Quaternary geology of the Campbellford, Trenton, Consecon, Tweed, Belleville, Wellington, Sydenham, Bath, and Yorkshire Island map-areas, Ontario

A thesis submitted to Brock University

by

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in partial fulfillment of the requirements for the degree of Master of Science February, 1984

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# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>viii</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Location</td>
<td>3</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>5</td>
</tr>
<tr>
<td>Previous Work</td>
<td>6</td>
</tr>
<tr>
<td>Physiography</td>
<td>7</td>
</tr>
<tr>
<td>Bedrock Topography</td>
<td>9</td>
</tr>
<tr>
<td>Drift Thickness</td>
<td>10</td>
</tr>
<tr>
<td>Bedrock Geology</td>
<td>11</td>
</tr>
<tr>
<td>Quaternary Geology</td>
<td>13</td>
</tr>
<tr>
<td>Glacial Geology</td>
<td>13</td>
</tr>
<tr>
<td>Landforms</td>
<td>13</td>
</tr>
<tr>
<td>Stratigraphy</td>
<td>15</td>
</tr>
<tr>
<td>Glacial Abrasion</td>
<td>16</td>
</tr>
<tr>
<td>Older Drift</td>
<td>17</td>
</tr>
<tr>
<td>Till</td>
<td>20</td>
</tr>
<tr>
<td>Drumlinized Till</td>
<td>21</td>
</tr>
<tr>
<td>Dummer Till</td>
<td>24</td>
</tr>
<tr>
<td>Wallbridge Till</td>
<td>26</td>
</tr>
<tr>
<td>Ice Contact Deposits</td>
<td>29</td>
</tr>
<tr>
<td>Proximal and Distal Outwash</td>
<td>30</td>
</tr>
<tr>
<td>Glaciolacustrine Geology</td>
<td>31</td>
</tr>
<tr>
<td>Distribution of Glaciolacustrine Features</td>
<td>32</td>
</tr>
<tr>
<td>Raised Shoreline Deposits</td>
<td>32</td>
</tr>
<tr>
<td>Nearshore Deposits</td>
<td>35</td>
</tr>
<tr>
<td>Offshore Deposits</td>
<td>36</td>
</tr>
</tbody>
</table>
FIGURES

Figure 1. Map Index

Figure 2. Location Map

Figure 3. Bedrock Geology

Figure 4. Borehole I, Smithfield

Figure 5. Borehole II, Experimental Farm

Figure 6. Borehole III, Campbellford Airfield

Figure 7. Textural Diagram for Map Area Tills

Figure 8. Borehole IV, Wallbridge
PLATES

Plate 1. View up ice of drumlin in clay flats near Menie, Campbellford map area.
Plate 2. Hummocky topography of Dummer Moraines in Campbellford map area.
Plate 3. Esker ridge at Cedar Creek, Trenton map area.
Plate 4. Cross-cutting striae at Point Anne quarry, Belleville map area.
Plate 5. Streamlined bedrock forms north of Marysville, Belleville map area.
Plate 6. Till in the core of a drumlin, Amherst Island, Bath map area.
Plate 7. Cobbly, bouldery, Dummer till near Read, Tweed map area.
Plate 8. Pebby Dummer till near Larkins, Tweed map area.
Plate 9. Ice contact delta foreset beds near Brighton, Trenton map area.
Plate 10. Glacirotectonic contortion of lacustrine sediments near Trenton, Trenton map area.
Plate 11. Ice contact sands and gravels capped by till in morainic deposit east of Trenton, Trenton map area.
Plate 12. Lacustrine clast in till of morainic deposit north of Johnstown, Trenton map area.
Plate 13. Boulders from Dummer till reworked into Lake Ontario lobe morainic deposit southeast of Halston, Tweed map area.
Plate 14. Glen Ross kame, Glen Ross, Campbellford map area.
Plate 15. 'Flow till' bed in extensive sand deposit north of Odessa, Sydenham map area.
Plate 16. Glacial Lake Iroquois bluff and boulder littered terrace near Brighton, Trenton map area.
Plate 17. Glacial Lake Iroquois nearshore sediments in bar complex near Little Lake, Trenton map area.
Plate 18. Sediment structures in glacial Lake Iroquois bar near Warkworth, Trenton map area.
Plate 19. Older raised river bar north of Trenton, Trenton map area.
Plate 20. Disturbed bedrock south of Roblindale, Tweed map area.
MAPS


Map 2. Quaternary geology of the Trenton-Consecon areas, Southern Ontario.


Map 5. Quaternary geology of the Wellington area, Southern Ontario.


Map 8. Major geological features of the Campbellford, Trenton, Consecon, Tweed, Belleville, Wellington, Sydenham, Bath and Yorkshire Island map-areas.
<table>
<thead>
<tr>
<th>MAP 1</th>
<th>MAP 3</th>
<th>MAP 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAMPBELLFORD (31C/5)</td>
<td>TWEED (31C/6)</td>
<td>SYDENHAM (31C/7)</td>
</tr>
<tr>
<td>MAP 2</td>
<td>MAP 4</td>
<td>MAP 7</td>
</tr>
<tr>
<td>TRENTON (31C/4)</td>
<td>BELLEVILLE (31C/3)</td>
<td>BATH (31C/2)</td>
</tr>
<tr>
<td>CONSECON (30N/13)</td>
<td>WELLPONTO (30N/14)</td>
<td>YORKSHIRE (30N/16)</td>
</tr>
</tbody>
</table>

**FIGURE 1. Map Index**
<table>
<thead>
<tr>
<th>(30N/13)</th>
<th>(30N/14)</th>
<th>(30N/15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSECON</td>
<td>MERRINCON</td>
<td>ISLAND</td>
</tr>
<tr>
<td>(31C/9)</td>
<td>(31C/3)</td>
<td>YORKSHIRE</td>
</tr>
<tr>
<td>BEETON</td>
<td>BERGELIGE</td>
<td>(31C/5)</td>
</tr>
<tr>
<td>WAB 5</td>
<td>WAB 4</td>
<td>BATH</td>
</tr>
<tr>
<td>(31C/2)</td>
<td>(31C/1)</td>
<td>(31C/1)</td>
</tr>
<tr>
<td>CAYWBERGLOAD</td>
<td>IWEED</td>
<td>(31C/1)</td>
</tr>
<tr>
<td>WAB 1</td>
<td>WAB 3</td>
<td>SADENHAW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WAB 9</td>
</tr>
</tbody>
</table>
ABSTRACT

Sediment relationships observed during geological mapping in southeastern Ontario indicate a relatively simple deglaciation history for the area during late Wisconsin time. The ice from the north (part of the Lake Simcoe lobe) and the Lake Ontario ice lobe, which were coalesced during most of late Wisconsin time, initially separated along the crest of the Oak Ridges Moraine. Available data indicate that the Oak Ridges Moraine is composed primarily of sediments pre-late Wisconsin in age capped by late Wisconsin till and interlobate deposits.

Retreat of the northern ice was relatively steady and resulted in the deposition of the Dummer Moraines, a facies of the drumlinized till to the south. Retreat of the Lake Ontario ice lobe into the Lake Ontario basin was interrupted by a re-advance which covered the southeastern half of the map area. The northern ice had already retreated from the area by this time. The Lake Ontario lobe was fed through the St. Lawrence Valley, indicating that the Ottawa Valley was ice filled at this time.

