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Quaternary Geology of the Durham Area

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ONTARIO GEOLOGICAL SURVEY

Open File Report 5596

Quaternary Geology of the Durham Area

by

D.R. Sharpe

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V.G. Milne, Director
Ontario Geological Survey

ABSTRACT

The Durham area has very large high-quality sand and gravel reserves that are examined in this report. These deposits occur here because of unique conditions and the deposits are of interest economically as well as geologically.

The thickness of glacial drift in the Durham map area is substantial, generally exceeding 30 m and in places it is up to 70 m thick. Some of this is older drift that consists of coarse bouldery sandy silt till deposited by an ice advance from the north. This advance of Catfish Creek ice (Nissouri Stadial) is the origin of most of the aggregate resources in the area, and these aggregates consist of durable carbonate rocks eroded from the area, especially the underlying dolostones of the Guelph Formation. The thinner, younger drifts, Tavistock Till, Elma Till, Neustadt till and associated glaciofluvial and glaciolacustrine sediments are all deposits resulting from re-advances or fluctuations of ice from the northwest as the glacier reworked the older sediments.

The Tavistock Till (Port Bruce Stadial) is a gritty silt to clayey silt till which consists of incorporated

lacustrine sediments deposited in front of Catfish Creek ice as the ice front receded to Holstein, in the northwest.

A minor ice advance to the Maple Lane moraine deposited the Elma Till (late Port Bruce Stadial). This till consists of a loose stoney sandy silt and it is found in the Maple Lane, Singhampton and Gibraltar moraines together with abundant stratified drift. The later two moraines represent lengthy deposition during the recession of Elma ice front and are flanked by extremely large glacial meltwater deposits. In the area northwest of the Singhampton Moraine, Elma Till is difficult to distinguish from Catfish Creek Till and essentially forms one till unit in an area where continuous deposition from Nissouri time through Port Bruce stadial time took place.

A late ice fluctuation or slump in the Saugeen River valley produced the Neustadt diamicton (late Port Bruce Stadial) consisting of reworked lacustrine silt and clay deposits•

Sand and gravel resources of high quality and large quantities occur in two main settings in the area. First, kame terrace outwash deposits form a large portion of the Singhampton and Gibraltar moraines. Second, large braided-channel outwash deposits occur in front of those two

large moraine systems. The quality of these deposits diminishes in the southeast corner of the area where the underlying shale of the Salina Formation contributed soft friable stone to the drift.

By understanding the character of the deposits in Durham, one may plan the most efficient use of the earth resources of some of the most scenic glacial landscape in Ontario.

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of the

DURHAM AREA (NTS 41A/22)

