight break of slope on the face of the bluffs.

(d) The Shoreline of Middle Lake Warren on the Paris Moraine to the south of Horner Creek.

The Middle Warren shoreline runs parallel to the Lower Warren shoreline for most of its length in this area, but it is considerably better defined. In fact, this shoreline shows its greatest development here. Along the steep, east facing ice contact slope of the moraine the feature is well developed in the more exposed locations (photo 7). Steep bluffs are cut into the sandy morainic fill, and there are definite though narrow benches. There are many cobbles here, consisting of limestone and of erratics, and they range up to 2' in diameter. At the northern tip of this section of moraine, an indefinite line of bluffs runs just to the south of Bishops Gate. Along the western side of this morainic island no shoreline features were found. This may be

Photo 6. The Middle Warren shoreline one mile west of Paris. The main break of slope is the moraine-sand plain boundary. Mid-way up the feature, the small break of slope is believed to be the Middle Warren shoreline.

Photo 7. The Middle Warren shoreline on the Paris moraine to the south of Mt. Vernon.

attributed to the unfavourable situation.

(c) The Shoreline of Middle Warren on the Tillsonburg Moraine to South of the River Nith.

For much of its course the Middle Warren shoreline runs parallel to the shoreline of High Warren, 15' to 20' lower in altitude. In the north, a large area (to the southwest of Falkland), that was awash in the waters of High Warren, forms a large flat-topped island in Middle Warren. The shoreline is represented by distinct terraces on the eastern and southern sides of this island (photo 8). Below this terrace is another distinct break of slope between the moraine and the adjacent sand plain.

To the south is a series of small islands. The shoreline on the eastern side of these islands (on the steep ice-contact morainic slope) is generally poorly defined since it corresponds closely with the boundary between moraine and sand plain. There was also a broad area of shallow water offshore. The western slope of the islands is very gentle and here no shoreline features are recognizable.

THE SHORELINE OF LOWER LAKE WARREN

The ice front at the time of Lower Lake Warren stood far to the east of Brant County. The shoreline follows the eastern side of the Galt moraine across South Dumfries Township, then runs southwestwards to the Tillsonburg moraine, and follows its eastern slope to the southern county boundary. The Paris moraine forms two large islands in this lake, whilst the Galt moraine forms several smaller islands. Between the Tillsonburg and Paris moraines, an extremely shallow area of the lake precluded the development of features along its shores.

Photo 8. The Middle Warren shoreline on the Tillsonburg moraine. Here it is represented by gently sloping bluffs and a distinct bench.

Photo 9. The Lower Warren shoreline near Branchton, represented by a bluff and bench with low beach ridges.

The height of this shoreline of the southern county boundary is 835'. It rises northwards to reach a height of 903' on the Galt moraine.

(a) The Shoreline of Lower Lake Warren on the Galt Moraine to the north of Blue Lakes

The shoreline runs southwestwards from the Wentworth County boundary across a section of Dumfries Township. There are well defined beach bluffs 10-25' high cut into the till at the edge of the Galt moraine. Near Branchton there has been some local dissection by post glacial streams, but generally the feature is fairly continuous. It varies in strength according to location. In some locations beach ridges are found at the foot of the bluff and are composed of gravel with cobbles up to 1' diameter. Sandy soil is found at the foot of the bluffs, and on the lower slopes of the bluffs themselves. (photo 9).

The best developed shoreline features in the region are found in the vicinity of Branchton. Due east of Branchton an exceptionally well defined bluff on the southernmost end of a morainic spur stands 50' high with a broad bench in front. It owes its form, no doubt, to its extremely exposed position. At Branchton the continuity of the shoreline is broken by the upstream end of a spillway which drains eastwards across the Galt moraine.

To the south of the spillway the beach continues as a well defined feature with associated sands, gravels and rounded pebbles in the soil forming a broad belt along the foot of the feature.

The inferred position of the shoreline continues westwards for almost a mile and then swings abruptly southwards and follows the steep front of the Galt moraine to within a mile of St. George. In this section shoreline evidence is extremely fragmentary. Small, localized

benches can be recognized and there are associated strips of sand beaches. In the northwestern 'angle' a beach has been constructed across the mouth of an embayment. It is thought that extreme development of morainic topography, such as is found here, is not conducive to beach development and preservation. The ice contact slope of the moraine is very steep. Beaches may be very narrow and obscured by soil creep and gullying. Numerous embayments, knobs and kettles tend to complicate the topography and make beach identification merely a matter of connecting all the bluff and bench type features at a certain height. Wave force would be broken by offshore submerged knolls and islands, reducing the probability of the development of well defined features. In many places at the supposed beach height, or slightly above, partially buried limestone boulders up to 12' in diameter were found. It is possible that they were exposed by wave action along this shoreline.

The character of the moraine changes one mile to the northwest of St. George. Topography becomes smooth and rolling and merges almost imperceptibly with the adjacent sand plain. The shoreline here turns and runs towards the southwest and well defined beach bluffs are found again at approximately 890'. The presence of these better developed features here is due to two factors: the waterlaid type of morainic topography is better suited to the development and preservation of bluff and bench features; the changing attitude of the shoreline from east-facing to south-east facing gives better exposure to direction of maximum fetch.

A well defined feature encircles a small island on the northern outskirts of St. George. Associated beach deposits are exposed in a

nearby sand and gravel pit (photo 10).

Between this section of shorelines and Highway 24, the beach is represented by a small topographic feature which is rather indefinite in places but can be followed fairly continuously. The weak development here was due to presence of shoals within half a mile of the shore. The only breaks in the shoreline occur where it is crossed by several large gullies which trend towards the southeast.

To the west of Highway 24 is an area of well developed knob and kettle type morainic topography, and as in the similar area to the northwest the shoreline becomes indistinct. A very well developed feature, however, is found on the high spur of moraine which overlooks the secondary road and causes its slight deviation to the east of Blue Lakes. Here, there is a 10' high, steep bluff immediately below the crest of the spur. Associated materials vary from coarse sand to cobbles up to 1' in diameter, and these have been quarried fairly extensively. To the west of this bluff is a large sandspit developed by deposition of materials carried westward, (photos 11 and 12). This is the best example of a sandspit within the region.

From the sandspit the shoreline trends roughly westwards towards the Grand River at approximately 865'. In this section features are generally well developed although complicated in some locations by the Blue Lake spillway channel which will be discussed later. Westwards to Blue Lakes is a well defined bluff 20-30' high with a narrow sandy beach at its foot. To the north of Blue Lakes the shoreline occurs midway in altitude up the steep concave bank of the spillway channel and the representative feature is frequently only a narrow terrace or

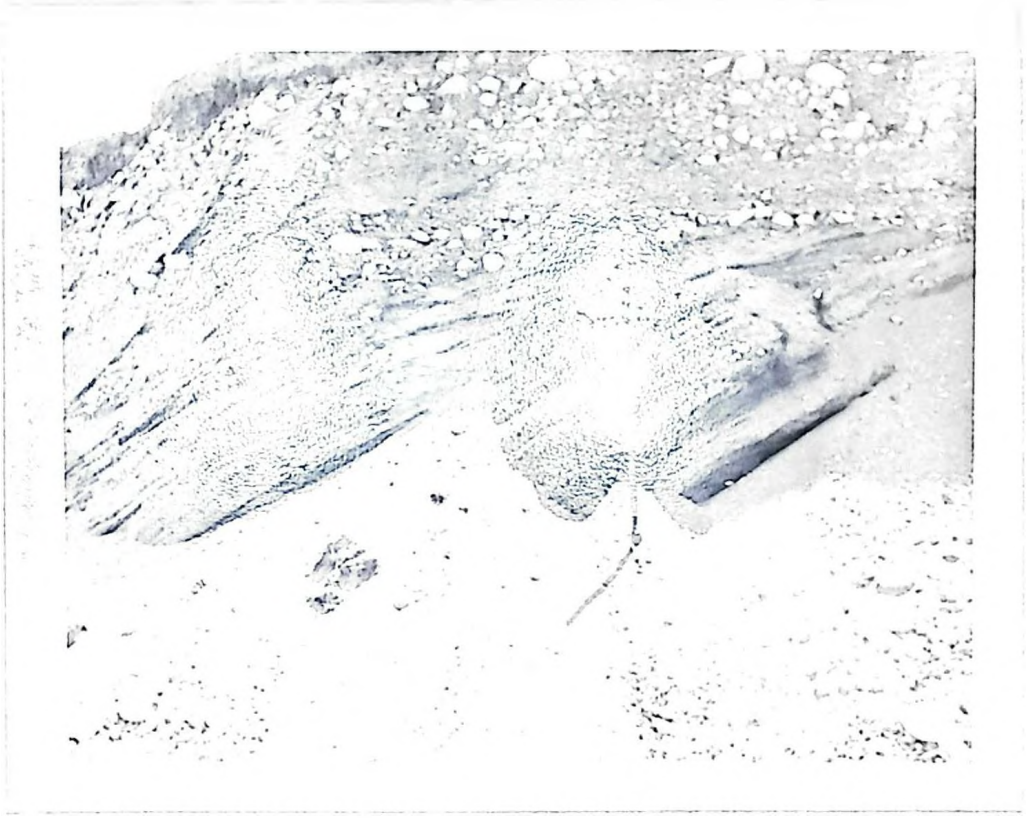


Photo 10. Section in the gravel pit at St. George. Steeply dipping sands and gravel beds are truncated by the horizontal Lower Warren Beach.

Photo 11.

Photo 12. Gravels and sands of the Blue Lakes sandspit. Photo 11 shows a strike section and Photo 12, a dip section.

Photo 13. The Middle Warren shoreline east of Blue Lakes. Numerous trees occupy the steep bluff, but there is no bench. The flat land at the right hand side of the photograph is a spillway terrace.

Photo 15. The Lower Warren shoreline south of the Religious Colony. The upper, indefinite break of slope is the shoreline, whilst the lower break of slope marks the boundary between moraine and spillway plain.

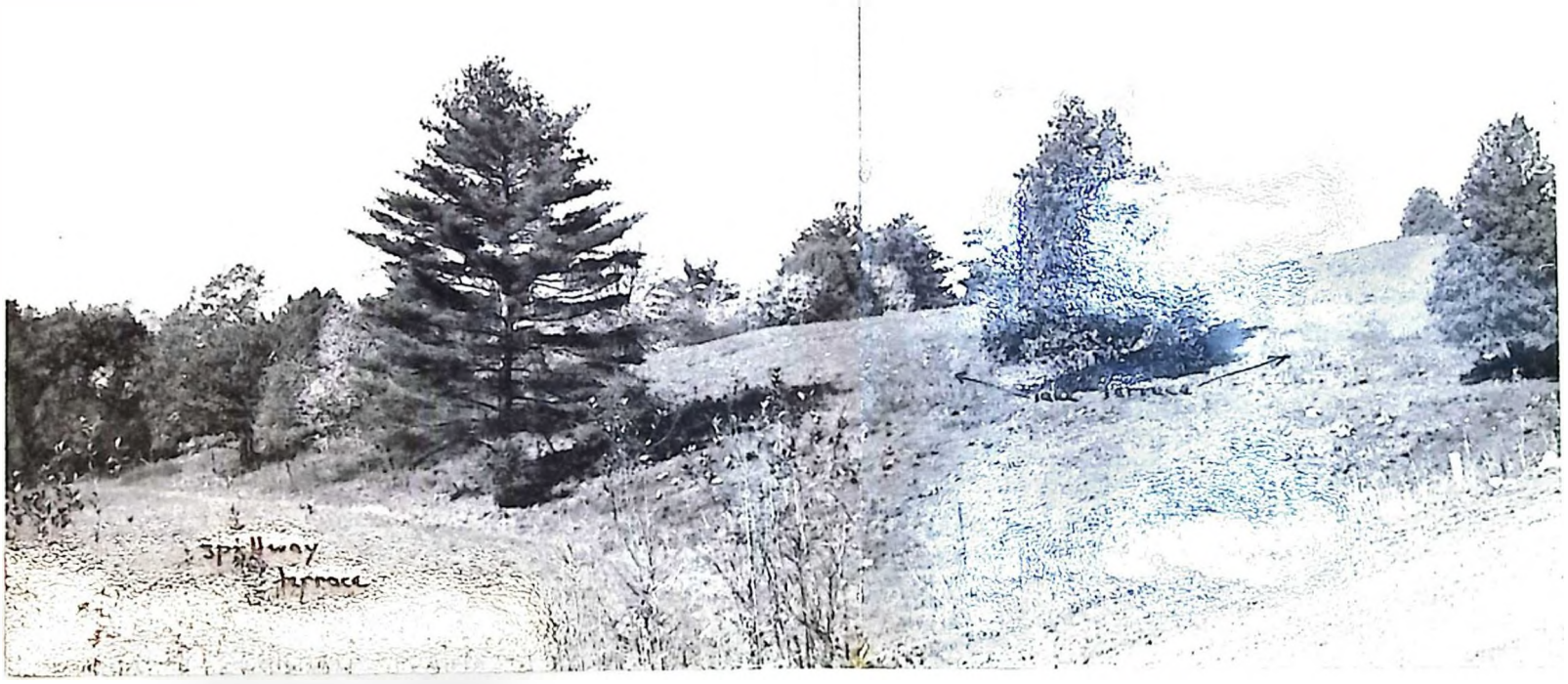


Photo 14. The northern bank of the Blue Lakes spillway channel showing the terrace formed by Lower Lake Warren.

break of slope (photos 13 and 14). Cobbles, gravels, and large, sub-angular limestone boulders are associated with this feature.

To the southwest of Blue Lakes, a well defined feature appears consisting of a steep bluff, a well defined break of slope at its foot, and a broad bench. The feature ends at the edge of the Grand River Valley.

(b) The Lower Warren Shoreline between Blue Lakes and the Grand River

This section of the Galt moraine formed a large island in Lower Warren. It is encircled by an unusually continuous shoreline. In the northwest the feature is continuous from a point just south of the Religious Colony to the northern tip of the island. It is represented by a bluff up to 60' high. The major break of slope here is formed by the junction between moraine and the plain of the Grand River spillway. The altitude of the Warren shoreline is indicated by a break of slope or slight terracing affect at 864' approximately, which is visible at the foot of the main bluff some 10-15' above the level of the spillway plain, (photo 15). Large scattered cobbles are found below the break of slope, gravelly soil occurs on the bluff accompanied by sand in localized areas. The weak development of the feature is due to its sheltered location on the leeward side of the island, and also to erosion by the spillway in late-glacial time. Gullies have developed on the face of the bluff during post-glacial time.

The importance of location with regard to the development of good shoreline features is well illustrated around the northern tip of the island. The change in attitude of the beach from northwest facing on the leeward side, to northeast, and east facing on exposed

side of the island, corresponds with a change from a poorly defined to a well defined beach feature.

From the northern tip of the island the shoreline trends south-westwards towards Highway 5. The beach bluffs are cut into the sandy till of the waterlaid moraine and form comparatively gentle features. There is a broad sandy bench in front of the line of bluffs which grades gently into the adjacent sand plain. The feature crosses Highway 5 about a mile from its junction with Highway 24, and then continues southwards to cross this highway, and to the southern tip of the island half a mile beyond.

Immediately to the south of the well developed bluff behind the Religious Colony the continuity of the shoreline is broken by a broad embayment in the moraine where, since the location is extremely sheltered, no shoreline features are to be found. To the south however, a good feature is seen where the junction between the moraine and the spillway plain coincides with the shoreline break of slope. The soil at the foot of this bluff is extremely sandy but this is partially due to the parent material of spillway sands and gravels. This feature runs southwestwards, crossing Highways 5 and 24, to the southern tip of the island.

(c) <u>The Lower Warren Shoreline on the Galt Moraine to the South of the Grand River.</u>

This section of the Galt moraine formed four small islands in Lower Warren in the four localities where the moraine rises above 850'. Shoreline features are well defined on their windward sides.

(d) The Lower Warren beach on the Paris and Tillsonburg Moraines to the North of the River Nith.

In this area, the land surface into which spillway features have been cut consists of waterlaid moraine and sand plain. The Lower Warren shoreline is seen merging with the valley sides of the Grand River three miles to the northeast of Paris. There is a well defined line of bluffs cut into sandy till running without a break from the Grand River to just beyond Highway 24A (photo 16). Scattered cobbles are widespread along the foot of the bluffs. Sandy soil is predominant but since this is an area of waterlaid moraine this is not a distinguishing criteria. 300 yards to the east of the highway a small upper beach feature becomes separate from a lower spillway feature. The beach bluffs form a gentle but definite feature up to 20' high with a broad, gently sloping bench in front. Beach materials are well exposed in a gravel pit adjacent to the highway (photo 17). The Middle Warren beach is not far distant, so some of the beach material may be related to this feature. The Lower Warren beach appears to be cut into Middle Warren beach deposits.

To the west of the highway the feature continues as a well developed south facing bluff 10-15' high. There is an associated bench up to 70 yards in width cut in the sands and gravels of the spillway plain. Continuity of these features is interrupted by a small valley formed by the lowest spillway terrace, and a small sandspit has developed across the mouth of this embayment. The shoreline is represented by well developed features on the western side of this embayment but its continuation southwestwards, following the break of slope formed between the eastern edge of the Tillsonburg moraine and the adjacent sand plain,

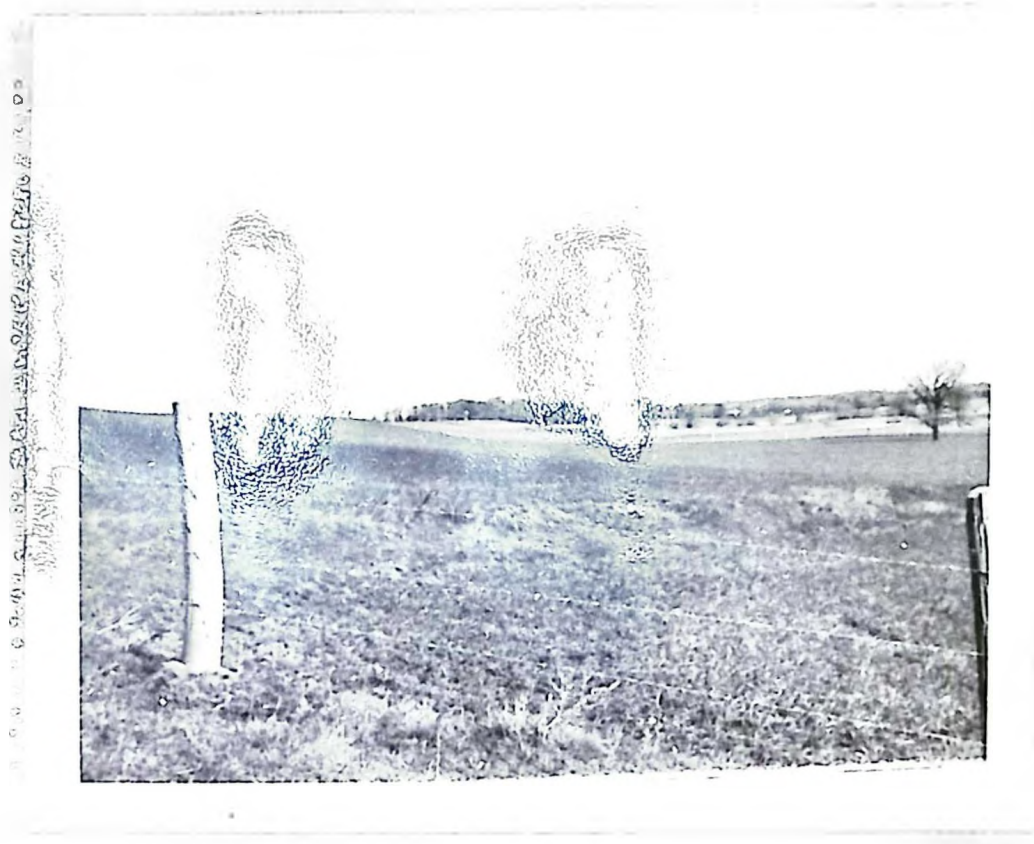


Photo 16. The Lower Warren beach on the northern Paris moraine occupies a position mid-way up this bluff which is a constructional morainic feature. In the distance, the beach bluff becomes separate as indicated.