High level glacial lakes fronted the ice during deglaciation. These waters quickly fell to low levels as the ice retreated from the St. Lawrence Valley, opening lower outlets.
INTRODUCTION

Geological mapping for this study involved re-examination of surface deposits in the following NTS map areas: Campbellford (31 C/5), Trenton (31 C/4), Consecon (30 N/13), Tweed (31 C/6), Belleville (31 C/3), Wellington (30 N/14), Sydenham (31 C/7), Bath (31 C/2) and Yorkshire Island (30 N/15).

Mapping at a scale of 1:50,000 was carried out during the 1980, 1981 and 1982 field seasons. Stratigraphic drilling was carried out during February and March of 1982.

Preliminary geological maps were prepared in a format consistent with similar studies throughout the province and provide a data base for further studies and development in the area.

Field work involved the examination of natural and man-made exposures. Hand augers and soil probes were used to gather additional data. Examination and sampling of the surficial sediments was done primarily along township roads and, when necessary, on private land with the landowner's permission. Supplementary information was obtained from water well records. Air photographs were used extensively to delineate map unit boundaries. Deposits were mapped only if the sediment thickness was one metre or more. If the surface deposit was less than one metre in thickness the underlying unit was mapped.

In addition to the preliminary maps and accompanying marginal notes, descriptions of the major depositional units are given with emphasis on glacially derived sediments and
their depositional history.
LOCATION

The field area is located in southeastern Ontario between Latitude 44°30'N and Lake Ontario to the south and Longitude 76°30'W and 78°00'W (Figure 2).
ACKNOWLEDGEMENTS

Able and willing field assistance during field mapping were provided by M. Winton, T. R. Donley, T. S. Russell, A. Stachlinski and H. Foy. Useful field discussion was provided by J. Terasmae, J. Mastro, E. Grynach, J. Barnett, D. Sharpe and E. V. Sado.

Lands whose access to the grounds, pits and quarries aided in the extension of surface information.

The Ministry of the Environment provided water well records and aided in the interpretation of sediments in areas of new mineral research and of the Ministry of Northern Development's laboratory analysis.

The research was supported by the Northern Ontario Geological Survey (now) and by the Federal Department of Energy, Mines and Resources (now) and the Ontario Ministry of Natural Resources under the Mineral Resources Program of the Eastern Ontario Regional Agreement.
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Landowners who provided access to their lands, pits and Quarries aided in the extension of surface information.

The Ministry of the Environment provided water well records which aided in the interpretation of sediments in areas of thick drift. The Mineral Research Branch of the Ministry of Natural Resources carried out laboratory analysis.

This project was part of the Southeastern Ontario Geological Survey (SOGS) which was funded equally by the Federal Department of Regional Economic Expansion (DREE) and the Ontario Ministry of Natural Resources under the Minerals Program of the Eastern Ontario Subsidiary Agreement.
PREVIOUS WORK

A number of geologists have examined sediments of the area beginning in the early 1800's. Comprehensive studies of the geomorphology and sediments of the area were carried out later. Spencer (1882 and 1888) traced glacial Lake Iroquois raised shoreline features through the area as did Coleman (1937 a,b) who, in addition, examined many lower shoreline features and glacial sediments along the north shore of Lake Ontario.

The area was initially mapped in a regional physiographic study of Southern Ontario by Chapman and Putnam (1951, 1966). Detailed preliminary maps of all but the Bath (31 C/2) map areas were later prepared by Mirynech and placed on open file by the Geological Survey of Canada in 1978 (Mirynech 1978).

A Ph.D. thesis by Mirynech (1962) presents the detailed Quaternary geology of the Campbellford (31 C/5), Trenton (31 C/4) and Consecon (30 N/13) map areas.
PHYSIOGRAPHY

The area mapped in this study includes part or all of several physiographic regions defined by Chapman and Putnam (1966). These regions are: the Oak Ridges, Peterborough Drumlin Field, South Slope, Dummer Moraines, Napanee Plains, Prince Edward Peninsula and the Iroquois Plain.

The Oak Ridges is defined by Chapman and Putnam (1966) as an interlobate moraine. In this study the Oak Ridges is re-defined to include voluminous buried sediments of probable pre-Late Wisconsin origin. Sandy interlobate deposits cap the Oak Ridges in the western part of the Trenton (31 C/4) map area. The surface of the remainder of the Oak Ridges has been heavily drumlinized by the coalesced ice lobes and forms distinctive highlands north to Hastings and northeast to Pancake Hill.

The Peterborough Drumlin Field also terminates in the western half of the map area. This physiographic region is characterized by numerous drumlins of a variety of shapes and sizes. This drumlin field extends south across the Oak Ridges and north into the Dummer Moraines.

The drumlin field south and east of the Oak Ridges has been defined as the Quinte Drumlin Field by Mirynech (1962). The western portion of this drumlin field is included in the Peterborough Drumlin Field by Chapman and Putnam (1966).

The South Slope is defined by Chapman and Putnam (1966) to be the southern slope of the Oak Ridges Interlobate Moraine. It is partially redefined here as the south slope
of the Oak Ridges sediment mass including the capping interlobate moraine. The south slopes of the sediment masses to the east of the Trent River may be included in this physiographic region.

The Dummer Moraines is an area of generally hummocky, stony topography beginning at the Precambrian-Paleozoic boundary and continuing southwards up to 26 kilometres in this area. Drift occurs in large patches in this area with intervening spaces of thin drift or bare bedrock plains. The topography of the Dummer Moraines occupies approximately the northern third of the map area and disappears to the east just northeast of Varty Lake.

The Napanee Plain occupies most of the area east of Trenton, south of the Oak Ridges and Dummer Moraines, and north of the Bay of Quinte. This is a nearly flat limestone plain cut by several river valleys. The rock is generally bare or has a thin drift cover. The Quinte Drumlin Field (Mirynech, 1962) occupies the southern portion of this physiographic region.

The Prince Edward Peninsula which occupies the area south of the Bay of Quinte is also a limestone plain but is marked by large north facing escarpments and bedrock valleys. The Quinte Drumlin Field (Mirynech, 1962) is present through the northern two-thirds of this area.
BEDROCK TOPOGRAPHY

Bedrock of the area consists primarily of plane bedded limestones dipping generally to the south at 1.8 to 3.8 metres per kilometre (Winder, 1955; Liberty, 1960, a,b). The bedrock topography is clearly visible throughout the eastern two-thirds of the area where drift is generally thin. The surface of the Paleozoic bedrock is broken by north facing escarpments of up to several tens of metres in height. The courses of the Napanee and Salmon rivers follow normal faults, each of which has a displacement of approximately 30 metres (Carson, 1981, a, b, c).

Bedrock topography is uncertain in the western central portion of the area because of the thick overlying sediments. Sparse bedrock outcrops and the depth of water wells in the area indicate that the bedrock topography is probably similar to that of the eastern part of the area.

The bedrock surface as well as the bedrock escarpments show ample evidence of abrasion and moulding by glacial ice.

Doming of the Paleozoic bedrock commonly occurs in the area. This is caused by draping of the Paleozoic bedrock over the irregular Precambrian basement rocks (Winder, 1955; Carson, 1980 a, 1981 a, b, c).

The extremely irregular topography of the Precambrian bedrock is exposed across much of the northern part of the area and in small inliers scattered throughout the remainder of the map area.
DRIFT THICKNESS

The thickest deposits of drift in the area occur in the Oak Ridges and associated sediment masses. In the extreme western portion of the Trenton map-area drift thickness in the Oak Ridges may exceed 200 metres. Sediment thickness through the main mass of the Oak Ridges is on the order of 100 to 120 metres. Drift thickness decreases in the northern and eastern portions of the Oak Ridges although still exceeding 40 to 50 metres.