SOUTHERN ONTARIO

by

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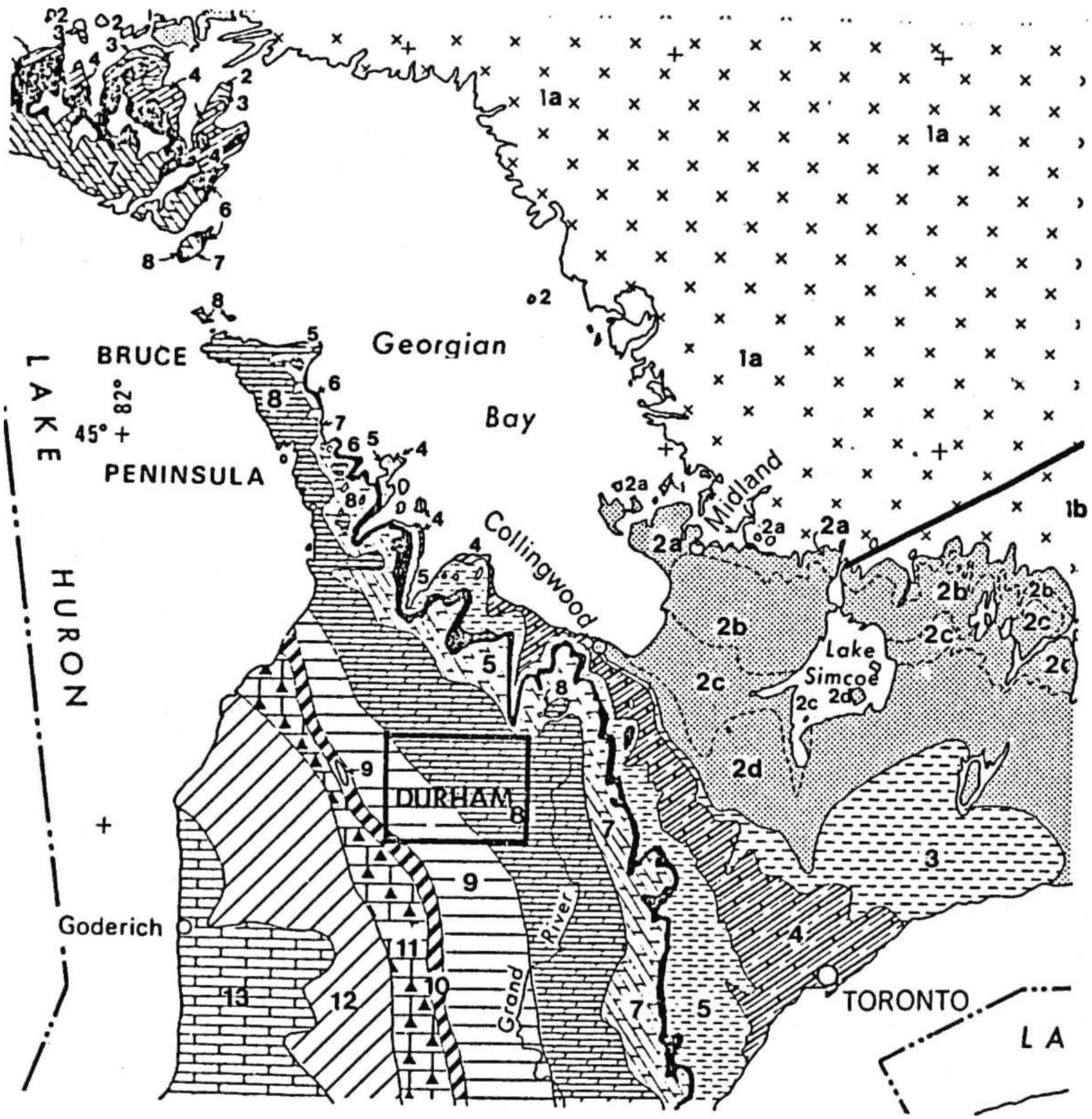


LEGEND

PALEOZOIC

DEVONIAN

13 DUNDEE FORMATION

12 DETROIT RIVER GROUP

SILURIAN

11 BOIS BLANC FORMATION

10 BASS ISLANDS FORMATION

9 SALINA FORMATION

8 GUELPH FORMATION

7 AMABEL FORMATION

6 CLINTON AND CATARACT GROUPS

ORDOVICIAN

5 QUEENSTONE FORMATION

4 GEORGIAN BAY FORMATION

3 WHITBY FORMATION

2 TRENTON AND BLACK RIVER GROUPS

a GULL RIVER FORMATION

b BOBCAYGEON FORMATION

c VERULAM FORMATION

d LINDSAY FORMATION

PRECAMBRIAN

1a WESTERN GRENVILLE

1b EASTERN GRENVILLE

Figure 1. Location Map

0 50 km.

QUATERNARY GEOLOGY
OF THE
DURHAM AREA (NTS 41A/22)
SOUTHERN ONTARIO

by

D.R. Sharpe

INTRODUCTION

Purpose of the Survey

The purpose of mapping the Quaternary geology of an area is: to establish the nature and character of the earth materials; to determine their areal and subsurface distribution; and, to help decipher the geological history of the Province.