Photo 17. Lower Warren beach materials exposed in a gravel pit to the east of Highway 24.

is not well defined. There is an offshore island here with a well developed feature along its exposed southern side, with a strip of extremely sandy soil along its foot.

Along the southern limit of this section of the Tillsonburg moraine, is a well developed, though discontinuous feature cut in the morainic till.

(e) The Shoreline of Lower Warren on the Paris Moraine between the River Nith and Horner Creek.

Along the eastern side of this moraine the shoreline lies along the approximate position of the boundary between moraine and spillway plain. A large area of shallow water offshore has prevented any strong development of beach features. A rounded bluff and bench which slopes and gently merges with the sand plain surface, occur in the more exposed locations. All shoreline features on the southern tip of this section of the Paris moraine have been destroyed by the post glacial erosion of Horner Creek.

On the southwestern section of this moraine is a well defined length of shoreline consisting of a sharp break of slope running along the foot of a series of spur bluffs. There is a broad bench in front with a veneer of extremely sandy soil. This feature continues northwards gradually decreasing in strength upon the gently undulating surface of the waterlaid moraine.

(f) The Shoreline of Lower Warren on the Paris Moraine to the South of Horner Creek.

This section of the Paris moraine formed a long and narrow island in Lower Lake Warren stretching unbroken from Horner Creek to the county boundary. The configuration of the moraine with its steep

eastern ice contact slope and long, gentle west-facing slope has had considerable influence on shoreline development. Along the eastern side of the moraine the Lower Warren shoreline runs slightly above the contact between moraine and the adjacent sand plain. A gentle break of slope representing the shoreline is found quite continuously along the foot of the moraine. Stronger development of the feature did not take place, despite the favourable aspect, due to very shallow water offshore. The feature reaches its strongest development just to the east of Mount Vernon where there is a steep bluff and a broad level bench. In a few locations on the eastern side of the moraine low beach ridges occupy the wave-cut bench, resulting from the reworking of the gravels of the adjacent plain.

Between Mount Vernon and Bishops Gate an indefinite break of slope represents the shoreline. To the south, no features are found on the western morainic slope, due to location and aspect.

(g) The Main Shoreline of Lower Lake Warren in the Tillsonburg Moraine

The interpolated position of this shoreline is shown on the accompanying map. This arm of the lake is too shallow (maximum depth 10'), and also too enclosed to permit the development of shoreline features.

THE LAKE WAYNE SHORELINE

This shoreline is relatively continuous where it follows the eastern slope of the Galt moraine in North Dumfries Township, but southwards, across Brant Township beach features are rare. The location of a considerable length of shoreline was interpolated. The Galt moraine formed several islands in Lake Wayne.

The shoreline is located at approximately 810' on the southernmost

island of the Galt moraine and rises to a height of 870' on the same moraine near Branchton.

(a) The Shoreline of Lake Wayne on the Galt Moraine to North of the Grand River.

At the Wentworth County boundary this shoreline is represented by a line of low, southwestward-facing bluffs cut in the till of the Galt moraine at a height of approximately 875'. Southwards towards Branchton, shoreline features are weak or absent, due to the fact that the inferred position of the shoreline lies along the edge of the limestone plain.

To the south of Branchton, features of this shoreline are once again found cut into the till of the Galt Moraine. An exceptionally well defined feature immediately to the south of the Branchton spillway channel trends from northeast to southwest following approximately the 875' contour on the topographic map sheet. Here, a 15' bluff shows some slight modification and has a number of extremely large, partially buried limestone boulders at its foot. These are sub-angular, and bedding planes and joints are clearly visible. There is a broad bench in front of the feature which is up to 100 yards wide, and with much sand and gravel in the soil. The strength of this feature is due to its favourable aspect, facing southeastwards and thus exposed to direction of waves with the maximum fetch, and also to the presence of deep water immediately offshore. (Lake reaches a depth of 75' at a distance of 300 yards from the shoreline).

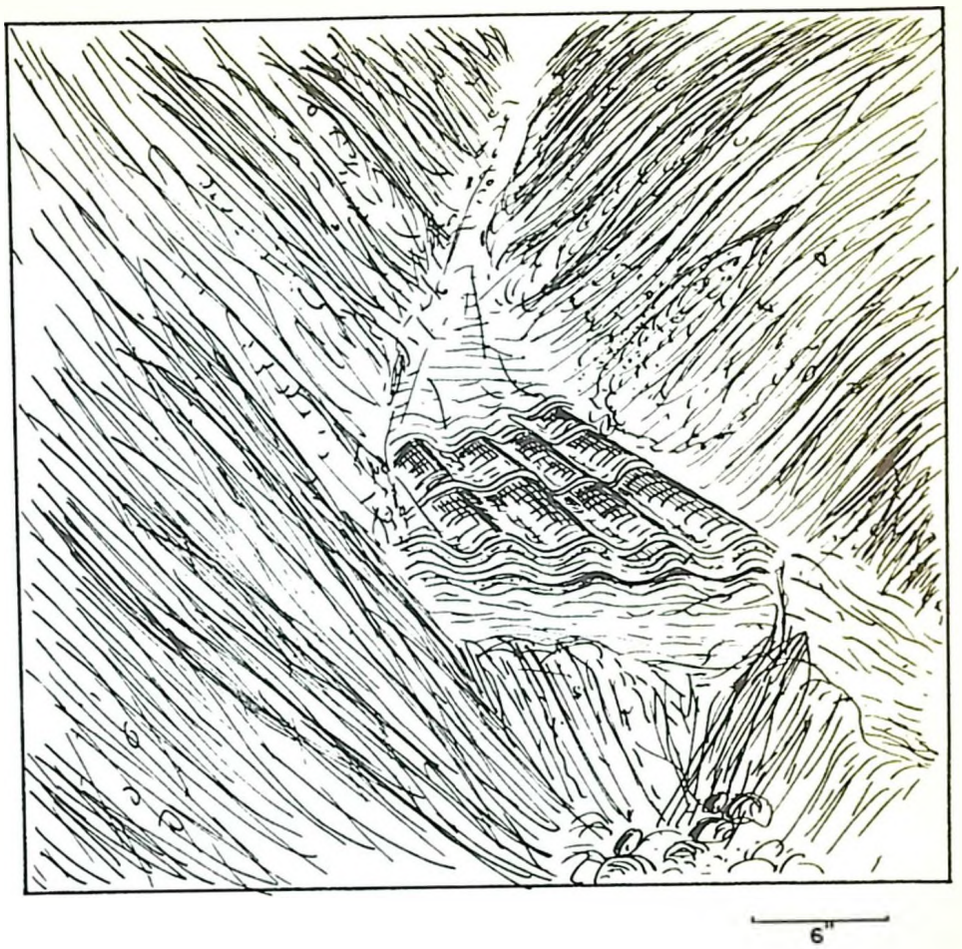
From this point, to within half a mile of St. George there is only scattered and fragmentary shoreline evidence. As with Lower Warren at this site, absence of features is due to shallow water offshore.

Also, the position of the shoreline here corresponds with the boundary between moraine and limestone plain in the north, and moraine and spillway plain further south. These boundaries form the only recognizable break of slope in the area.

Near St. George the shoreline changes its trend from almost north-south, to northeast - southwest, and a corresponding change to a well developed feature is found. This runs from St. George, westward, to just north of the junction of Highways 5 and 24. A topographically well defined feature partially encircles the St. George island. On the western tip of this island is a large sand and gravel pit where the succession of the Wayne and Lower Warren beaches is well illustrated. In the lowest part of the sand pit a fine set of ripple marks is displayed formed in a series of fine sand and silt beds, (fig. 5). These are believed to have been deposited in an offshore location in Lake Wayne. They are buried by approximately 20' of cross-bedded sands and gravels, deposited during lake transgression to Lower Warren. These steeply dipping beds are truncated by the horizontal Lower Warren beach (photo 10).

Between St. George and Highway 24 the Wayne shoreline is represented by an almost continuous line of bluffs cut into the sandy till of the waterlaid section of the Galt moraine. The line of bluffs coincides approximately with the boundary between the moraine and sand plain. Bluffs are quite steep (for the Wayne shoreline) and from 10-20' high, and there is a narrow bench at their foot. Small sand and gravel pits cut into the beach bluffs have exposed beach gravels and many cobbles. There are some areas of sandy soil.

FIGURE 5



RIPPLE MARKS FORMED IN LAKE WAYNE

EXPOSED IN THE GRAVEL PIT AT ST. GEORGE

The continuity of the bluffs is broken by several deep gullies of unusual form. They have steep sides and are flat floored, and the shoreline break of slope continues as the break of slope between gully floor and sides. Away from the shoreline the gullies become less well defined and more rounded; the gully floors have a steep gradient, and at the upstream ends merge gently into broad basin-like forms, or shallow kettle type depressions in the surface of the moraine. All these gullies are now dry, and it would appear that they originated during ice retreat from the Galt moraine, (and the corresponding falling lake level), as drainage channels from stagnating ice blocks and water pondings near the edge of the moraine. Since then, modification by lake action has produced the present form, with beach bluffs grading into the valley sides.

To the west of Highway 24, shoreline features continue but decrease in clarity. They are partially buried in places by materials deposited in the succeeding Lower Warren (photo 18). The shoreline then turns and runs almost due south along the eastern slope of the Galt moraine and the edge of the adjacent sand plain.

(b) <u>The Wayne Shoreline on the Galt Moraine to South of the Grand River</u>

This southern section of the Galt moraine formed three islands in Lake Wayne. The height of the shoreline ranges from approximately 820' on the northern end of the northernmost island to slightly more than 800' at the southern county boundary. Throughout its length the position of the shoreline approximately coincides with the boundary between moraine and sandplain, but since the Galt moraine is waterlaid here, there is no associated break of slope. Gentle, poorly defined shoreline features are characteristic. In the gaps between the islands,

Photo 18. The Lake Wayne beach exposed in a gravel pit mid-way between Blue Lakes and Highway 5. Layers of gravel and coarse sand overlying the beach were deposited in Lower Lake Warren.

sharp breaks of slope are due to post glacial stream erosion, and are not shoreline features. Along the western side of this moraine are a series of spurs jutting onto the adjacent sand plain. Steep bluffs have been cut in these exposed locations, but elsewhere shoreline features are absent and the sand plain merges imperceptably, and with no break of slope, into the moraine.

(c) The Main Shoreline of Lake Wayne

The location of this shoreline is somewhat arbitrary since there are no distinct features in the area. The shoreline was plotted according to heights determined by extension of those determined on the Galt moraine to the north. In some locations the shoreline follows terraces on the sand plain formed prior to transgression of this lake.

Reference

1. MacLachlan, D.C. "The Warren Shoreline in Ontario and in the Thumb of Michigan." Unpub. Ph.D. thesis. University of Michigan, 1939.

CHAPTER 3

ANALYSIS AND IDENTIFICATION OF THE SHORELINES

HEIGHT

The height of shoreline features was determined accurately at 20 locations within Brant and Wentworth Counties. The 5 locations in Wentworth County were based upon J. Horton's mapping,[1] whilst the 15 locations within Brant County represent places where clear cut shoreline features were traversed and measured from spot heights. The distribution of these locations with regard to the individual shorelines is rather uneven (fig. 6). There were three accurately surveyed heights on the Lake Wayne shoreline, ten on the Lower Warren shoreline, five on each of the Middle and Upper Warren shorelines and none on the Whittlesey shoreline. This irregular distribution results from not knowing to which shoreline the various individual features belonged when heighting was carried out. The absence of any heighting on the Whittlesey shoreline also results from lack of the initial accurate altitude data in that area, but estimated heights are believed to be accurate within 5'. Areally , the distribution of the 20 locations is

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1 Horton, J. H., 1961.

quite even (fig. 4), and it is believed that height data obtained does constitute a solid basis for subsequent reasoning.

Shoreline elevations were found to decrease generally from northeast to southwest. In the extreme northeastern part of Wentworth County, the highest shoreline elevation for the whole area was recorded at 948' on the Lower Lake Warren shoreline (although the steep gradient this implies leads one to doubt the accuracy of this figure; the original mapping may have been inaccurate). Karrow[2] and Horton[3] both give a height of 925' for this shoreline in the same area, and this would seem to be the more accurate. At the Wentworth and Brant County boundaries the Lower Warren Shoreline was recorded at 903', whilst both Karrow and Horton report it at a height of 905' on this section of the Galt moraine. This shoreline then decreases in altitude southwards to a height of slightly above 840' at the southern margin of Brant County. The trend of the other shorelines is similar.

The deformation of the five shorelines is shown on the accompanying diagram (fig. 6). Profiles were plotted along the bearing North 20° East which is the line of maximum tilt as defined by Hough[4] for the region of southwestern Ontario. Accurately heighted shoreline features are distinguished from locations where the height of the feature was estimated from its position with regard to contour lines and adjacent spot heights. As mentioned in the previous chapter, all recognizable

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2 Karrow, P.F., 1959.

3 Horton, J.H. (op. cit.)

4 Hough, S. L. 1958 P. 139

"shoreline type" features were plotted and originally all were transferred to this diagram. The grouping of features of various heights to form the five distinct shorelines as shown here necessitated the erasing of some features which originally appeared doubtful.

On the basis of this diagram the features plotted on the 1:50,000 and larger scale maps in the field, were linked as shown on the accompanying map (fig. 4). The positions of the shorelines were interpolated where no features had been found. Isobases for the five shorelines are based on the profile gradients and drawn perpendicular to this line of section (fig. 7).

One of the most prominent features of figure 6 is the great height variation at any one locality of the break of slope which was plotted as indicating the height of the shoreline. The greatest discrepancy recorded was at Kirkwall in Wentworth County where the Lower Warren shoreline is found outlining a small island which lies 150 yards in front of the main shoreline. The more exposed shoreline of the island was found to be 11' lower than the more sheltered section of the main shoreline. Large height discrepancies occur between locations which fall on the same isobase but are areally distant. This is probably due to local variations in the regional warp.

In his discussion on the relationship of the height of the notch at the back of a wave cut bench to sea (or lake) level, Zeuner[5] states that this relationship is not the same everywhere. "On shores with heavy surf,, where the action of waves of translation is intense, the

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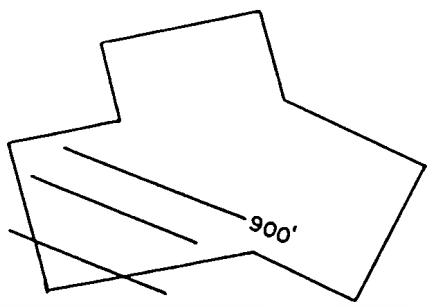
5 Zeuner, F.E., 1959. pps. 278-9.

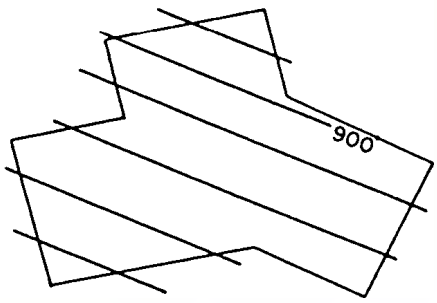
Figure 7

ISOBASES FOR THE GLACIAL LAKES OF BRANT AND WENTWORTH COUNTIES

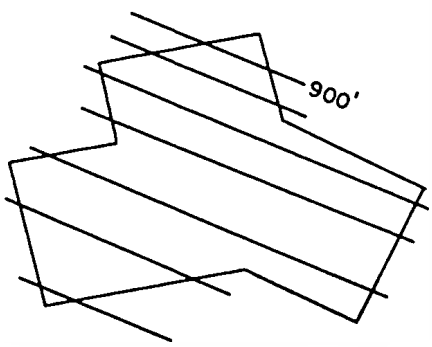
WHITTLESEY



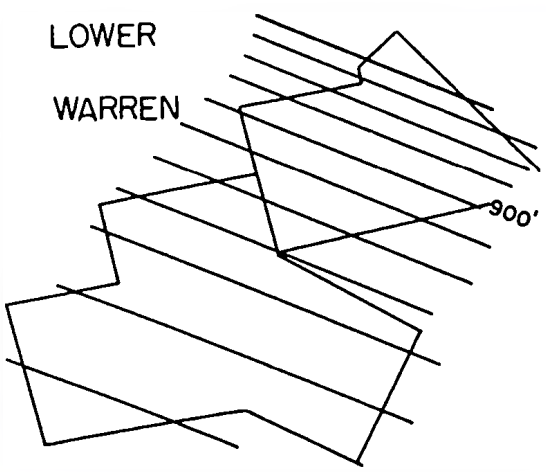
UPPER WARREN



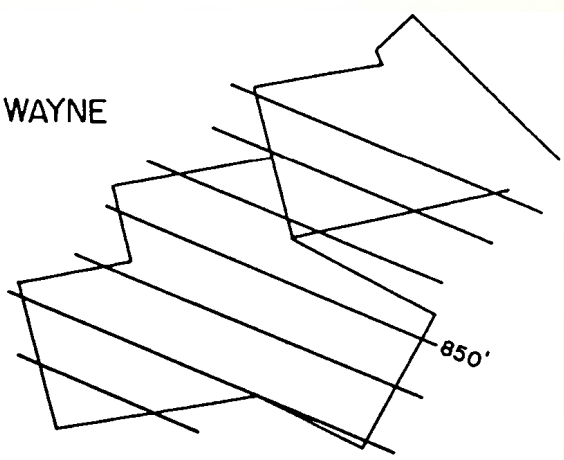
MIDDLE WARREN



LOWER WARREN



WAYNE



SCALE: 15 Miles to 1 Inch

ISOBASES at 10 foot intervals

abrading action reaches above the actual water level and the platform extends beyond the high water mark. A comparatively shallow offshore area (i.e. gently sloping) is necessary for the development of waves of translation." Zeuner also states - "It is probable that the relation of the intensity of the translatory waves to the resistance of the rock and steepness of the cliff determines whether the wave carved platform exceeds high water level or not. Along most perpendicular resistant cliffs its inner edge appears to remain well below high water mark, sometimes by several meters".

Thus the break of slope on the exposed shoreline may be either above or below the true lake level depending on the steepness of the general lakeward slope. Over the whole of the area studied, materials which have undergone shore erosion are unconsolidated and therefore comparatively weak. Therefore varying degrees of resistance to erosion are unimportant, and for the purposes of this argument, may be ignored.

Zeuner concludes - "The margin of error implied in determining the height of an ancient sea level from the inner edge of a bench, is several metres, though it will rarely exceed 4 metres". Thus a variation within 8 metre's (24') is possible. Variations in height found in Brant and Wentworth counties are considerably below this maximum, height differences of up to 10' being the most common.

DEFORMATION

All the shorelines are found to have undergone deformation to a varying degree. The average gradient over all the beaches in the area is approximately 2.5' per mile along the line of maximum tilt trending N. 20°E. This may be compared with gradients on the Algonquin and Iroquois

beaches as projected across this area from the west and east respectively.[6] The extended isobases for the Algonquin beach (extended from a comparatively southerly situation of that beach) show a gradient of 1' per mile. Isobases of Lake Iroquois show a hinge line passing a few miles to the south of Brant County, and a gradient of approximately 1.5' per mile to the north. Thus the gradient on the Brant County beaches is about twice as great as the gradient on the lower and later beaches, as is to be expected.