Sediment thickness decreases rapidly away from the Oak Ridges. North of the Oak Ridges in the Dummer Moraines sediment thickness is normally less than 10 metres and commonly less than 1 metre.

East and south of the Oak Ridges drift thickness exceeds 1 metre only in isolated drumlins, bedrock valleys and local bedrock depressions. Notable exceptions to this are the sediment accumulations at the heads of West Lake and Hay Bay.
BEDROCK GEOLOGY

Bedrock in this area consists primarily of middle Ordovician limestones of the Simcoe Group which overlie Precambrian metasediments and metavolcanics of the Grenville Province. Small outliers of the Potsdam Sandstone (possible Cambrian age) have been noted in the extreme northeastern portion of the area. Precambrian exposures are limited to the extreme northern edge of the map area and to several small, scattered inliers.

The Paleozoic bedrock of this area has been described in detail by Winder (1955) and Liberty (1960 a, b, 1963 and 1971) and later updated by Carson (1980 a, b, 1981 a, b, c, and 1982).

Exposures of bedrock are extensive through the northern, middle and eastern portions of the area but are sparse in the southwest due to the presence of thick drift in this area.
Phanerozoic

Paleozoic
Middle Ordovician

Simcoe Group
Lindsay Formation
Verulam Formation
Bobcaygeon Formation
Gull River Formation
Shadow Lake Formation

Landforms

A wealth of glacial landforms are present mainly in the western portion of the map area (maps 1, 2, 3, 4, and 5). Drumlin are the most striking and rugged features, most of them occurring in the Peterborough Upland field (Chapman and Putnam, 1966). They range in size from small mounds to several tens of metres in length. They are oriented in an easterly direction and are often aligned in festoon-like ridges which attain several kilometres in length (Plate 1).

Unconformity

Cambrian?

Potsdam Formation

Unconformity

Precambrian

Late Precambrian

Grenville Province

FIGURE 3. Bedrock Geology

The only end moraine identified in the area trends from the south slope of the Oak Ridges northwest approximately half
Figure 3. Bedrock Geology

ROCK UNITS

Middle Ordovician
Simece Group
Lindsay Formation
Verulam Formation
Bactrachon Formation
Gull River Formation
Shadow Lake Formation

unconformity

Cambrian
Potassum Formation

unconformity

Pre cambrian
Lafe Pre cambrian
Greenville Province
QUATERNARY GEOLOGY

GLACIAL GEOLOGY

The glacial geology of the area is recorded by a variety of surface deposits representing Late Wisconsin glaciation. The Oak Ridges may be cored by older (glacial and/or interglacial) sediments but these have not been seen in exposures.

Landforms

A wealth of glacial landforms are present mainly in the western portion of the map area (maps 1, 2, 3, 4 and 5). Drumlins are the most striking and prolific features, most of them occurring in the Peterborough Drumlin Field (Chapman and Putnam, 1966). They range in size from drumlinoid ridges several tens of metres in length to coalesced and en echelon forms which attain several kilometres in length (Plate 1).

The Oak Ridges is the largest feature of the area rising 237 metres above the Lake Ontario level and to 180 metres above the surrounding land. This feature occupies the west central portion of the map area (map 8).

The ice disintegration topography of the Dummer Moraines (Chapman and Putnam, 1966) is present through much of the northern 1/3 of the map area (maps 1, 3 and 6, and map 8). The relief of the Dummer Moraines ranges from almost zero to occasionally over 10 metres although this is often partially controlled by buried bedrock escarpments (Plate 2).

The only end moraine identified in the area trends from the south slope of the Oak Ridges northeast approximately half
way across the map area (map 8). This moraine has intermittent topographic expression, the maximum relief of approximately 10 metres occurring at Matson Lake 1.5 kilometres northeast of Brighton (map 2 and map 8).

Eskers of varying size and length occur throughout the map area (Plate 3). The longest and most well formed eskers were observed through the western and northwestern portions of the map area (maps 1, 2 and 3). Many of the esker ridges extend out of the map area to the north and west.

A number of ice contact deltas and outwash fans are well developed in the western portion of the map area (map 1 and 2). These features are usually hummocks and occasionally kettled. The outwash fans are usually associated with eskers and the ice contact deltas have steep ice contact faces occurring on their northeast flanks.

The major area of outwash occurs on the surface of the Oak Ridges and represents the eastern terminus of the Oak Ridges Interlobate Moraine (Chapman and Putnam, 1966) (map 2).

Many of the bedrock escarpments and valleys of the area have been moulded by glacial ice which resulted in streamlined bedrock forms such as the large rock drumlin south of the Bay of Quinte on map 2 and the scalloped escarpment edge through Ameliasburgh and Mountain View shown on map 4.
Stratigraphy

The oldest sediments of the area are buried within the Oak Ridges and related sediment masses (map 8). These sediments are overlain by deposits of both the northern and Lake Ontario ice lobes. The northwestern part of the area was affected by the northern ice lobe while the southwest was under the influence of the coalesced lobes and a late advance of the Lake Ontario lobe. The late advance of the Lake Ontario lobe partially reworked glacial and glaciolacustrine sediments and further abraded the bedrock. With the exception of the Oak Ridges Interlobate Moraine most proglacial sediments were deposited into glacial lakes. These sediments combined with sediments eroded from glaciolacustrine shorelines mantle much of the glacial deposits in the western part of the area and some of the bedrock in the east.

The till of the Dummer Moraines forms a continuum with the heavily drumlinized till of both the northern and Lake Ontario ice lobes.
Glacial Abrasion

Glacial striae and groove marks are preserved mainly beneath fine grained sediments (clay or till) which protected the bedrock from subaerial erosion and percolation of ground waters. Glacial striae are well preserved through the central and eastern portions of the map area (map 8) and grooves with up to 1/2 metre of relief can be observed along the 401 highway between Napanee and Kingston.

Grooves and cross-cutting striae are evidence of at least two directions of ice movement within the area (Plates 4 and 5). The first set of striae parallel drumlin orientation. In the northwestern portion of the area ice movement was to the south and curved southwest in the southern and eastern portions of the map area. Overall ice movement was into the Lake Ontario basin. In the south and east cross-cutting striae indicate a second, late ice movement from the St. Lawrence river valley which spread northwestwards from the Lake Ontario basin.

Glacial modification of bedrock escarpments was extensive and resulted in streamlined and scalloped forms described earlier in the landforms section.
Older Drift

The oldest deposits of the area lie buried within the Oak Ridges (map 8). Water well data show the presence of over 100 metres of sediment within the body of the mass. This figure added to local relief suggests that the actual thickness including the capping interlobate moraine may exceed 200 metres in the western extreme of the Trenton map area (map 2). Water well data also show the presence of a complex stratigraphy consisting of clays, silts, sands, gravels and tills of varying relationships through the portion of the deposit present in the map area.

Similar deposits have been identified in water well records of sediment masses separate from the main body of the Oak Ridges (map 8). These masses of sediment extend north to Hastings and the Campbellford Airfield (map 1) and northeast to Pancake Hill (map 3).