This information can then be used by a variety of persons and organisations (such as planners, engineers, hydrologists, conservation authorities, etc.) to effect the best use of the earth resources in the area including the design of structures and facilities thereon. The information obtained in this geological survey may thus be used for the preparation of other special interest or thematic reports and maps.

Location and Access

The Durham area (N.T.S. Sheet 41A/22) is bordered by latitudes 44°00' west and 44°30' north and longitudes 81°00' west and 81°30' west (Figure 1). The area includes parts of Grey County and a very small portion of Wellington County and covers approximately 1100 km^2. Durham, Ayton, Holstein and Priceville are the main population centres.

King's Highway 4 and 6 provide the major road access to the area. The Canadian National Railway and Canadian Pacific Railway have rail lines through the map-sheet.

Present Survey

Field work for this survey began in 1975 and was completed in May 1976. Field information was gathered by examining roadcuts, streambanks, excavations and by hand probing and augering. In total, about 2500 field locations were studied. Power augering provided some subsurface information. Well records and borehole records from engineering firms and government agencies also aided subsurface interpretation. The physical attributes of the soils collected in the field were assessed by laboratory analysis. A preliminary map of the Quaternary geology of Durham preceded this report (Sharpe and Broster, 1977).

Acknowledgements

I thank the many individuals and agencies who assisted in this project. The Water Resources Branch of the Ontario Ministry of Environment and the Highway Engineering Division, Ontario Ministry of Transportation and Communications provided subsurface information and engineering reports. The Geoscience Laboratory of the Ontario Geological Survey conducted laboratory analysis of sample material.

B.E. Broster mapped the area west of Highway 6 in 1975 and W.A.D. Edwards did additional field checking in that area in May, 1976. G.R. Jamieson and S. Boyd provided enthusiastic field assistance in 1975 and M. Hradsky and D.J. Storrison did likewise in May 1976. Ann Naluzay assisted with preparation of the figures. The residents of the study area were very cooperative in allowing access to field sites.

Previous Work

Previous work in the Durham area includes the early general surveys made by W.E. Logan and F.B. Taylor and the physiographic study by Chapman and Putnam (1966).

The importance of Logan's report relates to sand and gravel resources. Logan (1863) outlined the "Artemesia

Gravels'* that include a major portion of the Durham area less a 150 km^ area in central Normanby Township. The "Artemesia Gravel" formation comprises a very large system of sand and gravel deposits fronting the Singhampton-Gibraltar and Paris-Gait moraine (Sharpe, 1975, 1979, Feenstra, 1975).

Logan also discussed the "Saugeen clay", exposed along the Saugeen River. This deposit is thin-bedded and calcareous and overlies the "Erie clay", a clay unit that consists of till, including many striated stones. Along the South Saugeen River near Neustadt about 5 m of "bluish" (unoxidized) clayey deposits with pebbles were found underlying a similar thickness of gravel. More Erie deposits (about 5 m of oxidized clay) are exposed along the South Saugeen River where it leaves the south edge of the map area. The "Saugeen clay" is probably a lacustrine clay (unit lib) and the "Erie Clay" is possibly the Neustadt diamicton (unit 10) or a finer facies of the Elma Till (unit 5) on the current map.

Taylor's report (1912) is also of importanc in identifying in sand and gravel resources. He recognized the major southward flowing "ice-border drainage channels and gravel terraces" associated with the Singhampton and Gibraltar Moraine. He correlated the Paris moraine with the Singhampton moraine that trends to the south through Bunesson and Holstein in the present map-area. However, he was most impressed by the great gravel terraces around Durham and he also noted the northwest-southwest trending eskers between Priceville and Mount Forest.

More detailed comments on the area (Taylor, 1939, Chapman and Putnam 1943, 1949, 1951, 1966) will be reviewed under specific topics to follow.