Considerable increase in gradient towards the northern limits of the beaches is evident in the case of the four lower shorelines. For example, the Lower Warren shoreline is first seen at 845' in the southern part of Brant County. Along the line of maximum gradient it rises 1.9' per mile for 8 miles to the north, 2.9' per miles for the next 8 mile section, 3.5' per mile for the next 8 miles, and the increases to over 4' per miles to its northern limit (although this may be inaccurate as previously stated). The gradient in this northern section is comparable to the gradient of 4' per mile of the northern section of the Algonquin beach in the northern Huron basin.[7]

IDENTIFICATION

Identification of the shorelines was carried out by an analysis of the most recent literature on the chronology of the Great Lakes basins, and its application to the analysis of features mapped in the field.

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[6] Hough, J.L. (op. cit.). p. 220 and 224.

[7] Hough, J.L. (op. cit.). p. 224.

The three major moraines of Brant County are, from west to east, the Tillsonburg, Paris and Galt moraines. Putnam and Chapman correlate these three moraines with the triple morainic strands which elsewhere in Ontario and in Michigan mark the glacial readvance of the Port Huron substage. The correlation of the Tillsonburg moraine with the first strand of the Port Huron system is less definite than the correlation of the Paris and Galt moraines with the second and third strands. They state "... unless the Tillsonburg moraine is considered to be part of the Port Huron morainic system, the Erie ice lobe must be credited with a strong readvance that was not matched by the Huron lobe".[8] In the light of subsequent work, and also with regard to the conclusion of this thesis, the correlation of the Tillsonburg with the first strand of the Port Huron system would appear to be correct.

In his chronology of the Great Lakes, Hough states that Lake Whittlesey was in existence at the time of the maximum extent of the Port Huron ice. Thus the first morainic strand of the Port Huron, which in Brant County is the Tillsonburg moraine, is contemporaneous with Lake Whittlesey. Retreat of the ice front to the second strand of the Port Huron moraine was associated with lowering of the lake level to Upper Lake Warren, which is thus associated with the Paris moraine in Brant County. Further retreat to the third and final stage of the Port Huron substage is represented here by the Galt moraine, and is associated with slight lowering of the lake level to form Middle Lake Warren.

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[8] Chapman, L.J., and Putnam, D.F., 1951. p. 30.

Then followed the low water stage of the Two Creeks Interval. The next in the sequence of glacial lakes is Lake Wayne and it is not known whether this lake is related to a falling lake level prior to the Two Creeeks low interval or to a rising lake level during the subsequent readvance. Hough arbitrarily assigns it to the period of rise during the advance of the ice of the Valders substage. The maximum extent of the Valders ice is represented by the Fort Erie moraine, the next moraine east of the Galt moraine. This represents the position of the ice front at the time of Lower Lake Warren.

Thus these five lakes represent the eight highest lake stages in Brant and Wentworth counties, and occurred in direct relationship to the moraines of the area. Therefore it seems likely that field evidence for glacial lakes in this area can be related to the sequence of events outlined above.

Five different criteria were used for the purpose of identifying the shorelines, and these will now be discussed.

(1) IDENTIFICATION WITH REGARD TO BEACH GRADIENT

It is a characteristic of all the beaches of the early stages of the Great Lakes that they rise when traced northwards. The rise of the land surface is considered to be due to isostatic rebound since the weight of ice was removed from the area. Many beaches are found to be horizontal in the extreme southern sections of the lake basins, but to be tilted in the northern regions, thus indicating rising land to the north whilst the southern areas remained at the same elevation. The point where a beach begins to rise, that is, a line of zero uplift, is termed its hinge line. As the ice retreated further and further to

the north, so the area of land affected by tilting became limited to more northern areas. Thus the hinge line for any retreat stage is found to be north of the hinge line of the preceding stage.

For purposes of comparison the gradients of the more southerly sections of the beaches are discussed, since the northern sections of all beaches show considerable increase in upwarping northwards. These gradients are as follows (supposed chronological order):

Whittlesey	2.8' per mile
Upper Warren	2.6' per mile
Middle Warren	2.6' per mile
Wayne	2.2' per mile
Lower Warren	2.16' per mile

When placed in this order, beaches show a gradual decrease in gradient as is to be expected since the older beaches have undergone the longest period of upwarping. The Whittlesey beach shows the steepest gradient of 2.8' per mile, but it must be remembered that only the extreme northern section of this beach is seen in Brant County, and the gradient will therefore decrease considerably southwards.

Next in sequence the beaches of Upper and Middle Lake Warren show a slight decrease in gradient, both sloping at 2.6' per mile. The general similarity of gradient between these two Warren beaches, and the Whittlesey beach may be cited as evidence for the supposed lake sequence. Lake Whittlesey and Upper and Middle Lakes Warren formed an unbroken succession of lakes with no major periods of retreat or advance inbetween the lake stages, and thus the beach gradients may be expected to be somewhat similar.

Similarly lakes Wayne and Lower Warren form a chronological sequence, and their gradients of 2.2 and 2.16'/mile would appear to

support the theory of their identification. Lake Wayne is the older beach, and as expected, is slightly steeper than the beach of Lower Lake Warren.

The major "unconformity" of the sequence appears between the Middle Warren and the Wayne beaches where there is a variation in gradient of 0.4' per mile (the next largest variation in gradient between two adjacent beaches is .2' per mile). This break corresponds in the time sequence to the major ice retreat to the Two Creeks Low Interval, and thus a considerable period of time whilst the land, with the weight of much ice removed, underwent isostatic uplift.

A period of rapid uplift of the earth's crust in the Great Lakes region at this time is in accordance with the pulsatory sequence of upwarpings as first identified by Leverett and Taylor[9] in 1915 and later verified by Flint. Leverett and Taylor identified three pulses of uplift and dated them as follows:

(i) post Whittlesey and pre Algonquin (of intermediate magnitude)
(ii) post Algonquin and pre Nipissing (of greatest magnitude)
(iii) post Nipissing (of smallest magnitude).

Thus the period of uplift between lakes Middle Warren and Wayne corresponds to part of the first, and intermediate in magnitude period of uplift.

It seems likely therefore, from a comparison of beach gradients, that their tentative identification may prove to be satisfactory.

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9 Leverett, F., and Taylor, F.B. 1915.

(2) IDENTIFICATION WITH REGARD TO POSITION OF HINGE LINES

The position of the hinge lines for many of the glacial lakes have been accurately determined by several writers and summarized by Hough as shown on the accompanying map (fig. 8).

For the shorelines mapped in Brant and Wentworth Counties it is possible to calculate approximately the position of the various hinge-lines, since beach gradients, and vertical distance of beaches above the hinge lines are known. The results of this calculation are summarized in the following table.

Beaches in Chronological order	Gradient	Height above Hinge line	Distance to Hinge line from southern county boundary.
Whittlesey	2.8	142'	57 miles
Upper Warren	2.6	168'	65 miles
Middle Warren	2.6	163'	63 miles
Wayne	2.2	160'	73 miles
Lower Warren	2.16	160'	74 miles

In this calculation, it is once again the gradients of the more southerly sections of the beaches that are used, since these give the closest measure of the beach gradient between Brant County and the hinge line. This is the data that would be required for an accurate calculation. All beach gradients decrease southwards, and thus results of the calculations would be expected to indicate hinge lines too near to Brant County.

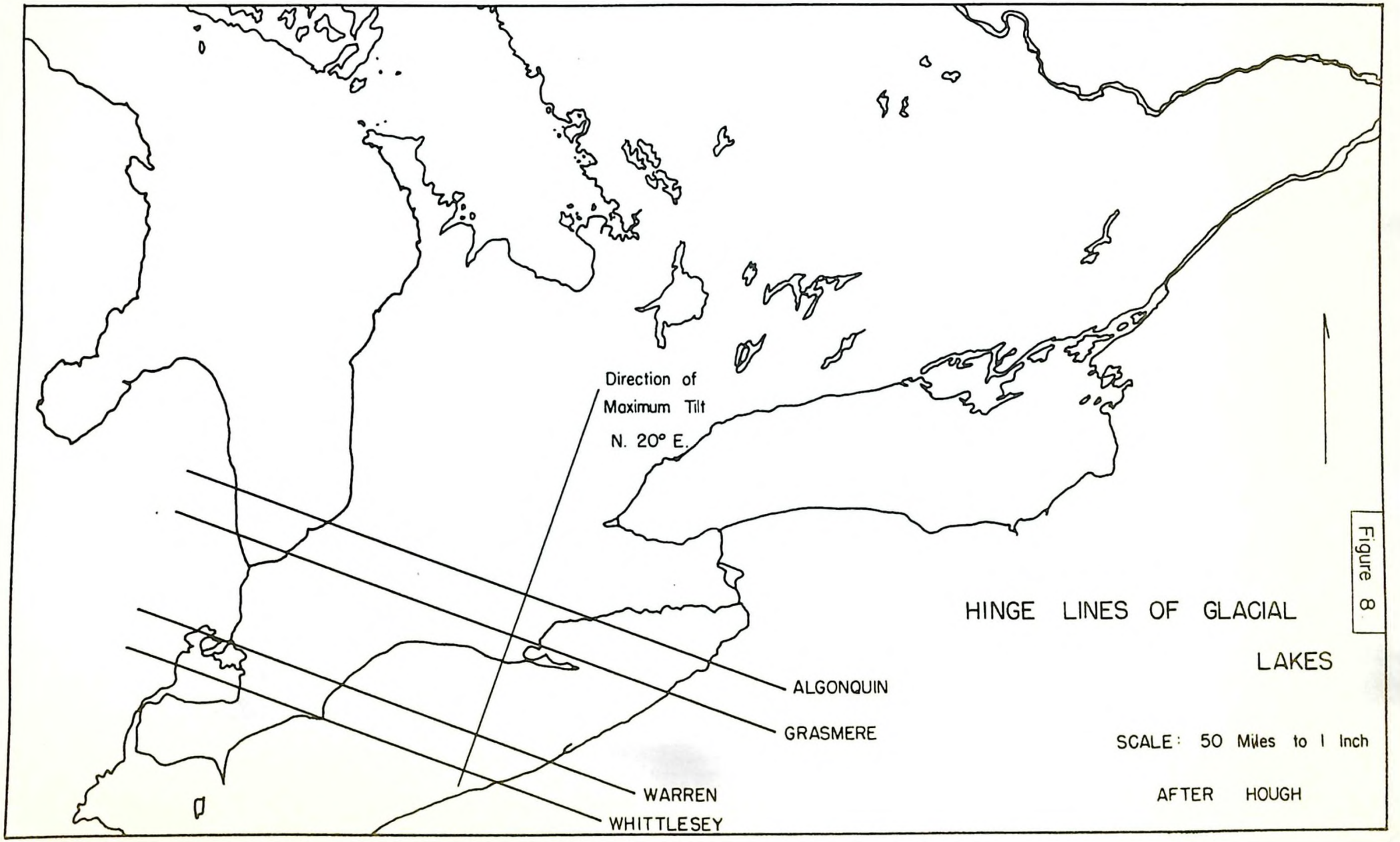

Figure 8.

HINGE LINES OF GLACIAL LAKES

SCALE: 50 Miles to 1 Inch

AFTER HOUGH

The above statement holds true for the Whittlesey beach. The distance measured from Hough's map between the Whittlesey hinge line and Brant County is approximately 75 miles, whilst the calculated distance is 51 miles. This great discrepancy is due to the use of the gradient of 2.8' per mile for the Whittlesey beach in the calculation. Only the extreme northern section of this beach is seen in Brant County, and its gradient will therefore decrease considerably southwards. The average gradient on this beach will be much less than 2.8' per mile, and the hinge line therefore, at a greater distance than 51 miles.

Hough places the Warren hinge line (he does not differentiate between the various stages of Lake Warren) 10 miles to the north of the Whittlesey hinge line at a distance of 65 miles from Brant County. The above calculation gives distances of 65, 63, and 74 miles to the Warren hinge line. There is a good correspondence therefore, between known and calculated distance to hinge line for the beaches of Upper and Middle Lake Warren. This indicates that the decrease in the gradient of these beaches between the southern boundary of Brant County and the hinge line is negligible. The variation of the Lower Warren beach - a distance of 74 miles to the hinge line is probably due to slight inaccuracies in height measurement, or in the projection of the beach profile across areas where its position was only interpolated, or to local differences in beach gradient due to structural factors; the latter reason is most probable.

The position of the hinge line for Lake Wayne is not indicated by Hough, but it will lie slightly to the north of the Warren hinge line. Therefore the distance indicated by the above calculation is too great,

and since this beach is closely related in many respects to the Lower Warren beach, the reasons for this anomaly are probably the same as those given above for the discrepancy of the Lower Warren beach.

Therefore it would appear that the criterion of calculation of distance to hinge line indicates quite definitely the correct identification of the Upper and Middle Warren beaches. Identification of the Whittlesey beach is neither definitely proven or disproved by this criterion. The variations in the case of the lower two beaches can be adequately explained.

(3) IDENTIFICATION BASED ON THE VERTICAL INTERVAL BETWEEN THE BEACHES

In the following table the vertical distance between the beaches, as deduced from fieldwork, is compared with the known[10] vertical interval between these beaches in their horizontal southern sections.

Beaches in order of height	Height at hinge		Height in Brant County South	
Whittlesey	738'		880'	
		48'		22'
Upper Warren	690'		858'	
		8'		13'
Middle Warren	628'		845'	
		7'		10'
Lower Warren	675'		835'	
		20'		20'
Wayne	655'		815'	

10 Hough, J.D., (op. cit.). p. 142.

From this table it can be seen that the interval between the supposed Lower Warren and Wayne beaches is, in actual fact, the same as the known interval between these beaches. Thus these beaches must remain a constant interval apart between their hinge line area and the southern boundary of Brant County. They diverge gradually as they are traced northwards across the county, until at the Wentworth County boundary they are 35' apart. This interval increases eastwards across Wentworth County to a maximum of 45'.

The known vertical interval between the Lower and Middle Warren beaches is 7', and this is compared with an interval of 10' between the two beaches in Brant County. This variation of 3' is so small as to be virtually negligible, but slight divergence of the beaches northwards is to be expected.

Similarly for the beaches of Middle and Upper Lake Warren, the known interval is 8' whilst the distance between the supposed continuations of these beaches in Brant County is 13'. The beaches would thus diverge 5' between their hinge lines and the southern county boundary, and once again, this seems to be a very likely situation. Northwards across Brant County the three Warren shorelines show only slight further divergences.

From this discussion of the vertical intervals between the lower four shorelines, it would appear that the original tentative identification is justified. There is however, some discrepancy with regard to the vertical distance between the Upper Warren and the Whittlesey beaches.

At the hinge line, there is a vertical distance of 48' between the Whittlesey and Upper Warren beaches, whilst in Brant County the interval between the two upper beaches is only 32'. Since the correlation

of the lower four beaches would appear to be correct, it seems likely that there is some reason for this discrepancy. It could be attributed to the influence of local structure upon deformation. The only other explanation that can be offered for this reversal of the more usual relationship, is that the land surface underwent some depression during the time between the existence of Lake Whittlesey and Upper Lake Warren. Such depression could be the delayed result of glacial readvance and related isostatic depression after the Cary-Port Huron low water interval when the lake basins were ice free. A depression of the land surface by 26' in the Brant County area would be necessary during the Whittlesey-Upper Warren interval to account for the present relationship between these beaches.

There are no records of such relationship between beaches having been previously determined, but this is probably due to the infrequency of detailed studies of beach profiles over comparatively long distances.

(4) MORPHOLOGICAL EVIDENCE FOR SHORELINE IDENTIFICATION.

The Whittlesey beach

Many writers state that the Whittlesey shoreline is the better developed of all the higher lake shorelines to be found in Southwestern Ontario. It was formed by a rising lake level and certain characteristic features result.

According to Leverett and Taylor[11]: "The manner by which Lake Whittlesey came into existence (by readvance of the ice and raising of the water level) explains certain characteristics which mark this beach more strongly than any other that has been found. Its course across

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11 Leverett, F., and Taylor, F.B., (op. cit.). p. 382.

the country is remarkably direct in view of its many crossings of river and creek valleys which appear to have been excavated to approximately their present depths before this beach was made. It crosses them in a direct line like a railroad embankment, in places standing 20' - 25' above the valley floor at its back ..... not the slightest evidence of wave action appears in embayments at its rear. This fact, and its extraordinary height and boldness suggest that it was built rapidly and was pushed a few feet up the slope whilst it was being built, so that the back shore of the bays closed by barriers was never exposed to wave action at the level at which the beach was made".

This description would appear to fit the Whittlesey beach as mapped in Brant County, although the features are generally not so distinct, no doubt due to the comparatively enclosed and sheltered nature of this section of the lake. Putnam and Chapman[12] describe Whittlesey as being "a poorly developed beach in Ontario", but it appears well developed in comparison with the shorelines of Upper and Middle Lake Warren and Lake Wayne.

Also Lake Whittlesey was of comparatively long duration and therefore quite well developed features are to be expected. Comparative length of duration of the lakes, and is indicated in the following table taken from Hough.[13]

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12 Chapman, L.J., and Putnam, D.F. (op. cit.) p. 65.

13 Hough, J.L. (op. cit.) p. 141.

Duration of Lakes

Lake Stage	Units of time	Transgression or Regression
Whittlesey	2	transgression
Upper Warren	1	regression
Middle Warren	1	regression
Two Creeks Low Int.	3 (?)	
Wayne	1	transgression (water washed)
Lower Warren	2	transgression

The Beaches of Upper and Middle Lake Warren

These two shorelines were formed by a falling lake level and both existed for only a short period of time. Shoreline features, as expected are comparatively weak and discontinuous and in several instances features are found at heights other than those of the major shorelines. These were no doubt formed during the period of falling lake level.

The Lower Warren Beach

This is a quite well defined shoreline throughout most of its length which is in accordance with a transgressing lake level. Also, the duration of Lower Lake Warren was for a relatively long period of time. Writing of this shoreline in Wentworth County, Horton states[14] - " ... the upper shoreline (Lower Warren) is by far the most strongly developed". Also, the only gravel beaches Horton found in Wentworth County were along this "upper" shoreline. This shoreline also shows the greatest number of shorecliffs and wave cut terraces.

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14 Horton, J.H., 1961 (op.cit.). p. 109.

The Wayne Beach

This shoreline was formed by a transgressing lake level, but also underwent submergence and therefore its features show results of water washing. Bluffs are generally more rounded and gentle along the shoreline and associated materials are mainly sand, cobbles and boulders being absent. In his discussion on the varying characteristics of the two Wentworth County shorelines, Horton states[15] ... "the lower (Wayne) shoreline is characterized by the development of larger and slightly more numerous constructional forms such as sandspits and bars".

During the existance of Lake Wayne, the ice front was readvancing from the east after the retreat to the Two Creeks Low Interval. At this stage the ice front was further to the east than during the succeeding Lower Lake Warren stage. Horton[16] gives evidence in agreement with this. In his discussion of lake conditions and wave action he reasons, by a consideration of the location of the best formed wave cut features, that a long fetch from the east-southeast was necessary. "In order for the east-southeast fetch to have existed, the ice front must have been located well to the east; even further to the east than its position during the existence of the first (i.e. Upper, i.e. Lower Warren) lake. This conclusion is supported by a stronger development of eastern features along the lower shoreline than along the upper shoreline."

Thus on the basis of morphological evidence, it would appear that there is good reason for the identification of the shorelines as above.

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[15] Horton, J.H. (op. cit.). p. 109.

[16] Horton, J.H. (op. cit.). p. 88.