Stratigraphic drilling at the Campbellford Airfield and the South Slope of the Oak Ridges (map 8, figures 4, 5 and 6) illustrates the complexity and variety of sediments present.
FIGURE 4. BH-I, Smithfield

FIGURE 5. BH-II, Experimental Farm

massive clayey-silt till, grey-brown near surface, dark grey at depth

massive to weak contorted beds of fine to very fine sand and silt, light brown to medium grey, thin beds of clayey-silt till near top

massive fine to very fine sand, light grey

laminated to rhythmically bedded (varved) silt and clay, medium to dark grey

massive clayey-silt till, dark grey

-- approximate contact sampled at 5 to 10 foot intervals

rhythmically bedded (varved) silt and clay, couplets 7 to 10 cm thick near top, thin to 0.5 cm at base

end of hole

end of hole

approximate contact sampled at 5 to 10 foot intervals
FIGURE 5. BH-III, Experimental Farm

massive sandy-silt till, grey-brown near surface, dark grey at depth

massive, medium sand, medium brown

massive to weak contorted beds of fine to very fine sand and silt, light brown to medium grey, thin beds of clayey-silt till near top

interbedded massive to finely bedded sand and silt and clay

laminated to rhythmically bedded (varved) silt and clay, medium to dark grey

massive clayey-silt till, dark grey

end of hole

sandy stony till, dark grey

end of hole

--- approximate contact sampled at 5 to 10 foot intervals
Four tills have been identified in the area. Three of the tills, the early till of the Lake Ontario ice lobe, the till of the Peterborough Drumlin Field and the till of the Dummer Moraine, form a continuum and are facies of one another. The first two tills (map unit 3) were deposited during incursion of the Lake Ontario and northern ice lobes and during earlier deglaciation. Their field characteristics are similar and they will be discussed together.

The third till, the late till of the Lake Ontario ice lobe, advanced out of the Lake Ontario basin. Although this till is often present in the Drumlinic deposits identified on map 8 it has not been given a separate designation in the geological maps.

For discussion purposes the till of the Drumlainised lobe will be referred to as the Drumlinised till. The till of the Dummer Moraines as the Dummer till and the till of the Late Lake Ontario ice advance as the Wellbridge till.

--- approximate contact sampled at 5 to 10 foot intervals
Till

Four tills have been identified in the area. Three of the tills, the early till of the Lake Ontario ice lobe, the till of the Peterborough Drumlin Field and the till of the Dummer Moraines, form a continuum and are facies of one another. The first two tills (map unit 3) were deposited during coalescence of the Lake Ontario and northern ice lobes and during initial deglaciation. Their field characteristics are similar and they will be discussed together.

The fourth till, the late till of the Lake Ontario ice lobe, formed as ice advanced out of the Lake Ontario basin. Although this till is often present in the morainic deposits identified on map 8 it has not been given a separate designation on the geological maps.

For discussion purposes the till of the coalesced ice lobes will be referred to as the Drumlinized till, the till of the Dummer Moraines as the Dummer till and the till of the late Lake Ontario ice advance as the Wallbridge till.
Drumlinized Till

This is the most common and extensive till of the map area (map unit 3). It is moderately stony with a Paleozoic clast content ranging from 88 to 98 percent in the west to 69 to 88 percent in the east and an overall average of 89 percent. The Paleozoic clast content drops to near zero in scattered deposits on the Precambrian Shield. Paleozoic boulder content is high in the north but drops significantly to the south. The matrix is composed of silty-sand to sandy-silt with low clay content (figure 7). The till is generally massive with well developed sub-horizontal fissility (Plate 6). Lenses and discontinuous beds of variably sorted sands and gravels are not usually present but where observed are moderately abundant through the section.

This till is exposed in, or underlies sediments of, the southern portion of the Campbellford (map 1), most of the Trenton (map 2), the southwest portion of the Tweed (map 3) and the northwest portion of the Belleville (map 4) map sheets. It is present in drumlins and till 'sheets' of limited extent through the remainder of the area. Additionally there are substantial occurrences at the heads of some of the larger bays on Lake Ontario and the Bay of Quinte.

Throughout the area much of the till is overlain by glaciolacustrine sediments with only the drumlin crests exposed.

Water well data indicate that many of the drumlins on the Oak Ridges, although mantled by till, may be cored by older sediments. These sediments have probably been moulded into drumlin forms and the till deposited on top or intruded
into the drumlin core.

The pre-existing sediments of the Oak Ridges appear to have had little effect on the characteristics of the overlying till. Local variations in the till matrix were noted but overall the characteristics of the till remained similar.

To the north this till apparently grades into the Dummer till. This relationship will be more fully described in the Dummer Till section.
Dummer Till

The Dummer till (map unit 4) most commonly occurs in hummocky deposits south of the Precambrian-Paleozoic rock contact. Several deposits do occur, however, north of the contact on Paleozoic outliers (P. Finmore, pers. com.). Hummocky deposits of the till may first appear immediately south of the Precambrian-Paleozoic rock contact or several hundreds of metres south of it.

The Dummer till also occurs in near-surface drumlin deposits and in these cases is difficult to distinguish from bedrock with a boulder litter on the surface.

Dummer till is generally very stony with stone size and lithology reflecting the bedding thickness, jointing and lithology of the underlying bedrock (figures 7 and 8). Paleozoic pebble content ranges from 65 to 100 percent with an average of 97 percent. The lithology of the boulders is almost entirely Paleozoic.

Overall the matrix of the Dummer till has a similar grain size distribution as the Drumlinized till (figure 7) and often shows a similar degree of overconsolidation although fissility is poorly developed. More commonly the matrix is unconsolidated as the deposits are often thin supported.

FIGURE 7. Textural diagram for map area tills
Laboratory analyses by sieve and hydrometere
Dummer Till

The Dummer till (map unit 4) most commonly occurs in hummocky deposits south of the Precambrian-Paleozoic rock contact. Several deposits do occur, however, north of the contact on Paleozoic outliers (P. Finamore, pers. com.). Hummocky deposits of the till may first appear immediately south of the Precambrian-Paleozoic rock contact or several hundreds of metres south of it.

The Dummer till also occurs in nearly flat lying deposits and in these cases is difficult to distinguish from bedrock with a boulder litter on the surface.

Dummer till is generally very stony with stone size and lithology reflecting the bedding thickness, jointing and lithology of the underlying bedrock (Plates 7 and 8). Paleozoic pebble content ranges from 43 to 100 percent with an average of 97 percent. The lithology of the boulders is almost entirely Paleozoic.

Overall the matrix of the Dummer till has a similar grain size distribution as the Drumlínized till (figure 7) and often shows a similar degree of overconsolidation although fissility is poorly developed. More commonly the matrix is unconsolidated as the deposits are often clast supported.

The stratigraphic relationship between consolidated and unconsolidated facies of the till is not consistent. In section one facies may be present without the other, they may overlie one another, be interbedded, or one facies may occur as blebs in the other. The contact between the facies appears graded although this is usually indistinct due to the coarse
nature of the sediments.

A number of drumlins and drumlinoïd ridges occur within the Dummer Moraines. Rare sections in these landforms expose till similar to the drumlínized till but commonly containing an unusually high number of subangular Paleozoic rock fragments especially near the base of the section.

Few striae were observed in the Dummer till area but where present in the northwest paralleled drumlin orientation (map 8). Several areas of striations and fluting in the central part of the map area parallel the late advance of the Lake Ontario ice lobe and will be discussed later.

Esker ridges present in the area of Dummer till appear unmodified although in the area of Lime Lake (map 3) hummocks of Dummer till were observed to lie upon the esker flank.

Dummer till often appears in the form of linear ridges and although these ridges are often locally aligned there is no overall consistency or relationship to ice flow direction.