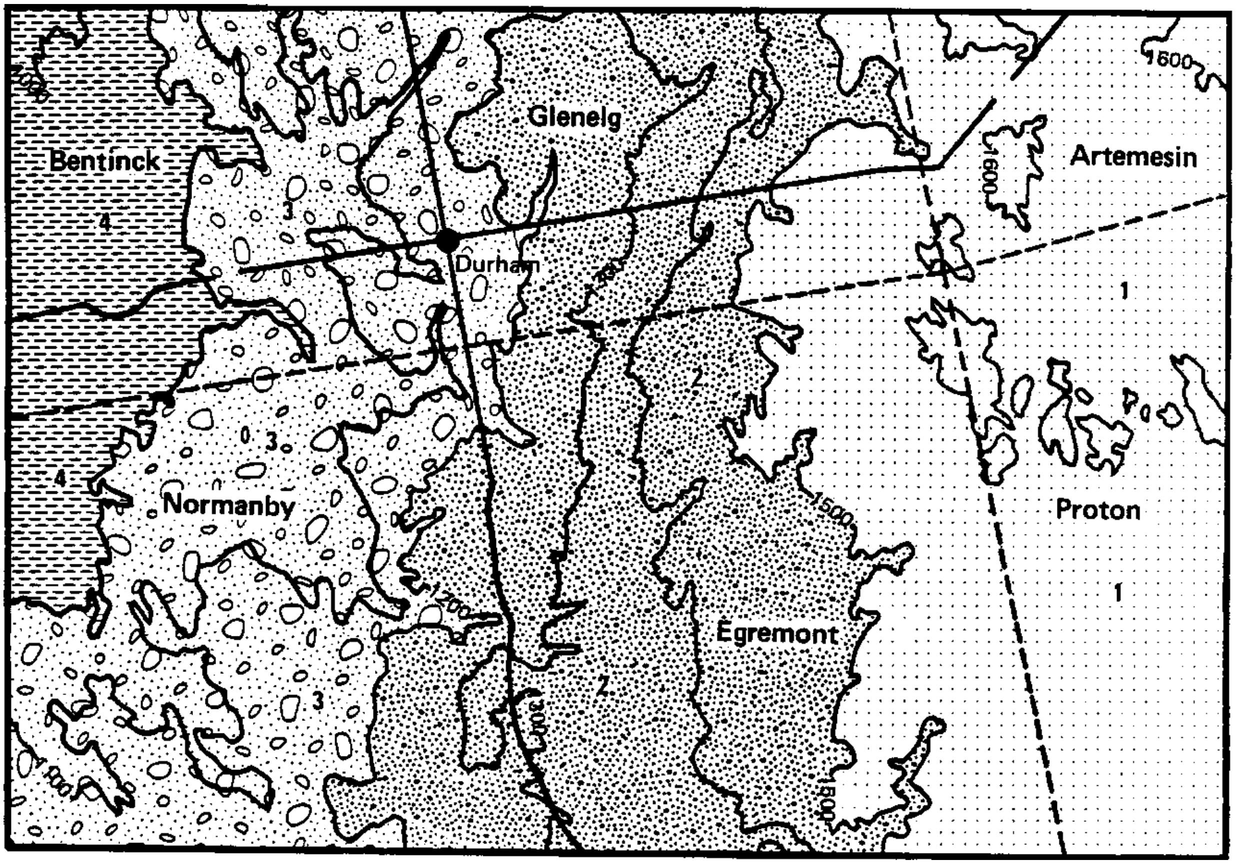
Topography and Physiography

Total relief in the Durham area exceeds 193 m and results in a varied surface topography (Figure 2). Four main topographic areas can be distinguished.

1. Above 1500 ft.[1] (458 m) lies the Dundalk till plain (Chapman and Putnam 1966). This surface is fluted and is only crossed by a few esker ridges and the Maple Lane Moraine.*

2. Between 1200 ft. (36 m) and 1500 ft. (458 m) the land is rugged in character and slopes noticeably to the west, reflecting the combined effects of: a) the southwesterly dip of the underlying Paleozoic rocks, and, b) the location of the Singhampton Moraine. This feature termed the Saugeen Kames by Chapman and Putnam (1966) comprises some of the best morainic topography in Ontario with large kames and kettles, steep ice-contact slopes (Photo 1) fronting massive ice-marginal terraces and extensive outwash channels.