(5) IDENTIFICATION OF SHORELINES BY ANALYSIS OF THEIR LOCATION ON THE MORAINES.

The chronology of the glacial lakes and moraines of Brant County was given briefly at the beginning of this chapter. The relationship between shorelines and moraines is indicated by the following table in which the possible and actual locations of each shoreline on each side of the moraines is indicated.

	Norwich		Tillsonburgh		Paris		Galt	
	west	east	west	east	west	east	west	east
Whittlesey	✓*	✓.	✓					
Upper Warren	✓ h	✓*	✓.	✓.	✓.			
Middle Warren	✓ h	✓.	✓.	✓.	✓.	✓.	✓*	
Lower Warren	✓ h	✓h	✓h	✓.	✓.	✓.	✓.	✓.
Wayne	✓ h	✓h	✓h	✓?.	✓.	✓.	✓.	✓.

✓ - indicates possible position of shoreline
* - indicates actual position of shoreline
h - indicates land above lake level.

This table is based on the theoretically possible location of a shoreline on the western side of the moraine of the ice barrier, and on all 'morainic islands' to the west.

In plan, as can be seen on the accompanying map, the shorelines fit well into the pattern indicated by this table. The Whittlesey shoreline is found along the east and west sides of the Norwich moraine, but not at all on the Tillsonburg moraine which was deposited by the ice front at this stage. Absence of the shoreline here is due to the fact that almost all of the Tillsonburg moraine was waterlaid and stands below

the level of Lake Whittlesey.

A shoreline corresponding in height to that of Upper Lake Warren is found in certain sections of the Paris moraine. Here, the moraine was built up above the level of its related lake and shoreline features are developed on the lakeward side of the morainic islands which stood along the ice front. These features end quite abruptly as the ice contact face of the moraine is approached, thus furnishing evidence for the co-existence of lake and ice front at this moraine. The Upper Warren shoreline is also found on both sides of the Tillsonburg, and on the eastern side of the Norwich moraine.

Shoreline features of Middle Lake Warren are found on the western side of the northern section of the Galt moraine and there are two associated small islands. To the north of Blue Lakes the shoreline outlines a conspicuous morainic ridge, extending southwards to the west of the Blue Lakes. Beyond this, it continues eastwards for half a mile or so to a second, prominent morainic ridge, and then ends quite abruptly. No trace of a shoreline at this height can be found further east. Thus it would seem, that the position of the ice barrier at this stage was at the second morainic ridge, and therefore Middle Lake Warren is associated with the Galt moraine. In the southern section of the Galt moraine the Middle Warren shoreline is found outlining several morainic islands which stood along the ice front at this stage.

CONCLUSION

The above discussion would appear to substantiate the previous evidence given for the identification of the shorelines as they were tentatively named. The conclusions of all five sections on shoreline

the level of Lake Whittlesey.

A shoreline corresponding in height to that of Upper Lake Warren is found in certain sections of the Paris moraine. Here, the moraine was built up above the level of its related lake and shoreline features are developed on the lakeward side of the morainic islands which stood along the ice front. These features end quite abruptly as the ice contact face of the moraine is approached, thus furnishing evidence for the co-existence of lake and ice front at this moraine. The Upper Warren shoreline is also found on both sides of the Tillsonburg, and on the eastern side of the Norwich moraine.

Shoreline features of Middle Lake Warren are found on the western side of the northern section of the Galt moraine and there are two associated small islands. To the north of Blue Lakes the shoreline outlines a conspicuous morainic ridge, extending southwards to the west of the Blue Lakes. Beyond this, it continues eastwards for half a mile or so to a second, prominent morainic ridge, and then ends quite abruptly. No trace of a shoreline at this height can be found further east. Thus it would seem, that the position of the ice barrier at this stage was at the second morainic ridge, and therefore Middle Lake Warren is associated with the Galt moraine. In the southern section of the Galt moraine the Middle Warren shoreline is found outlining several morainic islands which stood along the ice front at this stage.

CONCLUSION

The above discussion would appear to substantiate the previous evidence given for the identification of the shorelines as they were tentatively named. The conclusions of all five sections on shoreline

identification are summarized in the following table.

Tentative identification	Criteria for identification				
	1. gradient	2. hinge	3. vert. interval	4. morpho.	5. plan location
Whittlesey	✓	?	?	✓	✓
Upper Warren	✓	✓	✓	✓	✓
Middle Warren	✓	✓	✓	✓	✓
Lower Warren	✓	?	✓	✓	✓
Wayne	✓	?	✓	✓	✓

✓ - indicates a good correspondence
? - indicates some discrepancy

It can be seen from this table, that the shoreline identification corresponds very well to the criteria of gradient, morphology, and the location of shorelines on the various moraines. With regard to the evidence given by calculations of distance from southern Brant County to the hinge lines, the two higher Warren beaches correspond as expected, whilst the Whittlesey, Lower Warren and Wayne beaches show slight anomalies. These can however be adequately explained. Most of the information used is based on extrapolation from data of regions located a considerable distance from Brant County, as far as the American shore of Lake Erie. Thus there is possibility of accumulative error, errors in earlier work, and errors deriving from local variations.

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16. Horton, J.H. (op. cit.).

CHAPTER 4

MORAINES OF BRANT COUNTY

INTRODUCTION

As has already been mentioned in the previous chapter, the moraines of Brant County show an exceptionally close relationship to the associated shorelines. This relationship is illustrated by the occurrence of varying morainic types recognized in the field primarily by their distinctive landforms.

Previous writers have briefly referred to this relationship. With regard to the Paris moraine, Taylor states[1], " .... it is waterlaid south of Paris and becomes weaker .... ". Discussing the Tillsonburg moraine Chapman and Putnam state[2], "When building this moraine the glacier was washed by the waters of Lake Whittlesey to the south of Tillsonburg".* They also mention briefly characteristic differences between the waterlaid and landlaid sections of the Paris moraine[3]. "From Acton to Galt it is a high bouldery ridge. At, or near Paris, the

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[1] Taylor, F.B. 1913

[2] Chapman, L. J., and Putnam, D.F., 1951. p. 46.

[3] Chapman, L. J., and Putnam, D.F., (op. cit.). p. 47.

* The conclusion of this chapter indicates that the Tillsonburg moraine was probably waterlaid for a much greater distance to the northwest.

moraine was waterlaid and it grows steadily fainter towards Lake Erie. The Paris moraine differs in composition from those just described. South of Paris it is sandy and to the north it consists of loose, bouldery loam, the material being mostly dolomite from the Niagara Cuesta. The Galt moraine is similar in form and composition to the Paris moraine. It is a rugged stony ridge of loose loam till north of Brantford and a smoother, sandier ridge from Brantford to Simcoe."

The relationship between glacial lakes and moraines appears to be more complex than this. During the course of field work in Brant County and analysis of air photographs, four morainic types were recognized and identified according to their topographic expression and morainic materials. These types were:

i. landlaid moraine

ii. waterlaid moraine

iii. water washed moraine - originally either waterlaid or landlaid

iv. moraine partially buried by a veneer of more recent sands and gravels.

Various transition types also exist between these four major categories.

The aim of this chapter is to describe and analyse the moraines of Brant County. Part 1 will be chiefly a description of the moraines, dealing with major and minor topographic forms, the materials of which they are composed, and the soils which they give rise to, and air photo characteristics. Part 2 will deal with the analysis and origin of the features described.

PART ONE DESCRIPTION OF THE MORAINES

Each moraine will be dealt with separately and discussed with regard to distinctive regional characteristics.

THE GALT MORAINE

(1) To the north of Blue Lakes

This is the most extensive and unbroken morainic area in the region under study. The moraine reaches its maximum width of five miles just to the north of Blue Lakes and the village of St. George.

Throughout most of this section, the moraine shows the typical form of a steep east-facing ice contact slope and a longer, more gentle west-facing slope, although in many locations this slope has been steepened by erosion of the Grand River spillway to the west. Also, there are many minor ridges in the central part of the morainice area trending parallel to the major moraine.

The surface of the moraine illustrates well developed knob and kettle type topography. There are numerous steep-sided kettles, up to 40' deep forming blind depressions and many containing lakes and swamps. All show areas of ill drained ground associated with the development of dark humic soils on the floor of the depressions. Rounded, forested knobs rise to a height of 200' above the lowest morainic areas. In certain areas alignment of features has been observed. Elongated knobs and kettles are seen trending from northeast to southwest, parallel to the general trend of the moraine.

There is virtually no surface drainage on the moraine. A dense network of lines of seepage indicated on the air photos, shows no orientation except in peripheral areas. Here it has been "captured"

by streams heading back into the moraine from the surrounding areas of sand plain and limestone plain to the east, and the Grand River valley to the west. These are the only places where post glacial dissection has been active.

Doughnut forms[4], characteristic of areas of ice stagnation, are also visible on air photos. Doughnut forms and the numerous kettles give adequate evidence for ice disintegration and stagnation in this area.

There is a narrow belt of land bordering this morainic area to the south and east which shows sharply contrasting characteristics. The boundary between this area and the area just described is approximately the 900' contour. The topography here is of much lower relief and undulations are comparatively gentle. This may be described as a transition area between the morainic topography of the main area and the adjacent sand plains. On air photos the characteristic morainic forms are almost absent and replaced by forms more typical of a sand plain area although considerable range of relief is maintained.

Over most of the main morainic area loamy soils (Dumfries and London loam) predominate (photos 19 and 20). The subsoil is a coarse doney loam with clay in localized areas and generally many stones and some large boulders. Along the eastern margin of the area, corresponding with the peripheral belt just described, there is transition to a sandy loam. This is the Brantford loam and it is developed over a subsoil of stratified fine sand and silt which is comparatively stone free. To the north of this area of Brantford loam is a large region of Guelph loam which is distinguished from the Dumfries loam by the presence of

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[4] Gravenor, C.P., Green, R., and Godfrey, J.D. 1960. p. 11.

Photo 19. Dumfries loam developed upon the Galt moraine. In this section two feet of loamy soil is above gravel and pebble beds, grading downwards into morainic material consisting of distorted beds of sand and clay with large angular boulders.

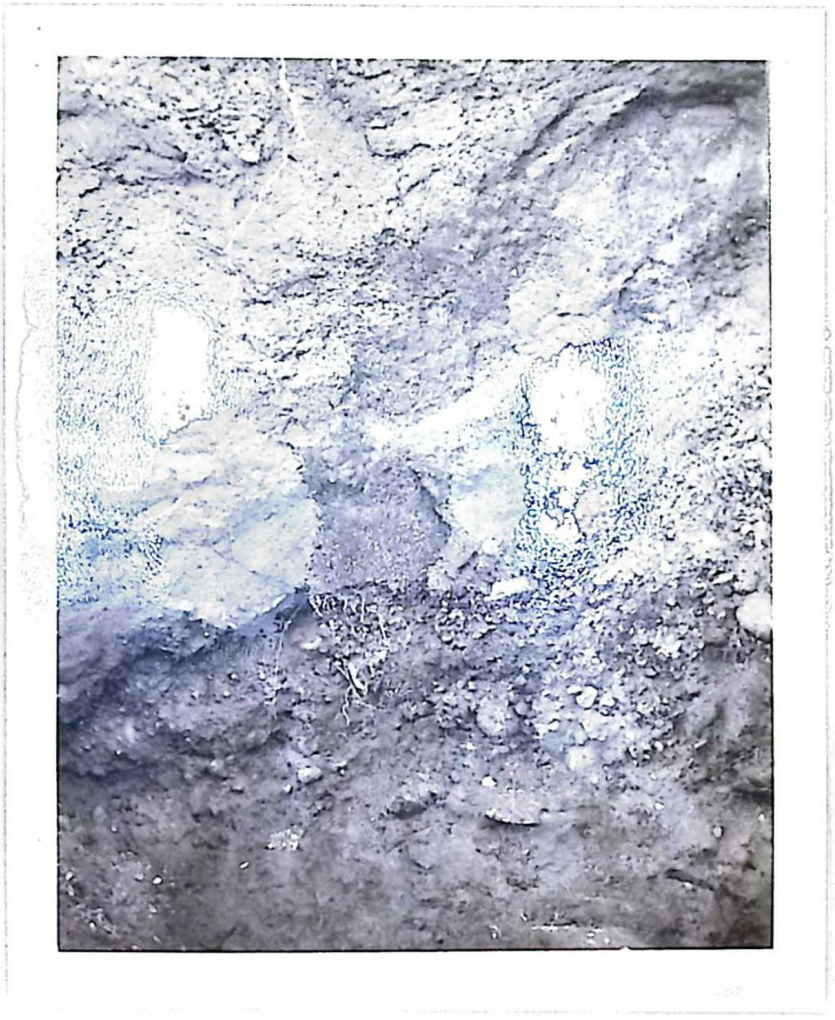


Photo 20. A close-up of the central section of photo 19, showing the loamy soil developed upon sand and gravel beds.

some clay loam and the absence of so many streams and boulders. Along the southern margin of the morainic area is a transition to the Fox sandy loam which is stone free and overlies stratified sand.

The western boundary of this section of the Galt moraine is partially overlain by the gravels of the Grand River spillway. Isolated knobs of morainic or kame material surrounded by gravel deposits are found near the edges of the spillway.

(2) The Galt moraine between Blue Lakes and the Grand River

Immediately to the south of Blue Lakes the Galt moraine is reduced drastically in both eastwest extent and topographic expression. Only in the highest areas does the topography bear any similarity to that north of Blue Lakes. There are two localized areas of knob and kettle topography, and large boulders are frequently found littering the surface. Elsewhere the ground is gently rolling and prominent knobs and kettles are absent. Local relief decreases towards the limits of the area and the surface shows no break of slope where the moraine merges with the sand plain.

Unlike the morainic area to the north, the east facing ice contact slope is comparatively gentle. There is an indefinite boundary around the whole of this area except in the northwest where the moraine rises abruptly from the plain of the Grand River spillway, resulting from steepening by spillway erosion.

Air photos show a typically mottled morainic surface and this is most definite in the highest areas. Some weak doughnut forms can be distinguished. Over most of the area seepage lines show some orientation and are related to gullies working back from the surrounding sand plain.

Once again, these features would suggest an area of transition between moraine and sand plain.

The predominant soil type, as in the area to the north, is the Dumfries loam. There are local variations within this type. Extremely sandy soil occurs in some places related to the shoreline. Generally this loam appears less sandy here than in the area to the north, although in some areas sharply undulating topography and steep slopes have precluded cultivation in an otherwise extensively cultivated area.

Due to the permeability of soil and subsoil, there is no surface drainage on the moraine. At the eastern limits of the area, soils show transition from the Dumfries loam to the Brantford loam and the Fox sandy loam, indicating increase in sandiness and decrease in stoniness. Along the western boundary is a transition to the Burford loam, a brown gravelly loam developed on the sand and gravel beds of the Grand River spillway.

(3) The Galt moraine to the south of the Grand River

The moraine here is represented by a near-continuous, low-lying, rounded ridge. Within the area, the topography is smooth and rolling in all but the highest areas above 860' where more typical morainic type topography is found. These areas are extremely localized except for one such area which occupies the ridge crest for a distance of one mile to the north of Oakland.

Both the eastern and western boundaries of the morainic area are marked by relatively steep slopes to the adjacent sand plain (photo 21). Along the western margin are several bold promontories where more rugged topography juts onto the sand plain. The eastern slope of the moraine is unusual in that it tends to be less steep than the western slope where the

morainic material becomes gradually buried beneath sands and gravels. Towards the Grand River the eastern slope of the moraine has been attacked and oversteepened by stream erosion, the streams heading back from the Grand River across the sand plain.

There are two breaks in the morainic ridge where there are drainage channels for the large area of intermorainic swampland to the west. These are located at Oakland and 1½ miles to the east of Mount Vernon station. The channels have flat sandy floors and steep sides cutting back into the moraine.

With regard to soil types, there is a good correspondence between topographic distinctions and the nature of the soil. Dumfries loam is found in the extreme northern section of the moraine, and also on the topographically outstanding area to the north of Oakland. The Dumfries sandy loam, distinguished from the Dumfries loam by its extremely sandy nature, occurs on the lower lying morainic area, both to the east and west of the "ridge". Elsewhere, the Fox sandy loam has developed on the moraine and also on the adjacent sand plain areas, and thus here, soil types do not distinguish morainic areas from sand plain.

THE PARIS MORAINE

(1) To the North of Paris

Topographically, this area may be divided into two sections separated along an eastwest line through Spottiswood Lakes.

The area to the south of Spottiswood Lakes rises gradually from the sand plain to the west to a maximum height of slightly more than 900'. The limits of the moraine are indistinct due to off-lap of the sand beds.

To the east this area is bounded by the Grand River valley.

From an elevation of 825' in the southeast the land rises gradually towards the north and northwest in a series of 50' - 70' high 'steps'. Each step forms a continuous and prominent feature of the landscape. Breaks of slope tend to be angular rather than rounded, whilst elsewhere the surface is gently undulating. Kettle holes and blind depressions are quite frequent and increase in number northwards and towards higher ground. Their form varies from the common rounded shallow forms to deeper, steepsided and branching features. Where shorelines are present they form comparatively distinct features.

Burford loam is developed over the entire area and also on the adjacent areas of sand plain. There are local areas of extremely sandy soil frequently associated with boulders and cobbles along the glacial lake shorelines (photo 22).

The fact that surficial materials do not distinguish this area from the surrounding sand plain areas would suggest that the morainic material here gives rise to topographic expression but has been partially buried by spillway sands and gravels which also cover adjacent areas.

Near Spottiswood Lakes, at an altitude of approximately 900' is an abrupt change from the smooth topography of the region just described to a typical knob and kettle region. There are numerous kettle lakes, indicative of ice decay and disintegration in situ.

Between Spottiswood Lakes and Pinehurst Lakes is a high curving ridge-like feature, 125' high and consisting of kame materials. In form, it is a double ridge bordered on either side by similarly oriented lakes. Other features of this kind, trending in the same directions, but not so

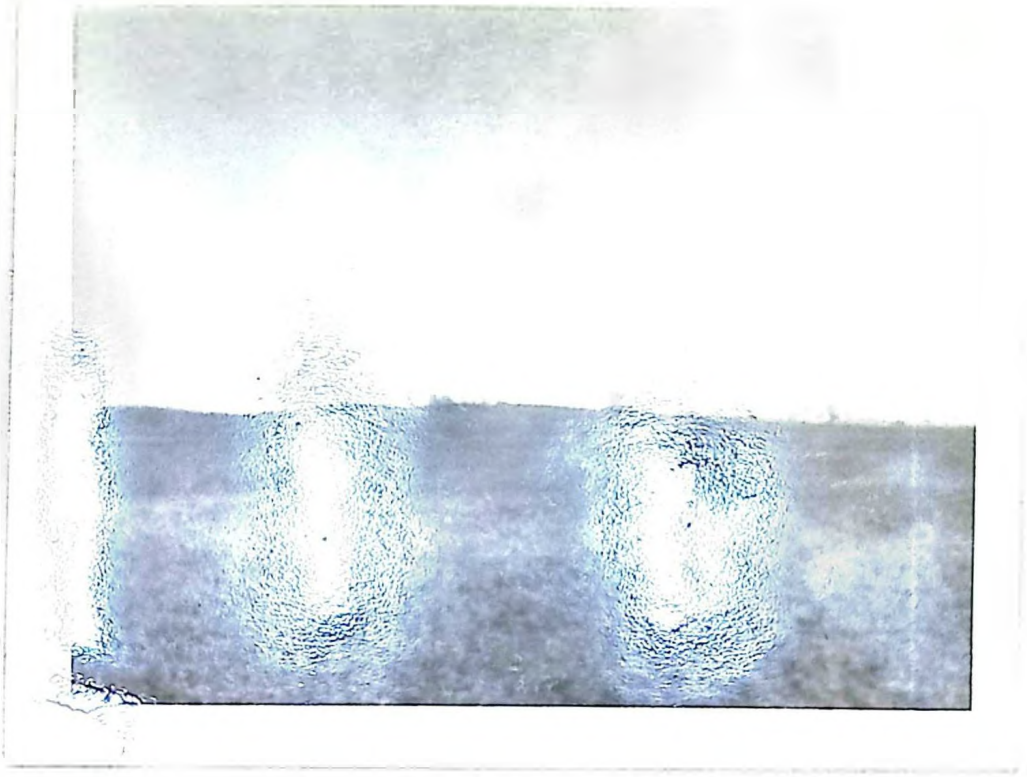


Photo 21. The waterlaid section of the Galt moraine rising above the spillway plain near Mount Vernon Station.