Dummer till occasionally grades into outwash sands and gravels which usually share the hummocky appearance of the till.
Wallbridge Till

Early deposits of the Lake Ontario ice lobe are preserved in the Quinte Drumlin Field (Mirynech, 1962). Descriptions of this till have been included with the drumlinized till.

Intermittently exposed ice marginal deposits from a late advance of the Lake Ontario ice lobe occur in a broad band from just east of Brighton to southeast of Halston (map 8). The following includes brief descriptions of observed morainic deposits.

Large ice contact deltas occur 2 kilometres east-northeast of Brighton and 1 to 2 kilometres west of Wallbridge. Pits in these deposits display large foreset bedding (plate 9) dipping northwest.

In a small road cut 1.5 kilometres west of Trenton 3 metres of contorted lacustrine sediments were observed. Recumbent folding and shear structures in these sediments indicate ice push from the south-southeast (plate 10).

One area of morainic deposits 6 kilometres northeast of Trenton contains coarse hummocky flow and lodgement tills overlying ice contact sands and gravels and overlain by varved silts and clays (plate 11). 2.5 kilometres west-northwest of this site fragments of laminated lacustrine sediment were observed in a fine-grained till-like deposit plastered against the southeast flank of a drumlin (plate 12). A small morainic ridge observed 1.5 kilometres south-east of Wallbridge is composed partly of clayey-silt till. The stratigraphic drill log of this deposit is shown in figure 8 and located on map 8.
Morainic deposits in a series of pits 2.5 kilometres southeast of Halston contain a series of flow and lodgement tills mixed with ice contact and outwash gravels over a series of lacustrine silts and sands. The upper tills of this deposit contain large blocks of Paleozoic rock reworked from the Dummer till of the area (plate 13).

The morainic deposits of the Lake Ontario lobe become 'lost' in the hummocky Dummer till topography further to the northeast. Striae from the late ice advance continue as far as Roblin, 21 kilometres to the east-northeast.

Water well data indicate complex subsurface stratigraphy along the morainic zone marked on map 8. The sediments in this zone are composed mainly of till, sand and gravel and are mantled by glaciolacustrine sands, silts and clays.
FIGURE 8. BH-IV, Wallbridge

Ice contact sands and gravels (map unit 5) occur in scarps, ice contact deltas, lee and stoss ends of drumlin and
ridge ridges, ice contact deltas, lee and stoss ends of drumline and
sediment masses, bedrock valleys and against bedrock escarpments. Large eskers containing sand and gravels occur in the
moraine deposits described in the previous section.

Large eskers occurring at Norwood, Campbellford, Stirling
(map 1), Frankford, Trenton (map 2), Pictou, Marjehawk (map 3),
Pictou and Cherry Valley (map 5) are bored by current, usually
faulted and distorted, beds of sand and gravel. The eskers
are of bedrock or those faulted by large deposits of outwash and,
rarely, of the Precambrian. Pebble percentages in eskers rise
from near zero in the Precambrian Shield to 50 to 75 percent
over Paleozoic bedrock.

Ice contact deltas in the Trenton area (map 7) contain
folded and faulted mixtures of till and gravel to their ice
contact faces. The remainder of these deposits are composed
primarily of sandy outwash.

Small kames occur in association with easter ridges and
the lee or stoss ends of drumlins and sediment masses. The
kame at Glen Ross (map 1, plate 14) is a good example of this
type of deposit.

Small deposits of ice contact sediments occur in the
Magog and Salmon River valleys (map 4 and 6) and along the
front of bedrock escarpments, for example 1 kilometer west of
Dumfriesville on map 4.

-----approximate contact
sampled at 5 to 10 foot intervals
Approximate contact
sampled at 5 to 10 foot intervals
Ice Contact Deposits

Ice contact sands and gravels (map unit 5) occur in esker ridges, ice contact deltas, lee and stoss ends of drumlins and sediment masses, bedrock valleys and against bedrock escarpments. Large amounts of ice contact sands and gravels occur in the morainic deposits described in the previous section.

Large eskers occurring at Norwood, Campellford, Stirling (map 1), Frankford, Trenton (map 2), Tweed, Marlbank (map 3), Picton and Cherry Valley (map 5) are cored by coarse, usually faulted and distorted, beds of sands and gravels. The eskers are often mantled and flanked by large deposits of outwash and, rarely, till. Paleozoic pebble percentages in eskers rise from near zero in the Precambrian Shield to 60 to 99 percent over Paleozoic bedrock.

Ice contact deltas in the Trenton area (map 2) contain folded and faulted mixtures of till and gravel in their ice contact faces. The remainder of these deposits are composed primarily of sandy outwash.

Small kames occur in association with esker ridges and on the lee or stoss ends of drumlins and sediment masses. The kame at Glen Ross (map 1, plate 14) is a good example of this type of deposit.

Small deposits of ice contact sediments occur in the Napanee and Salmon River valleys (map 4 and 6) and along the faces of bedrock escarpments, for example 1 kilometre west of Demorestville on map 4.
Proximal and Distal Outwash

Outwash sands and gravels (map units 6a and 6b) occur in deposits of substantial size throughout most of the map area. The largest deposit is the eastern termination of the Oak Ridges Interlobate Moraine at the west end of the Trenton map area (map 2). The thickness of this deposit is not known in this area but the presence of drumlins and local relief indicate that the sediments probably do not exceed 30 to 35 metres in thickness.

Outwash deposits below the level of the Oak Ridges Interlobate Moraine were deposited into proglacial lakes and as a consequence are mostly sandy in character, most coarse material having been 'dumped' at the glacier snout. Numerous exposures in outwash display interbeds of glaciolacustrine sediments and occasionally flow tills (plate 15).

With the exception of a few cases where the outwash built up above the proglacial lake level, most of the outwash deposits are smooth topped as a result of being deposited subaquously. One exception to this is the outwash at Stirling (map 1) which is also partially mantled by lacustrine clays attaining over 10 metres in thickness.

Outwash occurs in ice contact deltas in the Trenton map area (map 2), in fans and flanking deposits associated with eskers (maps 1, 2, 3, 4 and 5), in large plains to the north where it was largely reworked by glaciolacustrine activity (maps 1, 3 and 6), and along the Wilton Creek and Napanee River valleys (map 6).
GLACIOLACUSTRINE GEOLOGY

During the retreat of glacial ice from the area the ice front was a shoreline for lake phases which inundated all but a small portion of the map area. The western portion of the map area is partly dominated by large deposits of nearshore sediments and erosional bluffs of glacial Lake Iroquois. The major glaciolacustrine features of the area were previously described by Coleman (1937 a), detailed descriptions were later given by Mirynech (1962). A brief synopsis of the major features is given below.
DISTRIBUTION OF GLACIOLACUSTRINE FEATURES

Raised Shoreline Deposits (map units 9 a and b)

The highest (and earliest) glaciolacustrine sediments of the area occur in the extreme western part of the region and attain an elevation of approximately 229 metres (750 feet) above sea level. Sandy deposits of this lake mantle portions of the Oak Ridges beginning at the perimetre of the Oak Ridges Interlobate Moraine and extending down at least to the Lake Iroquois shoreline (map 2). No shoreline deposits were developed by this lake.

Shoreline deposits of glacial Lake Iroquois have been traced through the western portion of the map area at elevations of between ca. 183 and 198 metres (600 and 650 feet). These shoreline deposits extend off the map area to the west and are found as far east as Pancake Hill (map 3) which is washed to ca. 229 metres (750 feet). Land elevations through the remainder of the area were too low for Iroquois shoreline development.