Figure **2.** Main topographic and physiographic regions of the Durham area.



Key	Elevation	Physiography
EE)	>1500' (>458m)	Dundalk till plain
	(366Vrv4^8m)	Singhampton Moraine
	1000'-1200' (305m-366m)	Dissected Teeswater drumlin field
EH	<1000' (305m)	Lacustrine plain

Scale

0 5 10 km

Contour interval = 100 feet (30.5m)

3. Between 305 m (1000 ft.) and 366 m (1200 ft.) is a drumlin field dissected by three major meltwater channels. This area is the eastern edge of the Teeswater drumlin field (Chapman and Putnam 1966).

4. Below 305 m (1000 ft.) is a lacustrine plain once fed by meltwaters originating from the north and surrounded by kame hills in the south.

The various branches of the Saugeen river were very active glacial meltwater channels and now form deep river valleys. The drainage divides for these rivers are shown in Figure 3. These rivers all show a major jog to the northwest where they cross the contact of the Salina and Guelph Formations along which preferential erosion has occurred.

Agricultural Soils

Agricultural soils have developed on a variety of Quaternary sediments in the Durham area for approximately the last 14,000 years or since deglaciation. The soil profiles in the area are well developed due to the porous nature of the parent material. Oxidized C horizons extend several metres below the surface; however B horizons are generally colour horizons rather than textural B horizons. The geologic units indentified on Map P.1566 can be related to their soil catena grouping (Gillespie and Richards