Photo 22. Section in the waterlaid and partially buried area of the Paris moraine. Burford loam is developed upon deltaic gravel beds.

well developed are found in the area of the Paris moraine further to the north.

Soils of the area vary according to location. Dumfries loam is found in the areas of typical morainic topography with peat and muck soils on the floor of ill-drained depressions. There is a transition to Burford loam on the nearby areas of sand and spillway gravel plains.

(2) The Paris moraine between Paris and Horner Creek

The moraine here is represented by a broad ridge. It rises gently for a vertical distance of 75' to 100' from the sand plain to the west, and drops more steeply (ice-contact face) to the spillway plain of the Grand River valley to the east.

Areas above approximately 900' show typical knob and kettle topography although this is not so well developed as on the Galt moraine except in the area immediately to the south of Paris. Here, are prominent knobs and kettles. Lower lying areas of this moraine are characterized by smoother and more rolling topography which merges gently and imperceptibly into the sand plains. Shallow kettles are present in this area and breaks of slope here tend to be angular rather than rounded. Step, or terrace-like features which cannot be related to a known shoreline occur fairly frequently.

The boundary of the area is not well defined except in the northwestern section where the moraine drops steeply to the sand plain. This feature is probably due to oversteepening by spillway erosion and also modification by wave action of the glacial lakes, since this "bluff" represents more than one shoreline.

Dumfries loam occurs over most of the area showing some local variations which can be related to sand beaches along the shorelines of Upper and Middle Lake Warren (as in area to the north of Paris). At the limits of the moraine is a transition to the relatively stone-free and sandier Burford loam developed on the sand plain.

(3) The Paris Moraine to South of Horner Creek

In this section the moraine narrows considerably to a maximum width of one mile and runs due northsouth. There is a steep east-facing ice contact slope and a much more gentle western slope grading imperceptibly into the adjacent sand plain. The morainic ridge is smooth and well defined for most of its length, but there are several small, abrupt and sharply defined "hills" on its crest. These are generally uncultivated owing to steepness of slope and stoniness of soil.

The remainder of the surface of the moraine is of the typical "lowland" morainic type, but in some areas this smooth rolling surface is broken by a series of bold, but small-scale undulations forming numerous small blind depressions. Here, the soil is stony and its humic content would appear to vary greatly from place to place according to specific location (photo 23). These features are well defined on air photographs.

The main ridge of this moraine from Mt. Vernon to Scotland is overlain by the Dumfries loam. This grades very slowly into Burford loam on the sand plain to the west, but there is a much sharper transiton at the foot of the steep east-facing slope to extremely sandy soils. In the southern section, running northwards for 2½ miles from Scotland is a narrow strip of Brady sandy loam between the moraine to the west,

and the muck soils to the east. This is a dark brown, stone free sandy loam over grey sand. To the north, this is replaced by a belt of Fox sand occupying a similar situation as far north as Mt. Vernon. This is a light brown and yellow sand overlying reddish brown loam which in its turn overlies beds of stratified sand and gravel. Soil sequences described here are of value in determining the mode and sequence of deposition of the moraine and sand plain materials.

THE TILLSONBURG MORAINE

(1) To the North of River Nith

Although the Tillsonburg still exists as a recognizable morainic unit here, a short distance to the north near Ayr it merges with the kame and gravel area of the Waterloo sandhills and looses its identify. In northern Brant County the moraine is beginning to broaden and may be better described as an area of morainic topography rather than a morainic ridge.

The morainic area is dissected by several spillway channels which are now represented by flat floored valleys with misfit streams and gently sloping sides. (There is insufficient available relief to develop more typical steeply sloping sides.) Topography is gently undulating with no great development of morainic knobs although there are frequent kettles of moderate size and depth. Low rolling hills rising from the plain area are characteristic. The land gradually rises northwards and local relief also increases to the north.

The Guelph loam predominates in this area but there are quite large areas of London loam. These types are distinguished topographically;

Guelph loams occupy areas of typical morainic topography, "rolling with some low swales", whilst the London loam occupies - "smooth to undulating areas of poorer natural drainage, particularly with regard to the subsoil".[5]

Along the south and southeastern boundary of this area is a transition to the Burford loam of the sand plain areas. Further north the transition is from the Guelph loam of the Tillsonburg moraine to the Dumfries loam of the Paris moraine. The moraines are separated only by a narrow spillway channel floored by muck soils and some small areas of sandy loam.

(2) The Tillsonburg moraine south of the River Nith

To the south of the River Nith the moraine shows the characteristic ridge-like form, although it is broken into numerous isolated hills and small ridges separated by areas of sand plain. Generally the steepest slopes face east, but in places the west-facing slope has undergone oversteepening due to the action of spillway erosion, glacial lakes, or post glacial erosion.

The topography is mainly gently rolling but there are some exceptional areas. There is a large area of flat-topped moraine to the west of Falkland that has undergone modification by the planing action of waves of Upper Lake Warren. Further south, is a localized area of broken topography to the west of Northfield Centre, where the moraine consists of a series of isolated knobs.

The Tillsonburg moraine is represented by a variety of soil types. The Waterwashed section to the southwest of Falkland is not distinguished by its soil type, since the Burford loam is developed over both moraine and surrounding sand plain. Between this area and Horner Creek, Bookton

[5] Soil Survey.

sandy loam (a sandy loam developed over rolling clay loam) is found over both the morainic islands and the sand plain areas between. Between Horner Creek and Big Creek the main morainic ridge shows development of the Huron clay loam, but Bookton sandy loam occupies the morainic slope to the west. To the south of Big Creek the Bookton sandy loam occupies all the morainic areas. From analysis of the above facts it would appear that rolling clay loam underlies the whole of this area, but is overlain in all sections (except that between Horner and Big Creeks) by a sandy loam. Brady sandy loam, developed on sand beds occupies the narrow strip of land between moraine and the adjacent swampland to the east.

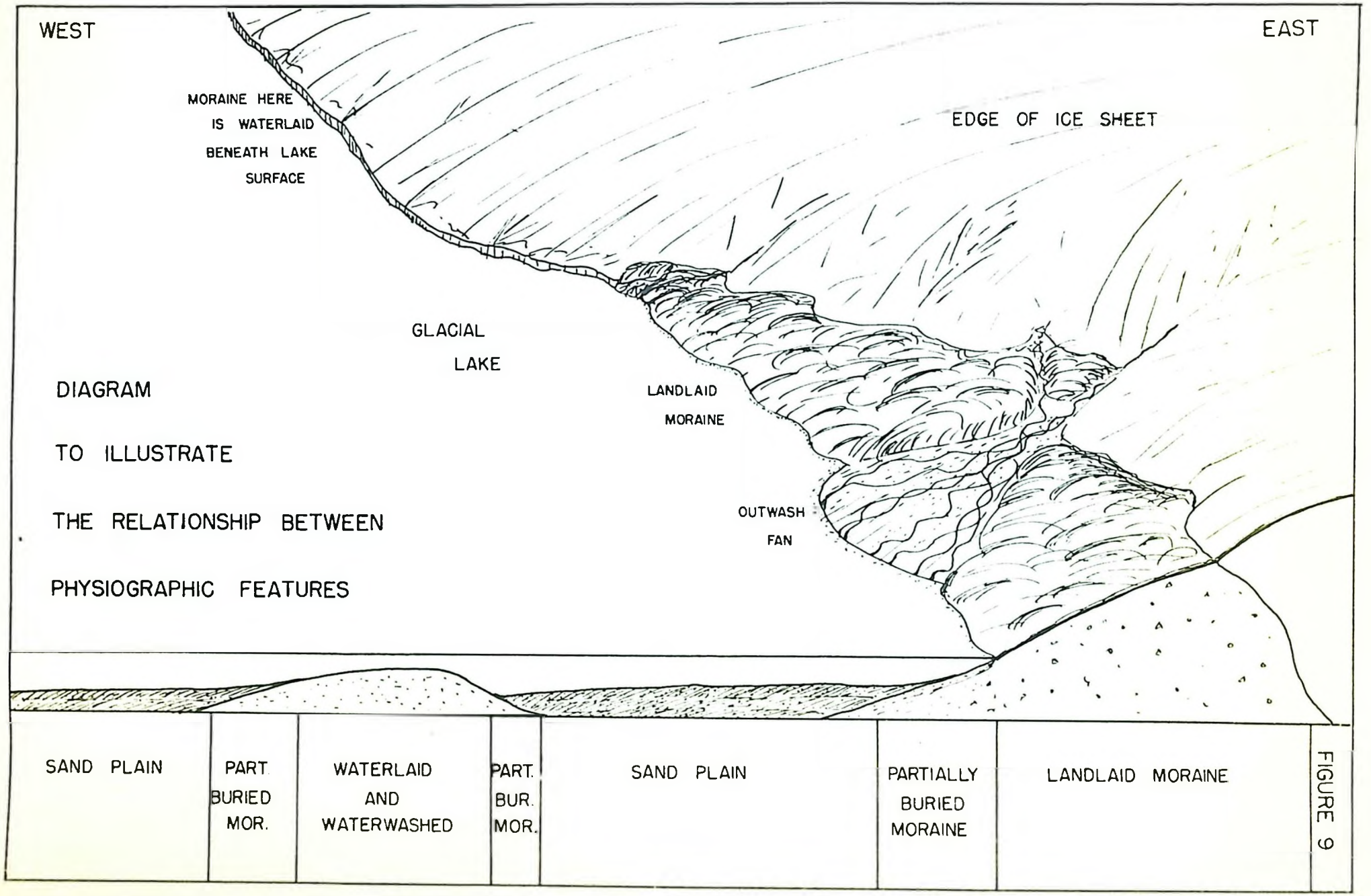
NORWICH MORAINE

The Norwich moraine follows the approximate eastern limit of the till plain which stretches westwards into Oxford County, and separates it from the sand plain area to the east. In places it is partially buried by sands and gravels, and the resulting form is a chain of isolated morainic 'islands' rising above the sand and till plains.

The soils developed on the Norwich moraine are the same as those of the Tillsonburg moraine. Sandy loam is found over a rolling clay loam with some stones in the clay loam. Along the margins of the morainic area these soils merge with the sandy stone-free loams of the sand plain to the east, and the clay loams of the till plain to the west.

PART 2 ORIGIN OF MORAINES Figure 9

In this section the mode of deposition of the various morainic


WEST
EAST
MORAINE HERE IS WATERLAID BENEATH LAKE SURFACE
EDGE OF ICE SHEET
GLACIAL LAKE
LANDLAID MORAINE
OUTWASH FAN
DIAGRAM TO ILLUSTRATE THE RELATIONSHIP BETWEEN PHYSIOGRAPHIC FEATURES
SAND PLAIN
PART BURIED MOR.
WATERLAID AND WATERWASHED
PART. BUR. MOR.
SAND PLAIN
PARTIALLY BURIED MORAINE
LANDLAID MORAINE
FIGURE 9

types and the formation of their characteristic topographies will be discussed.

Landlaid moraine consists of unsorted and unstratified material varying in composition from a sandy to a clay matrix. It contains stones and boulders of all degrees of roundess and angularity, and ranging in size up to blocks 12' in diameter. Materials are derived predominantly from bedrock limestones, but there are many erratics of granitic and gneissic rocks derived from the Canadian Shield. Erratic boulders tend to be intermediate in size. In areas of landlaid moraine large boulders are frequently scattered on the surface or partially buried.

This morainic type reaches its maximum development in the northern section of the Galt moraine. The breadth and bulk of this moraine indicate that the ice front stood here for a comparatively great length of time. The sharply undulating surface is underlain by coarse grained till and localized areas of stratified gravel forming kames are common. Blind depressions are of varying origin; many are kettles resulting from partial burying of ice blocks and subsequent collapse. These tend to be more circular in form than blind depressions originating during the construction of the moraine. Such features indicate the stagnation and decay of the peripheral area of the ice sheet whilst in this position.

The northern section of the Paris moraine shows similar features. Kame structures here have been previously described. In the northern section of the Tillsonburg moraine, relief is more subdued, and in relation to this the clay content of the morainic material is higher than in the gravelly Paris and Galt moraines. Kettles are frequent and tend to be comparatively small, indicating decay and stagnation of the

ice front whilst in this position, but little deposition relative to the Galt moraine.

Other smaller areas which display the characteristics of landlaid moraine are found on the crests of the more southerly morainic ridges and are indicated on the accompanying map. These areas frequently consist merely of an isolated "knob" built above lake level at the time of deposition, or a series of knobs forming the ridge top.

These morainic areas were built against the ice front and above lake level. Consequently one may expect to find evidence for a shoreline bordering these features on their lakeward side, but this is not always the case. It would appear from field observations that the lakeward side of an area of landlaid moraine, during the period of its deposition, is frequently the side of outwash constructional forms. Outwash plains grade gently into the lake plain, and the break of slope between rough morainic topography and the smooth outwash plain which it is possible to mistake for a shoreline, is in actual fact several feet above lake level (fig. 9).

Waterlaid moraine is formed when the ice front is below the level of the lake surface. Material is generally sorted, coarser material being deposited near the ice front, and finer material further away on the flanks of the morainic areas. Consequently the moraine consists of stratified sands and gravels deposited as coalescing deltas giving rise to angular breaks of slope and terrace like features. Some kettles are formed resulting from the collapse of the surrounding material after the melting of buried or partially buried ice blocks. Kettles are comparatively small and shallow and tend to be circular.

Topographically areas of waterlaid moraine are quite distinct from areas of landlaid moraine. There is considerably less local relief, slopes are less steep, and the land surface is gently undulating.

Waterwashed moraine is defined as having been submerged during the existence of at least one glacial lake. The surface of the moraine has undergone a smoothing or a planing off action. Frequently a thin veneer of water worked materials - sand, gravel and cobbles, can be recognized. Since these areas generally correspond to areas of waterlaid moraine, the topography is generally the same, as previously described, with, if anything, slightly less local relief and more subdued undulation. It merges into the wave cut bench upon approaching a shoreline.

The chief distinguishing characteristics are location with regard to the shorelines, relief, and nature of the surface materials. Morainic type features are faintly visible on the air photos.

Partially buried moraine includes all areas where morainic material has been overlain by materials, chiefly, sand and gravels, deposited as spillway or delta plains. Such areas are found on the flanks of all the moraines adjacent to sand and gravel plains. The transition between morainic and spillway areas is almost always gradual and it is this zone that represents areas of partially buried moraine. These regions are distinguished by virtue of relief and location.

Occasionally, as along the western boundary of the northern section of the Galt moraine, morainic hills and knobs may protrude through the gravel and sand beds to form 'islands' rising above the plain areas.

It is realized that the latter three categories of water-washed, waterlaid, and partially buried moraine are somewhat inclusive and over-

lapping, but the distinction is justified since it is of great use in the analysis of topographic types and in the deduction of a chronology for Brant County.

On the basis of these distinctions a map was constructed showing areas of landlaid, waterlaid and waterwashed moraine. Morainic types were plotted with regard to isobases and to contour lines, and a close correlation was found between topographies described in the first part of this chapter, and the distinctions shown on the map, figure 10.

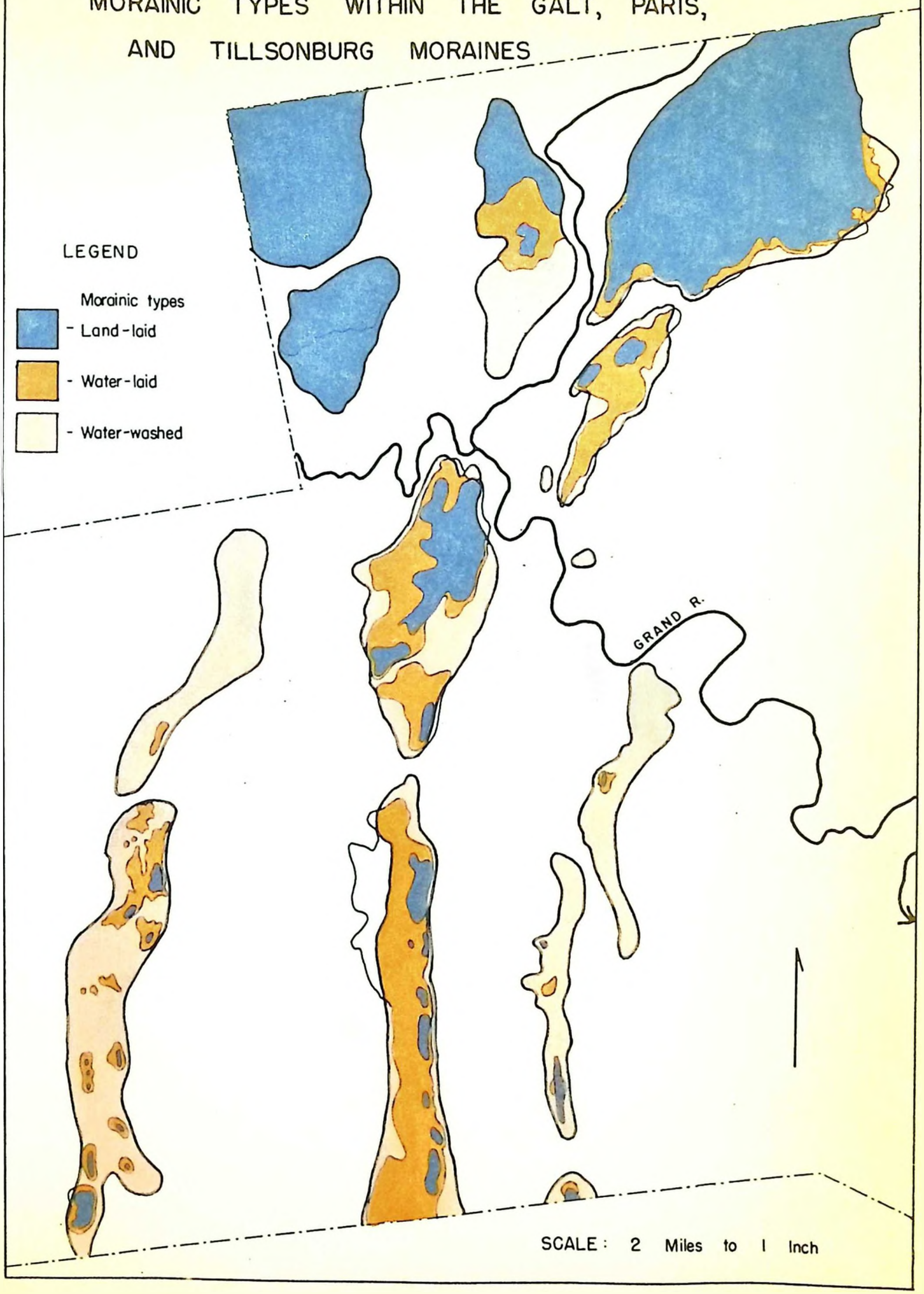
With regard to the Galt and Paris moraines the areas of landlaid moraine are seen to correspond with areas of well developed morainic topography, with Dumfries loam. In the southern section of the Galt moraine, the Dumfries loam shows close relationship to the areas of landlaid moraine, and there is an especially good example of this in area to north of Oakland. The Paris moraine to the south of the River Nith is indicated on the soil map as Dumfries loam, whilst the morainic type map indicates large areas of waterlaid moraine here adjacent to the landlaid morainic areas. This is probably because soils developed on the coarser waterlaid morainic material adjacent to the landlaid moraine are included within this category.