The shoreline features of glacial Lake Iroquois consist mainly of: large erosional bluffs, large terraces which are often boulder littered (plate 16), spits, baymouth and offshore bars, tombolos and gravels deposited on the northwest side of wave-planed uplands. Developments of these features is in a northwest direction indicating that prevailing storms came from the southwest.

Glacial Lake Iroquois shoreline features are most strongly developed on the south flank of the Oak Ridges sediment mass. Development of the Iroquois shoreline is
progressively less northward for three reasons: 1. because the lake followed the ice northwards less time was available for shoreline development; 2. as more land was exposed by the ice the glacial lake's northern shoreline was protected by islands and what was then the Oak Ridges peninsula; and 3. due to uplift during the period of ice retreat. The major offshore shoals and islands of glacial Lake Iroquois were: Pancake Hill (map 3), the Oak Hills (maps 1, 2 and 3), Pyears Hill (map 1), Sullivans Hill (maps 1 and 2) and the uplands east of Campbellford (map 1) and south and southeast of Murray Marsh (map 2).

Glacial Lake Iroquois shoreline sediments are generally coarse, being composed of well rounded gravels and some sands. Sedimentary structures in these deposits range from plane and ripple laminated beds to trough cross-bedding and 2 to 3 metre foresets in spits and bars (plate 17 and 18).

The post glacial Lake Iroquois series of glacial lake raised shorelines are: Frontenac, Sydney, Belleville and Trenton (Mirynech, 1962). The beach deposits of these glacial lake stages are poorly developed and discontinuous. Traces of the Sydney lake stage were not identified in this study. Sediments along the Trent River valley formerly correlated with this lake stage (Mirynech, 1962) have been re-interpreted mainly as older fluvial deposits related to the draining of glacial Lake Alqonquin.

The percentage of Paleozoic pebbles in raised beach sediments ranges from 48 percent near the Precambrian-Paleozoic rock contact and 81 to 96 percent in areas of reworked glacial
sediments, to 100 percent on the bedrock plains of Prince Edward County.
Nearshore Deposits (map unit 8)

Plane bedded and ripple laminated medium and fine sands occur in extensive deposits through the southwest portion of the map area. Much of these sands were supplied to offshore areas from the shore bluffs of glacial Lake Iroquois. A large portion of this sediment was also provided by glacial meltwater, especially in the area of the Oak Ridges Interlobate Moraine, near esker ridges and in the northern portion of map 1.

Extensive sand deposits are not found associated with the poorly developed raised shorelines in the eastern part of the map area.
Offshore Deposits (map unit 7)

Glaciolacustrine deep water silts and clays are most extensive through the southwestern map areas. These sediments probably originated from shoreline erosion and meltwaters. The presence of extensive varved or varve-like deposits suggests a large input of fines from the glacier.

These deposits are more extensive than the nearshore sands and are present in patches across the map area. Silt and clay deposits locally attain over 10 metres in thickness in the southwest and occasionally in bedrock valleys in the east.

Two specific areas where thick deposits of silty-clay were observed were: 3 kilometres north-northeast of Stirling (map 1) where more than 10.3 metres of silt and clay were logged in a borehole; and 1.5 kilometres north of Kingston (map 6) where relief in a hummocky clay plain exceeds 6 metres. Several exposures in the Trenton map area (map 2) exhibited silts and clays of comparable thickness.

In areas of limestone plains the silt and clay deposits are usually on the order of 1 metre in thickness.
Older Fluvial Deposits (map unit 11)

Old fluvial bars along the Trent River system are associated with high level terracing and major abandoned or misfit stream valleys (maps 1, 2 and 8).

Ancient bars of well to very poorly sorted gravels occur along the ancient river bed, around channel obstructions (usually terraced drumlins) and built out from the abandoned river shore.

One large deposit occurs at Hastings (map 1) but most older fluvial sediments are present below Meyersburgh (map 2) and best developed between Frankford and Trenton (plate 19).

In addition to erosion along the Trent River valley, a major abandoned channel passes through Godolphin between Hastings and Campbellford (map 1) and another is now occupied by the lower reaches of Cold Creek which flows into the Trent River at Frankford (map 2).

Large abandoned channels along the lower reaches of the Moira River (map 4) are related to post-glacial channel migration and intermittent flooding.
Eolian Deposits (map unit 10)

Small areas of dune development are present at the east edge of the Murray Marsh (map 2), at Wallbridge (map 4), east of Waupoos East (map 7) and below South Bay in Prince Edward Peninsula (map 5). These deposits are generally composed of fine to very fine sand and are presently stabilized.

Extensive but thin deposits of windblown sands mantle portions of the glaciolacustrine sands of the area. These deposits are difficult to recognize because they are usually only several centimetres thick and highly modified by soil development and frost action.
POST GLACIAL GEOLOGY

Crustal Rebound

Detailed shoreline elevation measurements by Coleman (1937) and Mirynech (1962) indicate that maximum differential crustal uplift following deglaciation occurred in the direction N20 E. Present tilt of the raised shorelines in the area is approximately 0.7 metres per kilometer. Calculations by Kite (1972) indicate that at present maximum uplift is occurring in the direction N33 E and is taking place at a rate of 0.89 centimetres per 100 years in the western extreme of the map area and at 1.68 centimetres per 100 years at Kingston.
Organic Deposits (map unit 12)

Organic deposits are common throughout the map area. Peat occurs in small depressions and along stream and river valleys in areas of both thick drift and extensive bedrock plains.

The largest and thickest deposits of peaty material occur in The Big Swamp and The Little Swamp (map 4). Thickness of organic deposits in these swamps can reach several metres (J. Terasmae, pers. comm.).

A potential area of thick organic deposits is Murray Marsh. Although less than 2 metres of peat was probed, thicker deposits may exist in more inaccessible parts of the marsh.

Large deposits of marl occur in Dry Lake (map 3) and several other marl deposits are present in small lakes throughout the limestone plains.
Alluvium (map unit 13)

Modern alluvium deposits are extensive only in the south-west portion of the map area where streams have been able to cut meandering channels into glacial and glaciolacustrine sediment.

In the limestone plains and areas of thin drift major stream courses follow bedrock valleys. In these valleys alluvial deposits are scattered, restricted mainly to wider parts of the bedrock channels.

Most alluvial deposits are composed of an upward fining sequence grading from gravels at the base to muds (often organic rich) at the surface.
Modern Shoreline Deposits (map units 14 a and b)

A number of well developed beach deposits occur along the Lake Ontario shoreline. The major deposits from west to east are: a large tombolo at Pres'qu'ile, sand bars at Wellers Bay and North Bay (map 2), Pleasant Bay and Hyucks Bay (map 5) and very large bars almost closing off West and East Lakes (map 5).

Large sand dunes are built over and behind most major shoreline deposits. Portions of these dunes have been stabilized by the natural incursion of vegetation. Other parts of these bars are presently being stabilized by vegetation introduced by man.

Lakeshore bluffs and pebbly beach deposits have formed where drift and in some cases where bedrock meets the Lake Ontario shore. Large bluffs in drift occur mainly in the western part of the area. Bedrock bluffs and flaggy beach deposits are present along portions of the Lake Ontario shore of Prince Edward County (maps 2, 5 and 7).

The largest beach bluff observed occurs on the west shore of Amherst Bay on Amherst Island. At this location a drumlin has been cut in half lengthwise by wave action creating a bluff approximately 15 metres in height (map 7).
DEGLACIATION HISTORY

OLDER EVENTS

Exposed sediments in the map area record only events of late Wisconsin or younger age. Sediments buried in the Oak Ridges and related masses of surficial deposits, however, may record events dating back to even pre-Wisconsin time.