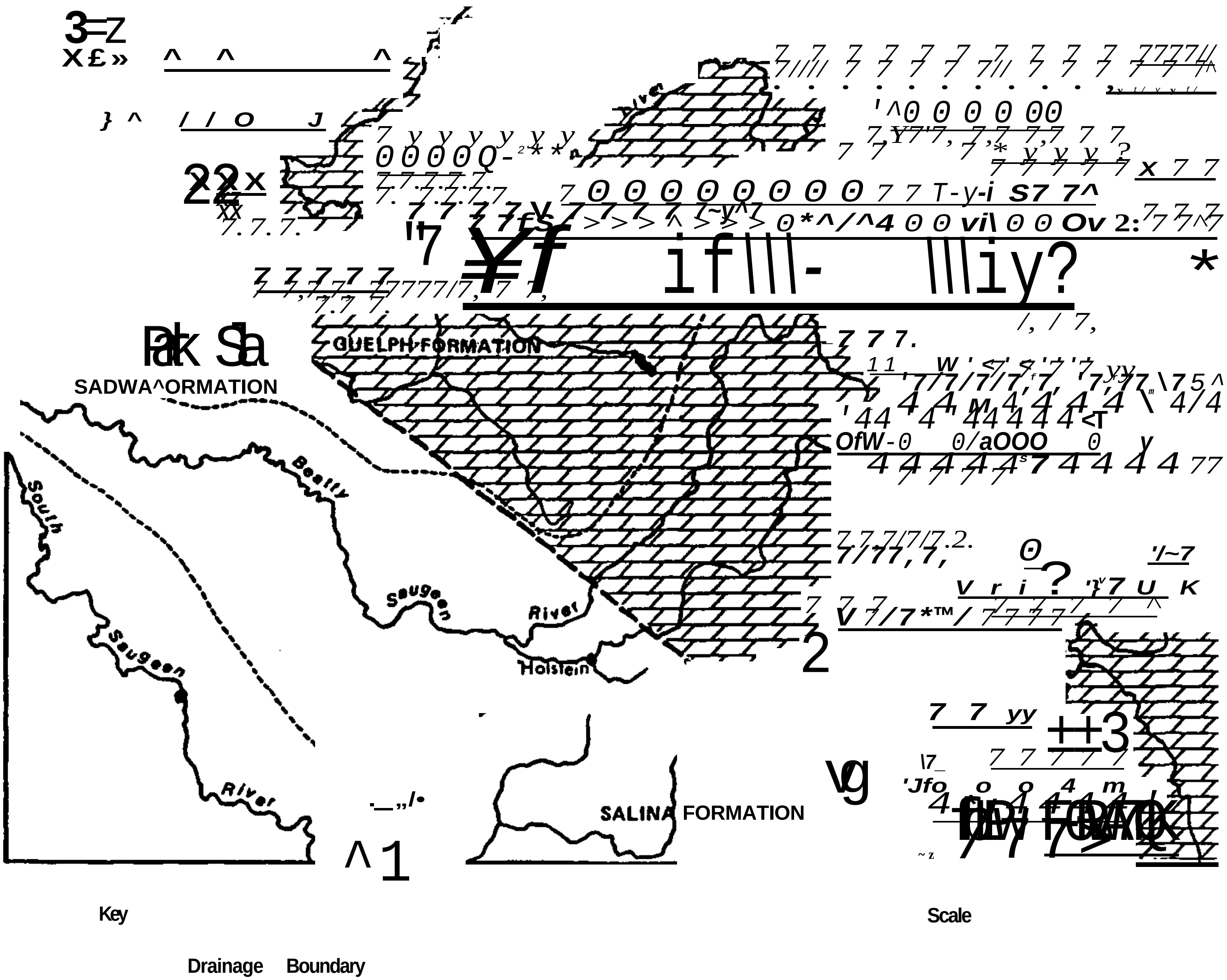


Figure 3. Paleozoic geology of the Durham area with drainage divides superimposed.

1954)• This strong correlation between the sediment type and the soil catenas (Table l)is an aid for extrapolating sediment type from a soils map of Grey County. Conversely, generalized soil units can be made from geological maps elsewhere in Grey County.

TABLE 1

SOIL SERIES DEVELOPED ON SEDIMENTS OF THE DURHAM AREA

SEDIMENT	SOIL CATENA	MOST COMMON SERIES	SOIL TYPE
Elma Till	Harriston	Harriston,Listowel	Loam and Silt Loam
Tavistock Till	Harriston	Listowel, Parkhill	Silt Loam
Ice-contact Stratified Drift	Pike Lake	Pike Lake	Loam
	Donnybrook	Donnybrook	Sandy Loam
	Waterloo	Waterloo	Sandy Loam
Outwash Gravel	Burford	Burford, Gilford	Loam
	Sargent	Sargent	Loam
Glaciolacustrine	Sullivan	Sullivan	Sand
	Fox	Granby, Brady	Sandy Loam

NOTE: The remaining geologic units in the Durham area do not have distinctive soil series associated with them.

Paleozoic Geology

The bedrock geology in the Durham area consists of two formations of Silurian age (Liberty and Caley 1969; Liberty and Bolton, 1971)• The Guelph Formation underlies the eastern two-thirds of the area while the younger Salina Formation occupies the western third (Figure 3). The Guelph strata are exposed along the Saugeen River (Photo 2) and the Rocky Saugeen River and consist of pale brown, thin to medium-bedded, fine-to-medium crystalline, massive dolostone. The strata are vuggy and porous in reefal complexes, and these properties can be observed at the outcrop on Highway 6, north of Durham. Salina Formation rocks, best exposed along the South Saugeen River, (Photo 3) are thin-bedded, soft green grey to red shale, interbedded with grey-brown dolostone. These rocks are fine grained and contain gypsum casts and local bituminous partings.