In the peripheral area of the northern section of the Galt moraine areas of waterlaid and water washed moraine are seen to correspond to the trancition zones of the soil types, where the loams of the main morainic area give way to the sandy loams of the surrounding sand plains.

The Paris moraine to the north of Paris, is an area of waterlaid and waterwashed moraine. The soil type is the Burford loam and it is homogeneous over the whole of this area and over the sand plain adjacent

Figure 10

MORAINIC TYPES WITHIN THE GALT, PARIS, AND TILLSONBURG MORAINES



to the west. Air photo characteristics would indicate that this is an area of partially buried moraine, and this is borne out by other observed facts of topography. This area is part of a broad spillway channel, and cross bedded gravels were found overlying morainic materials.

Burford loam also indicates areas of waterlaid and waterwashed moraine in the Tillsonburg area to the south of the River Nith, such as in the area to the southwest of Falkland.

The landlaid northern section of the Tillsonburg moraine is associated with Guelph and London loams. There is no clear cut soil type distinction of the southerly landlaid but waterwashed section, although there is a region of the more gravelly Burford loam just to the south which is possibly related.

In the southern section of the Tillsonburg moraine the Bookton sandy loam represents areas of waterlaid and water-washed moraine. The large area of Huron clay loam (which may be correlated to the Bookton sandy loam minus the surface sandy layer) is found in an area where there is a considerable amount of waterlaid but not water-washed moraine, and some landlaid moraine. Small areas of landlaid moraine forming prominent knob-like hills in the extreme southern part of the Norwich moraine are not distinguished on the soil map.

Along the eastern margins of the southern sections of both the Paris and the Tillsonburg moraines are narrow strips of sandy loam soils which are developed on the sands and gravels of the partially buried moraine here. The soil classification describes these soils - chiefly the Brady sandy loam - as being sandy loams over bedded sands and gravels (i.e. spillway deposits), over clay loam (i.e. morainic material).

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CHAPTER 5

C H R O N O L O G Y

The aim of this chapter is to give a chronological sequence of events for the retreat of the Wisconsin Glacier across Brant County, and to relate these events to the chronological sequence and time scale that has been established by Hough for the Great Lakes Basins.[1]

THE PLEISTOCENE ERA

The Pleistocene Era in North America consists of four distinct glacial stages and three intervening interglacial ages. Each stage is represented by a till deposit with a weathered zone at the top overlain by the non-glacial materials of the following interglacial stage. Although evidence of all seven stages is not present everywhere, sufficient data has been compiled to establish accurate age relationships. The interglacial ages are considered to have been long by comparison with glacial stages, each of which is believed to have existed for approximately 50,000 years.[1]

The final stage of the Pleistocene, namely the Wisconsin, has been dated the most accurately by modern radio carbon methods, but a general summary of the various stages and their ages is given in the following table.

---

[1] Hough, J.L., 1958.

Glacial Stage	Interglacial Stage	Approx. age in years
Wisconsin		10,000 - 50,000
	Sangamon	
Illinoian		300,000
	Yarmouth	
Kansan		700,000
	Aftonian	
Nebraskan		1,000,000

Of these glacial and interglacial stages it is only the most recent glacial stage, and the succeeding and present post glacial stage that are of significance with regard to the present morphology of Brant County. The retreat of the Wisconsin glacier is responsible for the formation of the landforms of the area, and during post glacial time these forms have undergone modification resulting in their present configuration.

THE WISCONSIN GLACIAL STAGE

The Wisconsin drift sheet covers the surface of most of Southern Ontario and the Great Lakes region. Its landforms have undergone relatively little modification and so a study of these features has enabled a detailed chronology for the retreat of the Wisconsin glacier in this area to be built up.

Seven glacial substages have been distinguished by Hough and it is to these that reference will be made later in this chapter. They are listed in the following table.

GLACIAL SUBSTAGES

7. Cochrane
6. Valders
5. Port Huron (Mankato)
4. Cary
3. Bloomington (late Tazewell)
2. Shelbyville - Iowan (early Tazewell)
1. Farmdale

The history of the Great Lakes begins at the Cary substage. Early in this stage the fluctuations of the ice front involved retreat into the lake basins and the subsequent formation of the early Great Lakes.

During the Cary substage formation of moraines took place individually in each of the lake basins. At the time of the following Port Huron substage however, moraines were built which can be traced from one lake basin to another. Using this Port Huron moraine as a reference datum a number of writers found it was possible to work backwards in time through the earlier moraines to establish a system of correlatives. A chronology for post - Port Huron events was established with regard to features of the lake stages and their contemporaneous moraines.

The formation of the Brant and Wentworth County landforms took place during the Cary, Port Huron and Valders substages. In Chapter 3 the Tillsonburg, Paris and Galt moraines were identified as representing the triple strands of the Port Huron substage. The Norwich moraine, since it predates the moraines to the west, must belong to the latter part of the Cary substage. The moraines of Wentworth County, related to Lakes Wayne and Lower Warren are assigned to the Valders substage.

For the sake of simplicity in the following discussion, the stages mentioned above have been further divided into minor stages. Each of these minor stages will be dealt with in chronological order.

Minor stages of Brant and Wentworth Counties

1. Pre Norwich moraine - late Cary
2. Norwich moraine - late Cary
3. The low-water stage of the Cary - Port Huron Interval
4. The Tillsonburg moraine and Lake Whittlesey - Port Huron

5. The Paris moraine and Upper Warren	- Port Huron
6. The Galt moraine and Middle Warren	- Port Huron
7. The Two Creeks low water stage	- Port Huron - Valders
8. The Valders readvance and Lake Wayne	- Valders
9. The Valders maximum and Lower Warren	- Valders

1. Pre-Norwich moraine

Prior to Lake Whittlesey the major lake to occupy the Erie and Huron basins was Lake Arkonn which existed during the latter part of the Cary substage (early post Lake Border stage of the Michigan basin). The ice front during the greater part of the time for which this lake was in existence stood well to the west of Brant County. Ice occupied all of the Ontario basin and the ice front stood well up on the high ground of northern New York State and occupied the eastern end of the Erie basin damming Lake Arkona. Drainage was via the Grant River channel in Michigan.

Three stages have been identified for Lake Arkona at levels of 710', 700' and 695' (hinge line heights). Each stage is correlated with a minor ice advance and each stage terminated by ice decay and retreat. Increased discharge during the retreat stages resulted in the lowering of the outlet channel by a few feet.

2. At the Norwich Moraine

The Norwich moraine probably was built by the third and final readvance during the existence of Lake Arkona. During retreat prior to this stage the ice sheet had deposited the till plain which stretches westwards into Oxford County from western Brant County. During the still

stand of the ice front at the Norwich moraine, Lake Arkona stood at 695'. The deformation of this shoreline is not known but it may be safely assumed that the northeastern arm of this lake did not reach as far north as Brant County, due to the comparatively high elevation of the land to the west of the moraine in this area. Thus the Norwich moraine for all its length in Brant County is landlaid (although much of it has undergone water washing by later glacial lakes).

3. The low-water stage of the Cary-Port Huron Interval

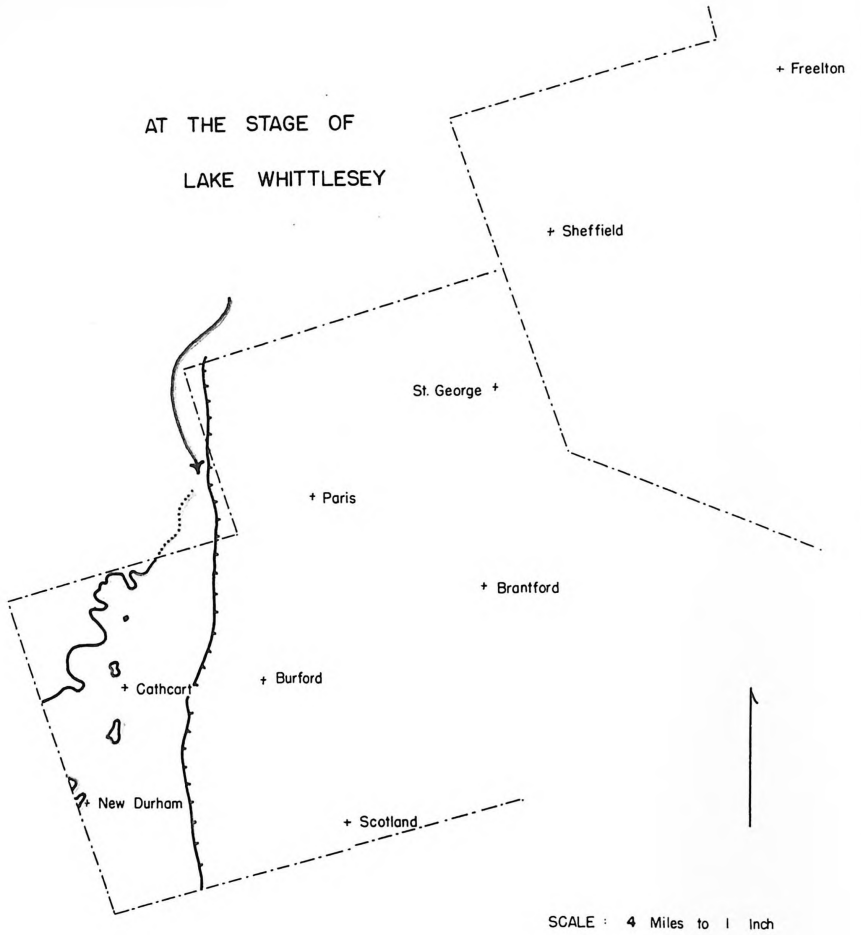
Evidence from various parts of the Huron, Erie and Ontario basins has been interpreted by Hough as indicating a fairly definite low water stage at this time:[1] " .... it appears likely that the ice front had retreated sufficiently far during the Cary-Port Huron interval to uncover outlets to the east which were low enough to drain the lake waters down to a low level".

4. Port Huron glacial substage - Tillsonburg Moraine, and Lake Whittlesey, Figure 11.

During the Port Huron readvance the eastern drainage way was blocked. Lake waters were ponded back until once again the Grand River overflow channel in Michigan was in use and the lake waters stood once more at 695'. This lake stage is termed the second Lake Arkona. Because this stage was followed by further readvance of the ice front, no moraine exists to mark this comparatively temporary stillstand. Slight upwarping of the land probably occurred during the preceeding low water stage, so it is thought that the water planes of the two lakes which stood at 695' diverge slightly northwards away from the hinge lines. As with the first Lake Arkona, it is likely that the second Lake Arkona did not extend north-

1 Hough, J.L. 1958. p. 147.

Figure 11



SCALE : 4 Miles to 1 Inch

LEGEND

FOR ALL LAKE STAGE MAPS

- county boundaries

- ice front

- generalized shoreline

- major spillway

eastwards as far as Brant County.

At the time of its maximum extent, the ice front of the Port Huron substage stood at the Tillsonburg moraine. Further west the readvancing ice front rode up the Thumb of Michigan to Ulby, thus separating the waters in Saginaw Bay from the waters in the Huron and Erie basins, and raising the latter to form Lake Whittlesey at 738' A.T. The drainage passed via the Ulby channel to Lake Saginaw and then via the Grand River outlet.

The extent of Lake Whittlesey in Brant County is shown on the accompanying map. The highly indented shoreline is the result of river valley erosion during the preceeding low water stage, and provides some evidence for this low water stage. As has been previously mentioned, the rising waters of Lake Whittlesey tended to build constructional forms across these embayments, but shoreline features are generally weak here, owing to the confined nature of the lake.

The Tillsonburg moraine is waterlaid, with only small scattered 'islands' of landlaid moraine, along almost the whole length of the ice front where it bordered the lake.

To the north of Brant County the ice front was stationary in the vicinity of the Waterloo sandhills. Ice front drainage followed a spillway channel which flowed, via the present sites of Ayr and Wolverton, to reach Lake Whittlesey somewhere in the vicinity of Richwood. This spillway is now the valley of the River Nith. Sands and gravels deposited on the floor of the spillway and valley train type features, indicating direction of flow, are clearly seen on air photos. Materials were deposited in Lake Whittlesey partially burying some of the lower

lying sections of the Norwich moraine and on-lapping on to the Tillsonburg moraine during its process of formation. Between the two moraines, sand and deltaic gravel beds were deposited on the lake floor, and these beds now represent the oldest section of the Brantford and Norfolk county delta.

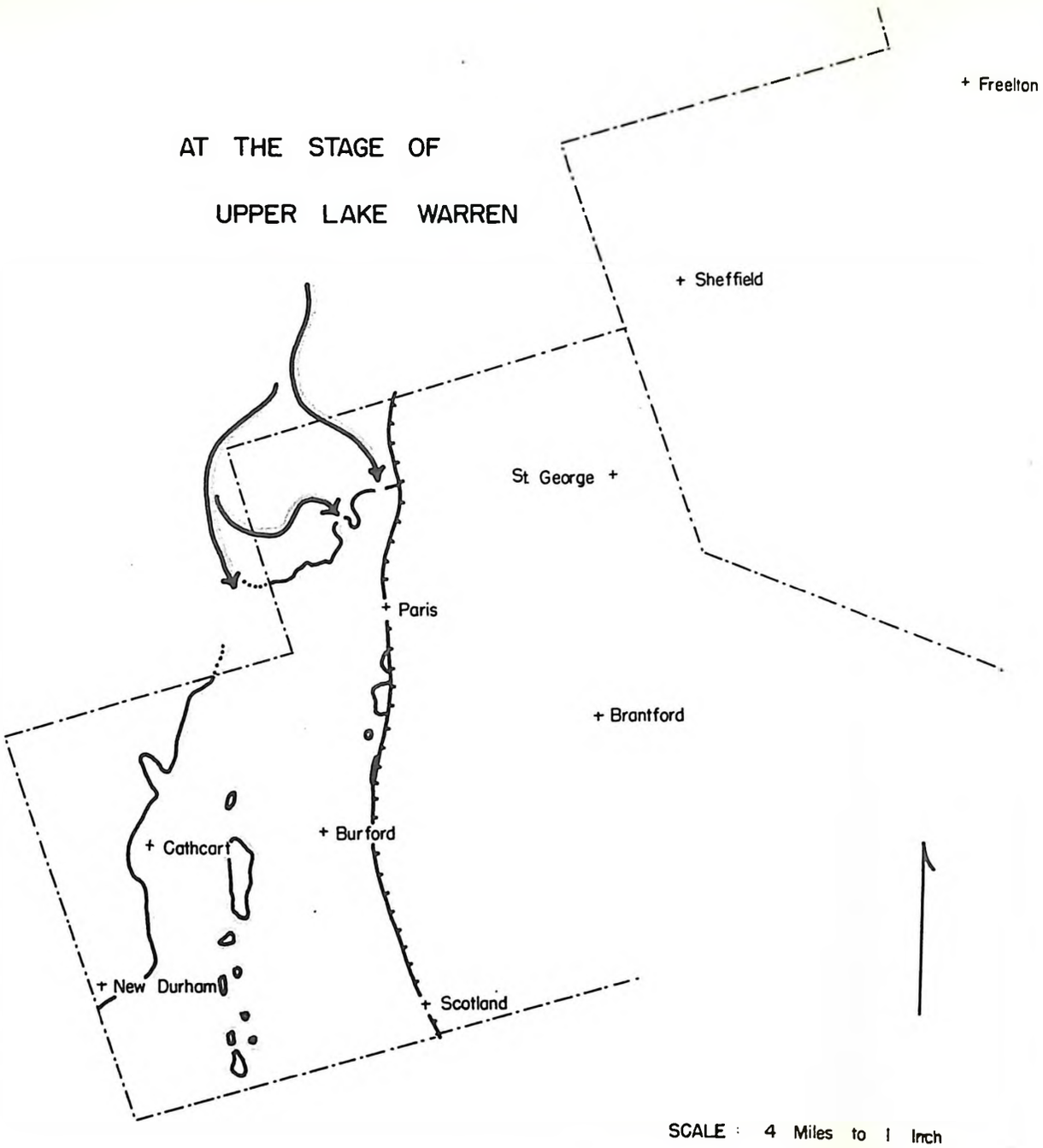
This stage was brought to a close by ice retreat. The ice backed down the Thumb of Michigan from the outermost Port Huron moraine, and once again the waters of Saginow Bay were linked with the waters to the east.

5. Port Huron glacial substage - Paris Moraine, and Upper Lake Warren
Figure 12.

The next stillstand of the ice was at the second Port Huron moraine. This is the Bay City moraine in Michigan and it is here correlated with the Paris moraine in Brant County. Discharge was once again via the Grand River in Michigan, but the lake level is a few feet lower than the lowest Arkona level. This is due to erosion of the channel during the time of increased discharge at the time when Lake Whittlesey was lowered. Upper Lake Warren stood in the Erie and Huron basins at a height of 690'.

The accompanying map shows the outline of this lake in Brant County. The main shoreline, extending from New Durham to north of Paris, is comparatively smooth. The Tillsonburg moraine forms an island archipelago lying midway between the main shoreline and the ice front. Along the position of the Paris moraine alternating sections of landlaid and water-laid moraine were being formed. Minor shoreline features at irregular heights were formed along the lake facing side of these morainic islands. Well developed shoreline features are found on the eastern and southeastern

Figure 12


AT THE STAGE OF
UPPER LAKE WARREN
+ Freelton
+ Sheffield
St George +
+ Paris
+ Brantford
+ Burford
+ Cathcart
+ New Durham
+ Scotland
SCALE : 4 Miles to 1 Inch

sides of the islands of the Tillsonburg archipelago facing the directions of maximum fetch. Fairly good shoreline features are found to the northwest of Paris where also the fetch is favourable. Elsewhere, however, major erosional and constructional forms are lacking due to sheltered locations and large areas of shallow water offshore.

There was major development of a number of spillway channels at this stage. Drainage from the ice front to the north passed down the channel now followed by the C.P.R. tracks between Dumfries and Ayr. Just to the north of Ayr, most of the drainage turned and flowed southeastwards towards Paris, entering Upper Lake Warren three miles to the north of Paris. The spillway of the previous lake, following the course of the present valley of the River Nith westwards and then southwards from Ayr, was probably still in operation. There is a terrace in this spillway resulting from the base level being lowered 48' to the new lake stage. This spillway entered Upper Lake Warren at the site of Canning. A minor spillway cutting through the Tillsonburg moraine to the east of Richwood was also in use at this time.

The two major spillways show exceptionally broad valley floors veneered with a considerable thickness of bedded sands and gravels. Valley train features here indicate directions of flow. Meltwater from a considerable length of the ice front drained via these channels accounting for their dimensions and the thickness of deposits. Spillway terraces indicate the use of each channel during two or more lake stages.

Deposition in Lake Warren reached its maximum at this stage (and in the succeeding stage of Middle Lake Warren). Sands and gravels from the spillways were deposited over a wide area of lake floor, this

being the second stage in the building of the Brantford and Norfolk county delta. Maximum deposition took place on the lake floor between the Tillsonburg moraine and the ice front. This deposition consisted partially of spillway material and partially of outwash material from the ice front giving rise to a great thickness of bedded sands and gravels with a complex bedding structure.