The sheer bulk and complexity of sediments buried in the Oak Ridges is indication of a protracted series of depositional events probably combined with intervening periods of substantial erosion.

Faulkner's water well drilling company of Peterborough retrieved fragments of wood from below 46 metres (150 feet) of sediment approximately 1 kilometre southeast of Cedar Creek (personal communication from property owner). The presence of wood fragments in the Oak Ridges is a clear indication of non-glacial conditions during at least one period of time during deposition.

Stratigraphic drilling, the results of which are presented in figures 4, 5 and 6 and located on map 8, show only sediments of glacial or periglacial origin in the upper part of the Oak Ridges and related sediment masses. These sediments have a complex stratigraphy making it difficult to correlate stratigraphic units between drill holes. It is also impossible to determine the age of the sediments immediately below the upper till.
DEGLACIATION

All field indications are that the late Wisconsin ice retreated from the area with no significant fluctuations or re-advances except for the late activity of the Lake Ontario ice lobe. Evidence of this late advance is confined to the southeastern portion of the map area (map 8).

Recent reviews and compilations which include the glacial history of this area often show a question mark or speculative ice margin isochrons in this area during deglaciation. Denton and Hughes (1981) for example have ice margin isochrons stop as they enter this area. A similar problem was found by Dreimanis (1977 a and b) and discussed by Terasmae (1980). Where authors have drawn ice marginal positions (Prest, 1970) these positions are uncertain and in some cases (example Gadd, 1980) have not met with general acceptance.

The major reason why it is difficult to define ice marginal positions in this area is that there are (with the exception of the Lake Ontario ice lobe) no major end moraines. Also there is no conclusive evidence of multiple tills in the northwest with the exception of older sediment buried in the Oak Ridges.

Several ice contact deltas and outwash fans on the Oak Ridges mark brief stands during the retreat of the northern ice but are not laterally correlatable nor are they traceable to other ice marginal deposits.

As the ice began to retreat from the area the top of the Oak Ridges was the first land to be exposed. As the northern
and Lake Ontario ice lobes retreated, large amounts of interlobate sands and gravels were deposited subaerially on the Oak Ridges (Gwyn and Cowan; 1978, Duckworth; 1979, Gravenor, 1957). As further retreat took place a high level glacial lake encroached upon the area between the interlobate deposits and the ice front. From this point on outwash debouched into the glacial lake and was dispersed in water. For this reason the eastern terminus of the Oak Ridges Interlobate Moraine is indistinct below the elevation of approximately 229 metres (750 feet). This was the highest elevation reached by glacial lake waters that inundated the area.

The development of the drumlins in the area of the interlobate moraine must have taken place earlier before initial deglaciation, when the coalesced northern and Lake Ontario ice lobes flowed into the Lake Ontario basin. There is no significant change in drumlin orientation or morphology on the north and south sides of the moraine.

Retreat of the northern lobe continued uninterrupted through the north part of the area. The retreating Lake Ontario lobe, however, underwent a readvance after the northern ice had retreated to some point north of the southern limit of the Dummer till.

Cross-cutting striae and flutings through the south and southeast portions of the area (map 8) give a clear indication of the direction of flow of the Lake Ontario ice lobe out of the Lake Ontario basin from the direction of the St. Lawrence River. Ice marginal deposits from the maximum of this late advance can be relatively continuously traced from Brighton
(map 2) to just southeast of Halston (map 3) through surface exposures and water well records. These ice marginal deposits contain sediments reworked from the Dummer till indicating that the northern ice had already deposited at least the southern part of this till.

Several explanations are possible to account for the late advance of the Lake Ontario ice lobe, the more plausible of these are briefly detailed below:

1) Retreat of the northern ice removing the ice 'dam' which had previously prevented the Lake Ontario ice lobe from expanding to the north.

2) Regional glacial resurgence but delayed advance of the Lake Ontario ice lobe as the ice front was much further from the accumulation zone. In this case the Lake Ontario lobe could be advancing during general regional ice retreat.

3) Independent advance or surge of the Lake Ontario ice lobe.

4) Sufficient thinning of the ice in the Lake Ontario basin for the ice to float in the glacial lake then present. Basal friction would then be minimal, the ice mass would expand into an ice shelf grounded at the edges. Southeast winds would help push this ice shelf against the north shore.

Possibilities 1 and 3 are impossible to evaluate in terms of the glacial sediment record although an independent advance of the Lake Ontario ice lobe seems unlikely.

Explanation number 2 also seems unlikely as there is no comparable end moraine from the northern ice in this area or
for some distance to the north (Henderson, 1973).

Possibility number 4 is also improbable as an ice shelf would not be able to 'feed' the sediments to the ice margin which were necessary to build the ice marginal deltas west of Brighton and southwest of Wallbridge. Also, striae show the ice advancing from the direction of the St. Lawrence River not as a mass spreading out from the centre of the basin.

It seems that the ice in the Lake Ontario basin was being fed from the east and was actively advancing along the basin margin.

Prior to the advance of the Lake Ontario ice lobe, deposition of the Dummer till was initiated.

Field and grain size relationships between drumlinized till and Dummer till described earlier and shown in figure 7 indicate a close relationship between the tills.

Several sections cut into the sediments in the area of Dummer till illustrate the type of mechanism which may be responsible for the formation of the deposit. One section on Highway 41 0.5 kilometres south of Roblindale (map 3, plate 20) exposes approximately 8 metres of rock which has been disturbed by glacial action. Beds of rock can be traced almost the full length of the section, and the stratigraphy of the rock beds is normal in relation to the bedrock of the area (B. A. Liberty, pers. comm.). Fractures and bedding planes in the rock are, however, filled with silty-sand till containing the occasional Precambrian pebble. This 'injection' of till has taken place through at least the upper 6 metres
of the section and evidence of similar processes have been noted elsewhere in the map area. Continuation of the process responsible for the 'injection' of the till into the rock would result in a jumbled mass of angular rock fragments with a 'foreign' till matrix. This would account for the overall similarity of the matrices of the drumlinized till and the Dummer till. It would also account for the mixture of lodgement till and loose Dummer till observed in numerous sections.

Sandy facies of the Dummer till were probably produced by 'washing' of portions of the deposit by proglacial and subglacial meltwaters. This is supported by the occasionally observed grading of Dummer till into small outwash deposits.

This 'injection' process would account for the similarity of the rock fragments found in the Dummer till to the immediately underlying bedrock.

The processes involved in the formation of the Dummer till were probably initiated by changes in the ice physics as the thinning glacier crossed the Precambrian–Paleozoic rock boundary just prior to deglaciation of the area.

Explained in the above fashion the Dummer till and the drumlinized till occur as facies of the same till sheet as proposed by Finamore (1982). The lodgement till was deposited by active ice and the Dummer till as a mixture of lodgement till and material melted out of the ice as the glacier retreated.

Processes involved in the formation of the Dummer till could probably be better explained by geologists well versed in ice physics.
Esker ridges were deposited subaqueously as the ice retreated from the area. Most of the subglacial drainage channels followed pre-existing topographic lows such as bedrock valleys, resulting in esker ridges deposited at an angle to ice movement and retreat.

Many of the outwash deposits of the area were probably partially deposited as a result of subaquatic density flows flowing southwards down bedrock valleys.