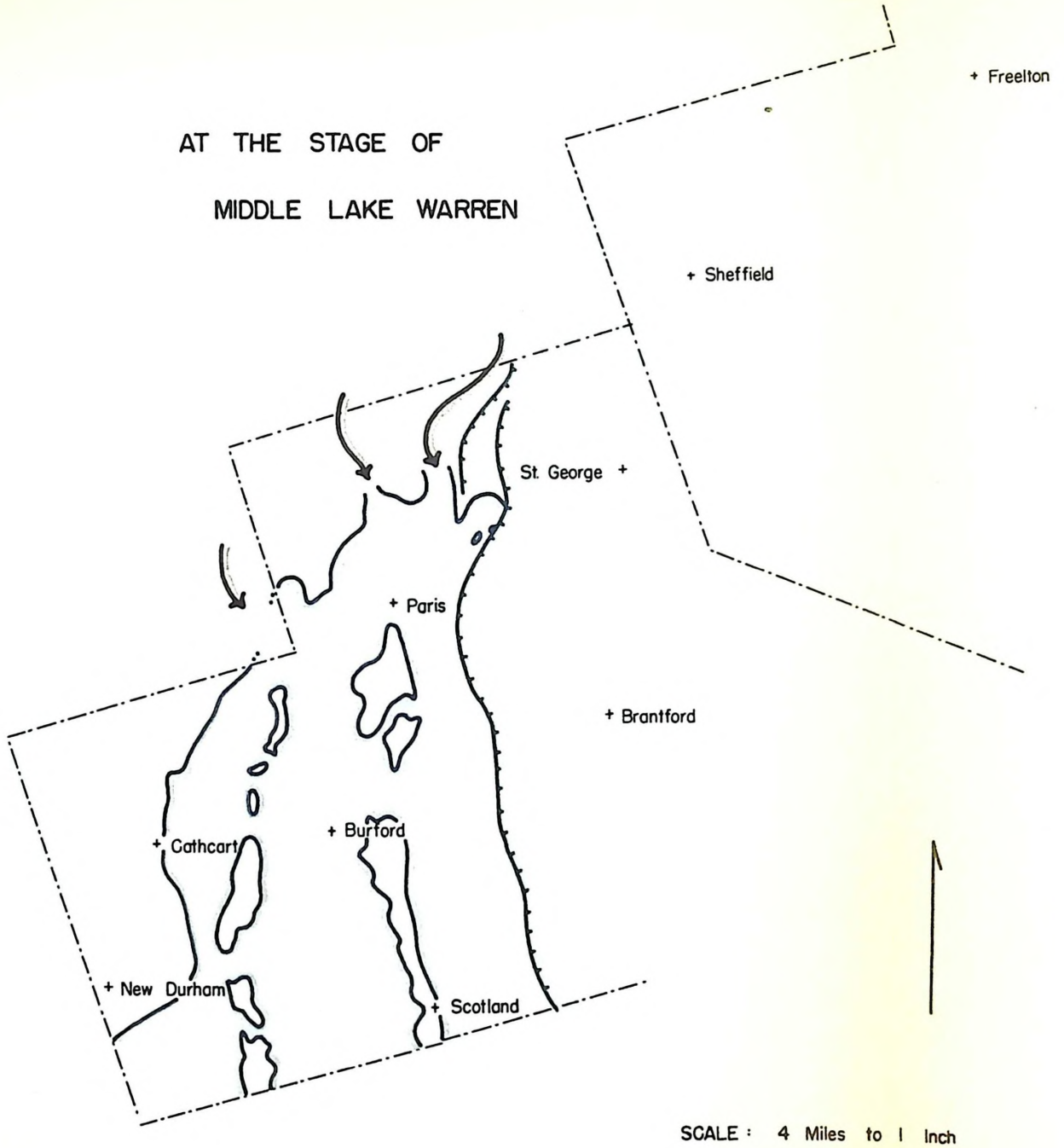
Large areas of the Tillsonburg moraine were submerged during this period and underwent modification due to water washing and also considerable areas were buried, to a varying degree, by deposition of sands and gravels. The section of the Tillsonburg moraine to the southwest of Falkland was only a few feet below the surface of Middle Lake Warren and consequently underwent a planing action, resulting in its present extremely level surface. Deposition took place around the morainic islands which now constitute this moraine between Horner Creek and the southern boundary of Brant County.

This stage was brought to a close by further retreat of the ice front and a related lowering of lake level.

6. Port Huron glacial substage - Galt Moraine and Middle Lake Warren
Figure 13

The period of ice retreat from the Bay City moraine in Michigan and the Paris moraine in Brant County resulted in increased discharge down the Grand River outlet and associated erosion and lowering of this channel. Subsequent slight readvance of the ice front to the Tawas moraine in Michigan and the Galt moraine in Brant County stabilized the lake waters at 682'. Thus the outlet channel had been lowered by 8' during increased discharge.

Figure 13


AT THE STAGE OF
MIDDLE LAKE WARREN
+ Freelton
+ Sheffield
St. George +
+ Paris
+ Brantford
+ Burford
+ Cathcart
+ New Durham
+ Scotland
SCALE : 4 Miles to 1 Inch

During Middle Lake Warren the ice front stood along the Galt moraine which is slightly more complex than moraines previously described. In the extreme northern section the moraine would appear to consist of two major strands which are clearly distinguished just to the north of Blue Lakes.

The shoreline of Middle Lake Warren is found running around the promontory formed at Blue Lakes by the more westerly morainic strand, indicating that the ice stood long enough at the more easterly strand to allow the development of shoreline features.

The Galt moraine is landlaid to the north of Blue Lakes, and with one or two exceptions, waterlaid to the south. Both the Paris and Tillsonburg moraines gave rise to a series of islands in Middle Lake Warren, dividing this section of the lake into three 'arms'. The most westerly arm is comparatively enclosed and shallow and the resulting shoreline features show only weak development in the few locations where they are visible. Shoreline features of the central and more easterly arms of the lake show much better development however. The best features are found on the easterly and south easterly facing morainic slopes, related to the direction of maximum fetch. Shallow water offshore tends to prevent any strong development of these features, consequently the western sides of the islands, i.e. the more gentle morainic slope, shows very little development of beach and bluff features.

To the north of Brant County, drainage from a great length of the ice front flowed along the large spillway in front of the Galt moraine. This spillway channel is at present occupied by the valley of Galt Creek to the north of Galt. To the south of Galt - as far as Paris, it is followed by the Grand River. The spillway at this stage, discharged into Middle

Lake Warren a few miles to the north of Paris. Deltaic deposits were built up over a wide area to the south (photo 24). Just north of Paris, a low lying section of the Paris moraine was partially buried beneath beds of sand and gravel. This was the second major stage in the building of the Brantford-Norfolk county delta. In the north, in the vicinity of Paris, deposits are seen to consist chiefly of current bedded gravels with occasional lenses of sand. The materials become progressively finer southwards towards Norfolk county. Soil types are also indicators of this change, the gravelly Burford loam, developed on the stratified gravel, being replaced by sandy loams - the Dumfries sandy loam, the Fox sandy loam, - over a subsoil of stratified sand with some gravel. The deltaic deposits gradually buried the lower lying sections of the Tillsonburg, Paris and Galt moraines.

This lake stage, and the Port Huron substage, was brought to a close by further ice retreat. Increased discharge during the initial retreat stages resulted in lowering of the Grand River outlet channel in Michigan so that the next high lake stage to discharge via this channel (which was Lower Lake Warren) stood at 675', 7' lower than Middle Lake Warren.

7. Retreat to Two Creeks Low Interval

During the initial stages of ice retreat from the Galt moraine two spillways were cut through this moraine carrying ice front drainage across to the Grand River spillway which was still in operation. It is believed that the ice retreated comparatively slowly at first, and thus these spillways were in use for a sufficient length of time to account for their present development..

Photo 23. The materiald section of the Paris moraine to the south of Horner Creek showing its gently undulating topography.

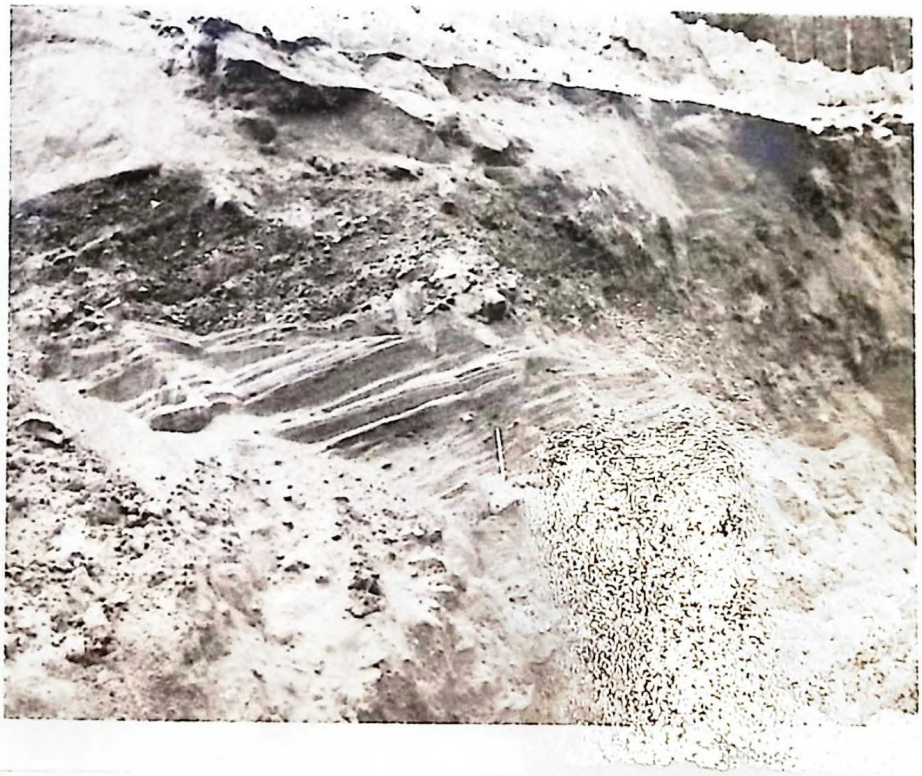


Photo 24. Cross-bedded sands and gravels of the Grand River spillway, exposed midway up the present valley side.

The more northerly spillway, flowing westwards from Branchton carried drainage from the ice front for a considerable distance to the north across Beverly and Puslinch townships, and as far south as one mile to the north of St. George.

The Blue Lakes spillway drained a relatively small length of ice front. It was cut across an originally low and weak section of the Galt moraine, and drained a small ponding which developed in the angle of the moraine here (photos 25 and 26).

During the ultimate stage of this glacial retreat waters in the lake basins were at least as low as at present. The Erie basin drained via the St. Davids drift filled gorge across the Niagara peninsula to the Ontario basin, which in its turn drained via Lake Champlain and the Hudson River lowland. The St. Lawrence valley was still blocked by ice at this time.

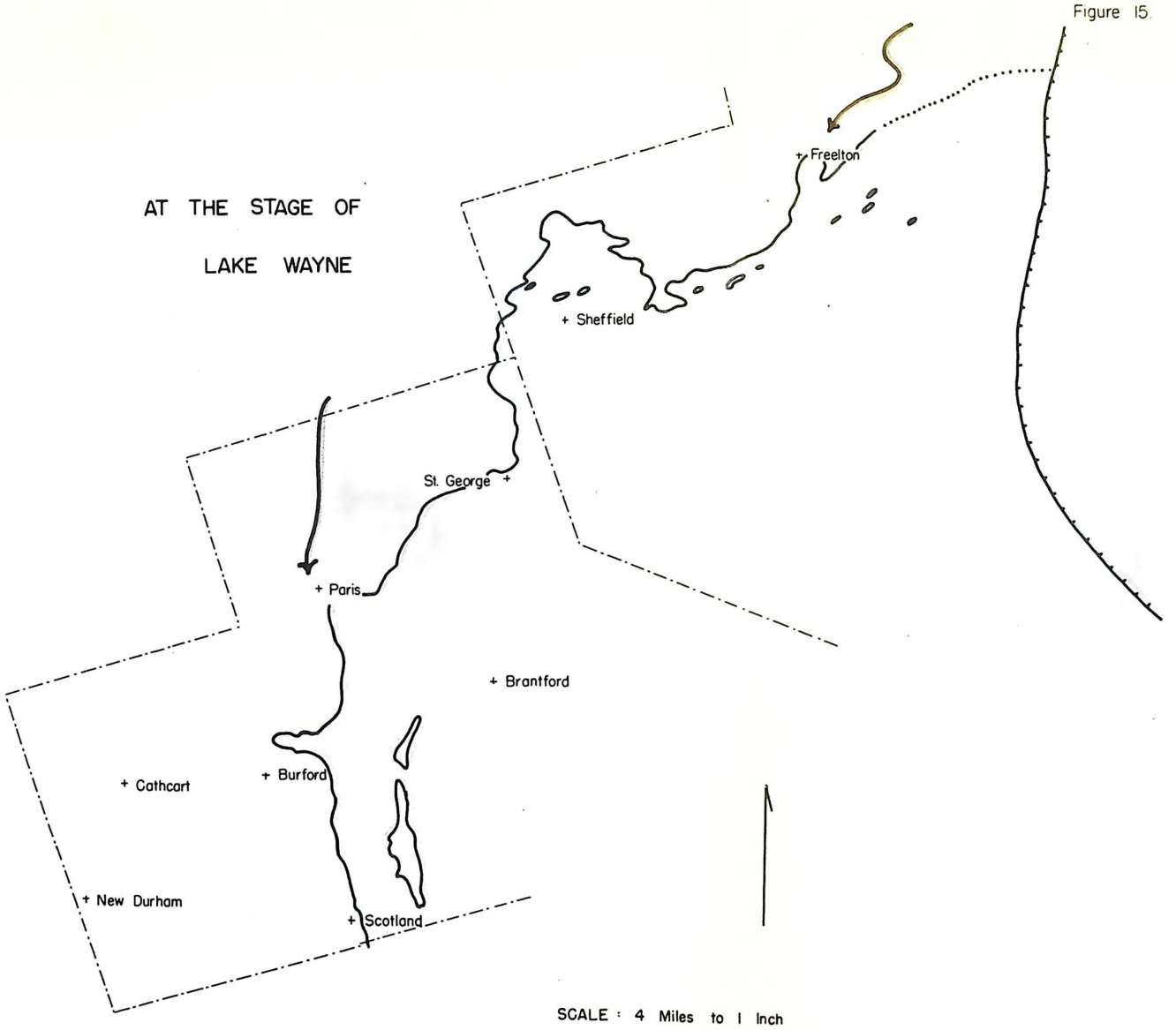
In Brant County the incision of streams into glacial deposits, and the grading to a low base level, began at this time.

8. The Valders Readvance and Lake Wayne Figure 15.

Sometime during the advance of the Valders ice there was a still stand long enough to enable the related glacial lake to form well defined shore features. This was Lake Wayne which stood at 655' and drained eastwards to the Mohawk Valley via some of the channels south of Syracuse. It is not definitely known whether Lake Wayne represents a stage during the retreat to the Two Creeks low stage or a stage during the subsequent readvance. Hough arbitrarily assigns it to the advance, and evidence given in chapter 3 would appear to verify this decision.

The exact position of the ice front at this stage is not known,

Figure 15.


AT THE STAGE OF
LAKE WAYNE
+ Freelton
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St. George +
+ Paris
+ Brantford
+ Cathcart
+ Burford
+ New Durham
+ Scotland
SCALE : 4 Miles to 1 Inch

Photo 25. The lowest terrace of the Blue Lakes spillway channel

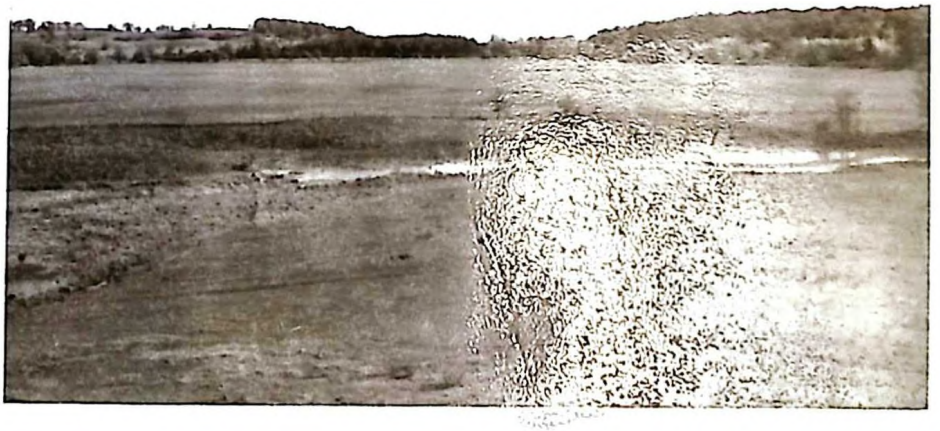


Photo 26. The Blue Lakes spillway channel showing the lowest (middle-distance with standing water) and main terraces.

but in order to maintain the lake at this level the ice front must have stood on top of the escarpment and thus have occupied a position between the escarpment and the Niagara Falls moraine. This arbitrary position is indicated on the accompanying map.

The shoreline of Lake Wayne in Brant County is not indented. It follows the eastern slope of the Paris moraine from the southern county boundary northwards to Paris. It then swings northeastwards to St. George and then northwards and into North Dumfries township, and then eastwards to Wentworth County. The Galt moraine, to the south of Brantford rose above the lake waters to form two large islands which serves the purpose of protecting the shoreline to the west from wave attack. Elsewhere there are recognizable shoreline features.

In Wentworth County the shoreline is complicated by numerous islands and promontories formed by the drumlins. Those drumlins show exceptionally well developed shoreline features on their south and southeast facing slopes in accordance with the direction of maximum fetch. The main shoreline is quite sheltered and shows relatively few results of wave action.

The Grand River spillway was once again in operation during the existence of Lake Wayne, working to the lower base level and forming prominent spillway terraces. The spillway carried drainage from the ice front far to the north where it stood on top of the escarpment, and the drainage entered Lake Wayne in the vicinity of Paris. Further sand and gravel deposits were at this time added to the deltaic area of southern Brant County and Norfolk county.

In the Beverly drumlin field sands and gravels carried by minor

spillways and outwash streams.were deposited around the drumlins adding to the gravel deposits formed during the retreat of the Port Huron ice sheet. Ripple marked sands and gravels, exposed in the St. George gravel pit were deposited at this time.*

This stage was brought to a close by further advance of the ice front. The eastern drainage way was blocked and outflow was once again via the Grant River channel in Michigan.

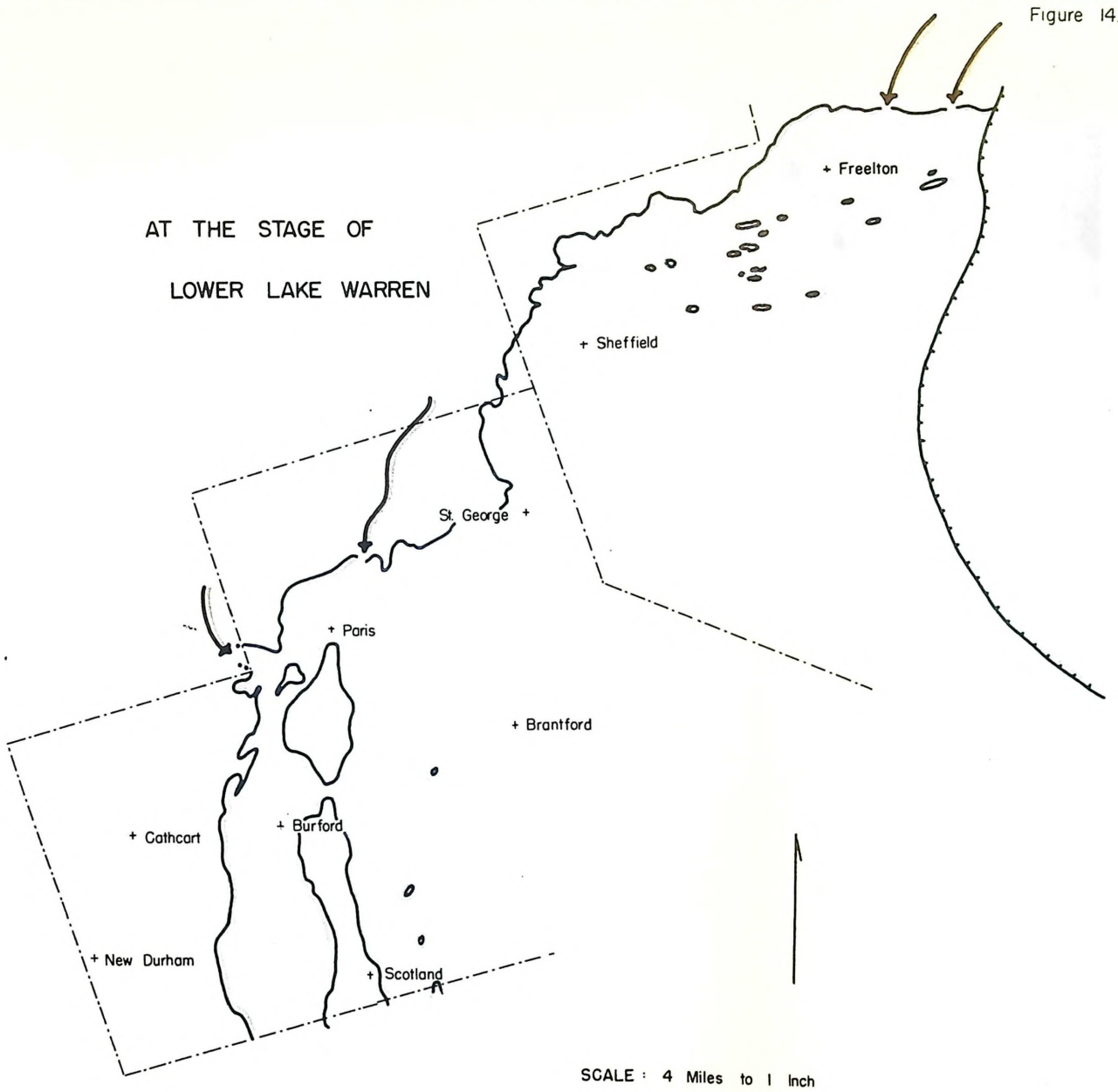
9. The Valders Maximum - Niagara Falls Moraine and Lower Lake Warren Figure 14.

At the stage of maximum readvance the ice stood at the Niagara Falls moraine in Wentworth County. Lake waters rose until they became stabilized at 675'. The Wayne shoreline was thus submerged resulting in the water washed features previously described. Lower Lake Warren transgressed into the area between the Paris and the Tillsonburg moraine although this arm of the lake was very shallow. The Paris moraine was partially submerged and formed two large islands to the south of Paris. The Galt moraine was almost completely submerged to the south of St. George.

In Brant County the main shoreline was quite smooth. Good shoreline features are developed on almost all the east and southeast facing slopes where the range of fetch is considerable. Once again the drumlin archipelago resulted in a complex shoreline in Wentworth county. The strongest features here tend to face southeastwards or southwards. South-facing features are relatively much stronger along the Lower Warren shoreline than along the Wayne shoreline, indicating the changing direction of fetch related to the readvancing ice front. Thus the long ESE fetch which formed the dominant features of the Wayne shoreline, was eliminated.

* see page 53 - figure 5.

Figure 14.


AT THE STAGE OF
LOWER LAKE WARREN
+ Freelton
+ Sheffield
St. George +
+ Paris
+ Brantford
+ Cathcart
+ Burford
+ New Durham
+ Scotland
SCALE : 4 Miles to 1 Inch

The Grand River spillway was still in operation whilst minor spillways carried ice front drainage to Lower Lake Warren in Wentworth County. This lake existed until ice retreat uncovered a lower eastern outlet.

Lower level glacial lakes were formed as ice retreat progressively uncovered lower outlets. The shorelines of these lakes were not identified or discussed since they may have occupied only a small area of Brant County and thus played only a minor part in its evolution.

Reference

1. Hough, J.L. Geology of the Great Lakes. University of Illinois Press, Urbana. 1958.

C O N C L U S I O N

The original purpose of this dissertation was to trace the continuation of the glacial lake shorelines of northern Wentworth County southwestwards across Brant County. The shorelines were tentatively identified and a chronology established for the area on this basis.

With regard to shoreline analysis, it is the comparisons between data which are usually of greater value than the absolute data. This is understandable since this work involves the detailed study of a relatively small region within a much larger area for which only general information is available for purposes of comparison.

The morphology of the Brant County moraines was studied with reference to the elevation and location of the supposed shorelines, and a close relationship was found between these features. Using this as a starting point, a chronology for the area of Brant and Wentworth Counties was developed in accordance with the glacial history of Southern Ontario.

Shorelines mapped and only tentatively identified by previous writers may now be identified more conclusively. The shorelines in Wentworth County are the two lower shorelines of the series of five, and thus are representative of Lower Lake Warren and Lake Wayne. Horton's original tentative identification* is thus corredt in part, since he suggested the diverging strands of Lake Warren as a possibility.

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* see p. 12

The beaches reported by Karrow* at 905' on the Galt moraine in northern Brant County, and at 925' on the drumlins to the south of Carlisle in Wentworth County are part of the Lower Lake Warren shoreline. Those he found at 875' near Carlisle and at 875' near Millgrove represent the Lake Wayne shoreline.

The beach identified by Putham and Chapman as representing Lake Warren, is considerably lower than the Warren beaches identified in this thesis.** They do not mention any higher beaches but express the opinion that this is rather high for a Warren beach in this area. It is now believed that this position is too low for the Warren beach and therefore must represent some more recent glacial lake stage.

Earlier writers show a similar tendency to locate the Warren and Whittlesey beaches at low elevations. Laverett's generalized description of the Lower Warren beach *** could, however, correspond to the Lower Warren beach described here, but the elevations he gives are usually below the elevations at which this beach was mapped by Horton.

It seems likely that several factors contributed to both erroneous identification and erroneous mapping of beaches by earlier writers. The reasons given in Chapter 2**** may account for the mistaken identification of beaches. Also, the highest expected elevations for the Whittlesey and Warren beaches were comparatively low, and thus discouraged the search for beaches at higher elevations. Furthermore, in past writing, various glacial lakes are thought to have extended further

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* see p. 12

** see pps. 11 and 12.

*** see p. 11.

**** see pps. 12 and 20.

east than is now known to have been possible because of the position of the ice front.

The location of beaches on moraines in Brant County corresponds to the placing of the moraines in the chronological sequence. Putnam and Chapman express doubt as to the inclusion of the Tillsonburg moraine within the Port Huron glacial substage*, but this would appear to be correct since it corresponds with all other evidences involved.

The chronology established here differs considerably from that given by Putnam and Chapman[1], but does correspond in all respects to that established by Hough. Putnam and Chapman give only the broad outline of the glacial retreat, and each moraine is by no means related to a distinct glacial stage as in Hough's chronology.

Hough[2] only arbitrarily assigns Lake Wayne to the rising lake level at the end of the Two Creeks Low Interval. Evidence given in Chapter 3 would substantiate this supposition. Features of the Wayne shoreline are quite strong despite the fact that it was submerged by Lower Lake Warren, and therefore it may be attributed to a rising lake level. Also, the beach gradient (fig. 6) is more akin to that of Lower Lake Warren than to the previous lake stages. It may thus be supposed that it is closest to Lower Warren in time, and thus related to the early stage of the Valders readvance.

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* see p. 62.

1 Chapman, L.J., and Putnam, D.F. 1951.

2 Hough, J.L., 1958. p. 151.

References

1. Chapman, L.J., and Putnam, D.F. — The Physiography of Southern Ontario. University of Toronto Press, 1951.

2. Hough, J.L. — Geology of the Great Lakes. University of Illinois Press, Urbana 1958.

A P P E N D I X

The purpose of this appendix is to discuss briefly geographical features which were noted whilst carrying out fieldwork and studying the topographic sheets of Brant County. They are not directly related to the main topic of this thesis. In many instances the direct effects of physiography and soil type on the agriculture of the region were noted. Settlement patterns and communication patterns are also closely related to geomorphological factors.

Soil Types

The close relationship between physiography and soil types was discussed for the morainic regions in Chapter 4. There is a similar correspondence over the remainder of the area (photo A1).

Land Use

Over the whole region land use would appear to be governed by two factors: i. relief and nature of terrain

ii. soil types

In the northern section of the Galt moraine is the area of most highly accidented topography in the whole region. The soils are very stony and large boulders are common. Here, many acres of land remain as rough pasture or forest. For similar reasons the kame area between Pinehurst and Spottiswood Lakes to the north of Paris is completely forested. Over all morainic areas, ill drained and steep-sided blind

Photo 1A. A location near Falkland. There is a clear distinction between the dark, ill-drained, and humic soils of the low-lying sandplain, and the lighter, and well drained soils of the morainic hills.

depressions remain under a forest cover.

The other major area where steepness of slope has precluded forest clearance is along the banks of the Grand River valley and the valleys of its major tributaries. The terraces and flood plains of these valleys have been cleared; terraces chiefly for cultivation and flood plains for pasture.

There is much land remaining in forest in Burford Township and in Oakland Township and the adjoining area of Brant Township. The lower lying sections of the intermorainic sand plain of the Brantford - Norfolk County delta are occupied by large areas of swamp forest (photo 2A). These lie adjacent to the eastern sides of the moraines, and tend to disrupt the grid pattern of the concession roads. The swamp forests frequently terminate abruptly at the well defined edge of a higher terrace which outlines much of the forest regions (photo 3A).

Between the Norwich and Tillsonburg moraines approximately 30% of the area is under forest. The forested areas can be directly related to the occurrence of the Granby sandy loam, which is one of the poorest soils in the region and described as dark grey sandy loam over sand with clay at a depth of three feet or more. It is ill drained.

Agriculture

The most widespread agricultural type is mixed farming, with variations and a trend towards more specialized types according to regional location.

Tobacco The tobacco belt of Norfolk County extends a considerable distance northwards into Brant County. Tobacco farms are located on the drier parts of the intermorainic sand plain areas (photo 4A).

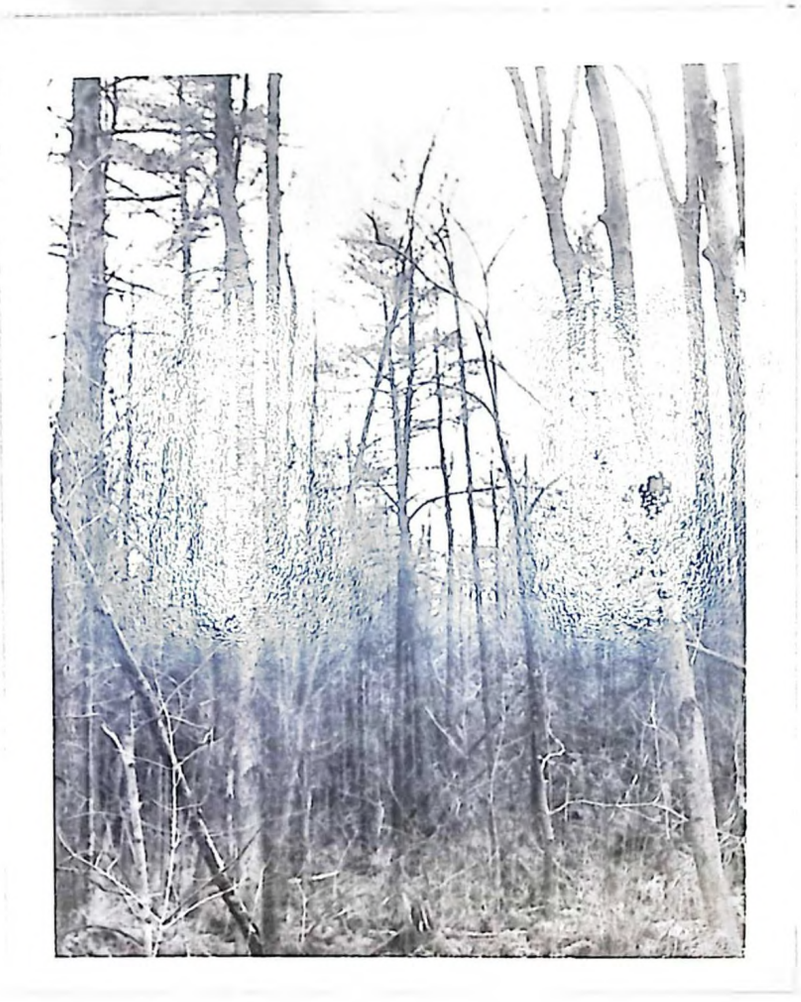

Photo 2A. A characteristic section of the swamp forest between the Tillsonburg and Paris moraines. White cedar is dominant.

Photo 3A. A view eastwards from the Paris moraine, showing the steep, east-facing slope of the moraine, and the abrupt change from cultivated land to swamp forest.

Photo 4A. A typical tobacco farm located on the sand plain between the Galt and Paris moraines.

The location of these farms with respect to soil type is extremely precise. Mixed farms are located along the crests of moraines in this area, but immediately to the west, on the long gradual slope where sand plain merges into moraine, the tobacco farms appear. On the western side of the moraine, isolated tobacco farms are located on the narrow belt of comparatively well drained sand plain lying between the moraine and the swamp forest (photo 5A).

Orchards Around Paris and further north on the Galt moraine, orchards show a characteristic location. They are almost invariably situated on the eastern side of a morainic area, on the fairly level ground of water-washed or waterlaid moraine, and adjacent to, or actually upon, the usually indefinite moraine sand plain junction. Such sites are frequently lake plains and shoreline benches also (photo 6A). The reasons for this location of orchards include the good drainage given by the sandy soils yet on quite flat ground. The factor of shelter from westerly winds since the highest morainic regions are located a short distance to the west of the orchard sites is also important.

Dairying There is a noticeable increase in the number of dairy farms as one moves westwards from the sand plain across the Norwich moraine into the till plain of Oxford County. The physiography of the latter is well suited to dairy farming.

Pattern of Settlement Rural settlement is most dense along major roads where there is dispersed ribbon development adjacent to the larger settlements, chiefly Paris, Brantford and Burford. A good example of this type of settlement is Mount Pleasant, a suburb of Brantford situated five miles to the south of that city on Highway 24.

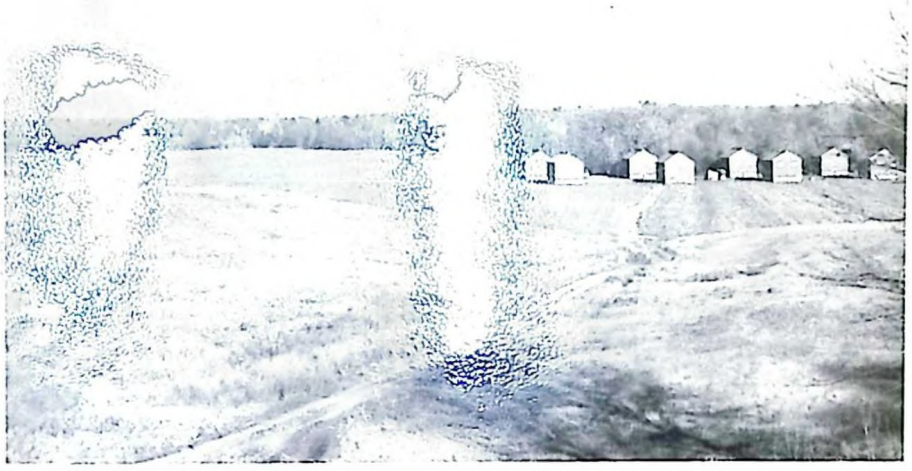

Photo 5A. A view northeastwards from the Paris moraine, showing the typical location of a tobacco farm on the narrow belt of sand plain between the moraine and the swamp forest.

Photo 6A. An orchard in the Paris moraine, typically sited on a broad shoreline bench, and also extending to the crest of the bluff.

Elsewhere the densest rural settlement is found on the best agricultural land of the well drained sand plain areas and in the regions of waterlaid moraine. Settlement in the landlaid morainic areas is comparatively sparse, whilst it is completely absent from the regions of forest swamp and flood plains.

In detail, farm buildings tend to be sited above the level of their surrounding area if at all possible. They are frequently located above beach bluffs and on the edge of terraces. In landlaid morainic areas farms have a wide distribution but they are invariably fouhd in sheltered situations on the leeward side of the ridge crests.

The larger settlements are located in the earliest settled areas which are those regions first cleared for agriculture. In the south-western part of the area, communities such as Harley, New Durham and Oakland, located on the well drained morainic ridges, are examples. In fact, they are located where the east-west major highways cross these ridges.

Pattern of Communications The overall gridded road pattern has been disrupted by a number of physical factors. The Grand River valley bisects the area, and has only three bridging points within the region, these begin at Brantford, Paris, and Glen Morris. Incision of the River Nith, and to a lesser extent Horner Creek also, give rise to irregularities in the road pattern. The road network is less dense in the forest swamp areas than elsewhere. In several instances, secondary roads are found following the crests of morainic ridges, especially in Burford Township and the adjacent parts of Brant Township.

The rail network shows a closer relationship to relief than the road pattern. To the north of Highway 5 east of Paris, there are only

two 'gaps' in the Galt moraine, namely the Branchton and Blue Lakes spillway channels. These are utilized by the only two railways to cross this section of the Galt moraine. (One of these has now been abandoned.)

Throughout the region the chief lines of communication run from east to west, whilst the grain of the land is from north to south. Relief is generally insufficient to deflect the main highways, but the railways do tend to follow the several gaps in the morainic ridges and to avoid, where possible, the ill drained intermorainic areas.

The Grand River valley is a line of communication only in one respect. It is followed by the tracks of the Lake Erie and Northern Electric line between Galt and Brantford.

Economic Geography The widespread sand and gravel deposits of the area have been quarried extensively. There are numerous small sand and gravel pits but these have been mostly abandoned or are used for purely local purposes. The larger pits are located near Paris and Brantford where there has been large scale removal of spillway deposits at Paris, and removal of terrace gravels of the Grand River at Brantford (photos 7A and 8A). Sand and gravel from here is chiefly transported to Toronto and Hamilton, and constitutes almost the entire supply of the latter city.

Erratic boulders are frequently used as building materials (photo 9A).

Recreation There are no major recreation areas within the region studied. Some of the lakes have private recreational facilities, for example, the larger of the Blue Lakes is the site of several privately owned cottages. In the hunting season the numerous wood lots and forested areas prove to be very popular.

It may be concluded that Brant County is a predominantly agricultural

Photo 7A.

Photo 8A. Spillway gravels are quarried extensively near Paris. These two photographs were taken in one of the larger gravel pits.

Photo 9A. A shop front at St. George illustrating the use of erratic boulders as a building material.

region, and that agriculture varies in correspondence with physiography. Settlement and communication patterns also show relationship to varying types of terrain.

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Maps

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National Topographic Series, Sheets:

40 P/1	Brantford
40 P/8	Galt
40 P/2	Woodstock (east half only)
40 I/15	Tillsonburg (east half only)
40 I/16	Simcoe (east half only)

Aerial Photographs. Series. A13340 nos. 9-17, 45-49, 69-73.
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