The origin of extensive (more than 1 kilometre) but thin (up to 10 centimetre) diamicton beds over at least 24 metres of ripple laminated and trough cross-bedded outwash sands in the Wilton Creek valley south of Wilton (map 6) is problematical. The fine grained nature and thickness of the underlying deposits give no indication of proximal ice as a source for the diamictons. Sediments slumping from the surrounding valley walls would not account for the extent of the diamictons. It is possible that these sediments were supplied as flow tills from the Lake Ontario ice lobe during its last retreat from the area.
GLACIAL LAKES

Glacial lake waters expanded in the area as the ice retreated. The first of these lakes attained a present elevation of approximately 229 metres (750 feet) above sea level and was present in the extreme west. This high level glacial lake probably formed under similar circumstances as did the Schomburg Pondings (Chapman and Putnam, 1966) and may have been an eastern extension of glacial Lake Peterborough (Gravenor, 1957). Drainage from this high level glacial lake must have been west.

Glacial Lake Iroquois existed during deglaciation of the area as shorelines of this lake can be traced off the map area to the north and as far east as Pancake Hill (map 3).

When the ice had retreated far enough to clear the next highest outlet at Covey Hill (Leverett and Taylor, 1915) glacial Lake Frontenac came into existence followed closely by the Sydney (?), Belleville, Trenton and Admiralty phases (Mirynech, 1962). Shoreline elevations have been well documented by Coleman (1937) and Mirynech (1962). Sly and Prior (in preparation) on the basis of seismic and acoustic data in the Lake Ontario basin and upper St. Lawrence River suggest that the low level Admiralty stage existed between the high levels of glacial Lake Iroquois and glacial Lake Frontenac. No such regressive and transgressive sequence was identified in the map area.
LAKE ALGONQUIN DRAINAGE

Ancient fluvial sediments and erosional terraces preserved along the Trent River valley record the occurrence of a flood of waters draining to some point below the present level of Lake Ontario. Mapping of these features has revealed the presence of abandoned channels along the course of the flow (maps 1, 2 and 8) but no deltaic deposits were identified. Possible deltaic deposits which occur in the Rice Lake area to the west (Coleman, 1937 a; Gravenor, 1957) may be related to an early drainage of glacial Lake Algonquin prior to the main flood.

The area of Murray Marsh (map 2) may have been a lake at the time of the drainage of glacial Lake Algonquin and as such may have acted as a catchment basin for much of the material eroded upstream. Subsurface drilling in this area would be necessary to confirm this possibility.
CHRONOLOGY OF EVENTS

The relative chronology of events has been presented in the previous discussions. The detailed radiocarbon chronology of the area has recently been discussed by Terasmae (1980) and included in an extensive regional correlation by Fullerton (1980). The following discussion is based on data presented by the above two authors.

Glacial ice probably covered the map area through late Wisconsin until the Two Creeks Interstadial. Deglaciation during the Two Creeks Interstadial occurred between 12,500 and 11,500 years BP (Terasmae, 1980). Ice left the map area probably between 12,500 and 11,800 years BP, just before glacial Lake Iroquois drained to lower levels. The Correlation study by Fullerton (1980) shows the drainage of glacial Lake Algonquin through the Kirkfield-Fenelon Falls outlet occurred between approximately 11,900 and 11,700 years B.P. This fits well with the relative chronology of the area. The short period of time remaining for the existence of glacial lakes between the Iroquois and Admiralty levels is supported by the poor development of intervening shoreline features.

'Old' dates of the Champlain Sea (11,900 ± 160 (GSC-1772), 12,200 ± 160 (GSC-1646), 12,800 ± 220 (GSC-1859) years BP (Fullerton, 1980) do not fit the chronology of the region. The late activity of the Lake Ontario ice lobe which was fed from the east precludes opening of the Ottawa Valley as early as proposed by Gadd (1980).
SUMMARY

The lateral distribution of surface sediments in the map area is commonly changeable and apparently complex. The overall stratigraphy, with the exception of the Oak Ridges, is relatively simple.

Water well data and stratigraphic drilling indicate that the core of the Oak Ridges and related sediment masses contain lacustrine material which is pre-late Wisconsin in age. Up to 30 metres of late Wisconsin glacial and glaciolacustrine sediments cover these earlier deposits.

During late Wisconsin glaciation the ice of the northern lobe and the Lake Ontario lobe were coalesced and moved as one south and west along the Lake Ontario basin. The main ice movement streamlined the bedrock and reworked and streamlined the upper sediments of the Oak Ridges.

During deglaciation the ice lobes separated along the crest of the Oak Ridges. Interlobate sediments were deposited on the surface of the Oak Ridges. These deposits are thick and hummocky in topographically high areas where deposition was subaerial and thinner and smoother in lower areas where deposition was subaqueous.

The northern ice retreated to the north with no evidence of readvance, depositing the Dummer Moraines as a facies of the drumlinized till to the south. The northern lobe also deposited numerous eskers and outwash deposits as it retreated.

The Lake Ontario ice lobe, after retreating to some point
in the eastern end of the Lake Ontario basin, re-advanced and re-covered approximately one-half of the map area. The ice front at the maximum of this re-advance butted against the Oak Ridges in the west and curved northwards in the east. In the northeast the ice marginal sediments become 'lost' in the hummocky Dummer till topography.

The late activity of the Lake Ontario ice lobe indicates that, as the ice was fed from the east, the St. Lawrence Valley, and therefore the Ottawa Valley, were ice filled until later during deglaciation than some radiocarbon shell dates indicate. The incursion of this ice into the north of the map area also indicates that the Dummer till had been deposited before this late advance.

The highest glacial lake level in the area existed at approximately 229 metres (750 feet). This initial glacial lake phase was followed by several lower phases but only well developed raised shorelines were left by glacial Lake Iroquois which occupied the Lake Ontario basin until the St. Lawrence Valley was deglaciated.
Plate 1. View up ice of drumlin in clay flats near Menie, Campbellford map area.

Plate 2. Hummocky topography of Dummer Moraines in Campbellford map area.
Plate 3. Esker ridge at Cedar Creek, Trenton map area.

Plate 4. Cross-cutting striae at Point Anne quarry, Belleville map area.
Plate 5. Streamlined bedrock forms north of Marysville, Belleville map area.

Plate 6. Till in the core of a drumlin, Amherst island, Bath map area.
Plate 7. Cobbly, bouldery Dummer till near Read, Tweed map area.

Plate 8. Pebbly Dummer till near Larkins, Tweed map area.
Plate 9. Ice contact delta foreset beds near Brighton, Trenton map area.

Plate 10. Glaciotectonic contortion of lacustrine sediments near Trenton, Trenton map area.
Plate 11. Ice contact sands and gravels capped by till in morainic deposit west of Trenton, Trenton map area.

Plate 12. Lacustrine clast in till of morainic deposit north of Johnstown, Trenton map area.
Plate 13. Boulders from Dummer till reworked into Lake Ontario lobe morainic deposit southeast of Halston, Tweed map area.

Plate 14. Glen Ross kame, Glen Ross, Campbellford map area.
Plate 15. 'Flow till' bed in extensive sand deposit north of Odessa, Sydenham map area.

Plate 16. Glacial Lake Iroquois bluff and boulder littered terrace near Brighton, Trenton map area.
Plate 17. Glacial Lake Iroquois nearshore sediments in bar complex near Little Lake, Trenton map area.

Plate 18. Sediment structures in glacial Lake Iroquois bar near Warkworth, Trenton map area.
Plate 19. Older, raised river bar north of Trenton, Trenton map area.

Plate 20. Disturbed bedrock south of Roblindale, Tweed map area.
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