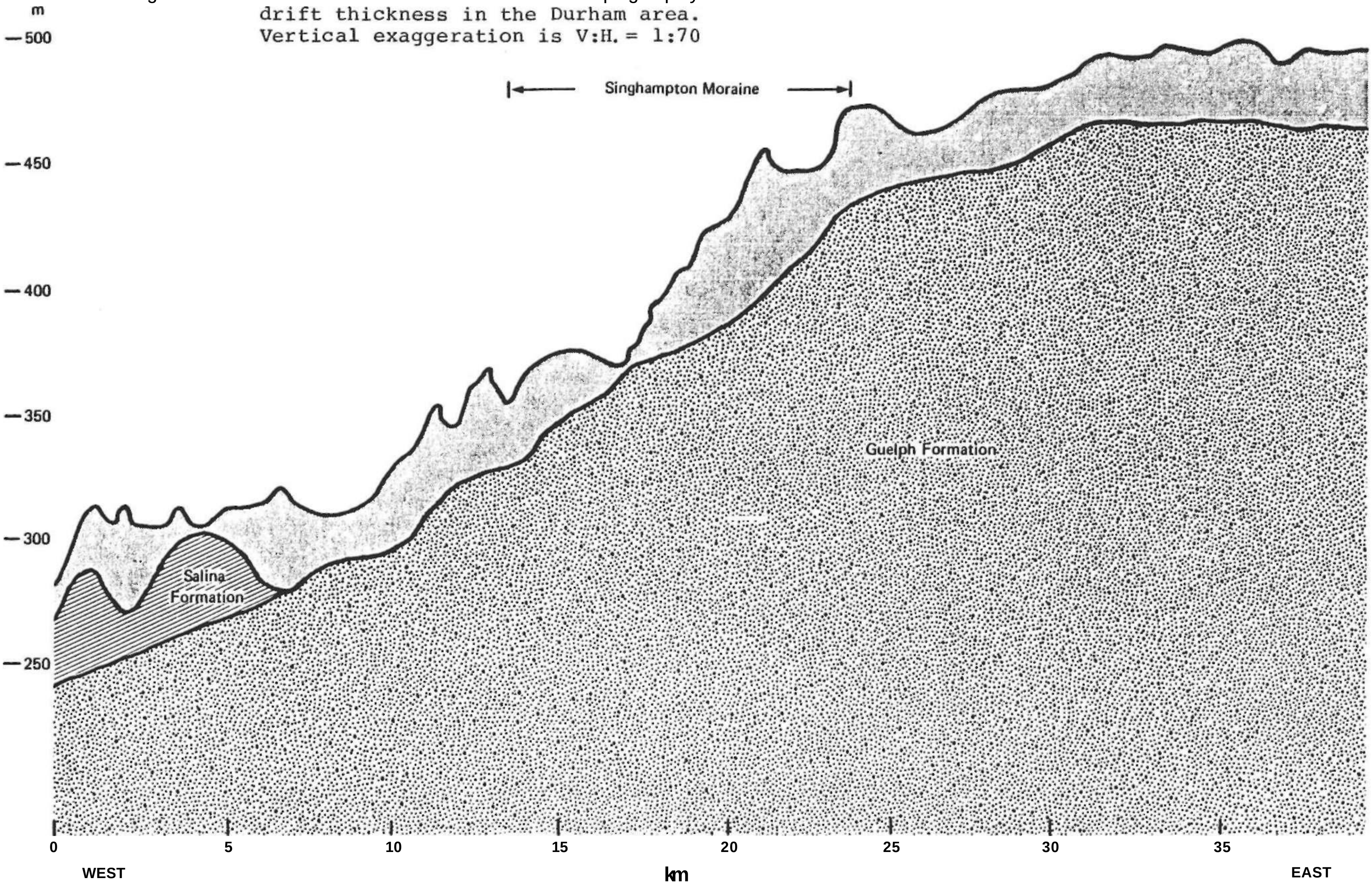
Additional outcrops of Guelph Formation were found along the Saugeen River approximately 1 km east of Durham and near Glenelg Centre, and of Salina Formation along the South Saugeen River, near Calderwood and 2 km east of Neustadt•

Bedrock Topography

The bedrock topography in the Durham map area (Sharpe and Clue, 1978) can be divided into two basic areas that reflect the underlying bedrock. In the east half there is a relatively level surface underlain by medium-bedded to massive dolostone of the Guelph Formation. This surface is somewhat disrupted in the northeast by the southerly extension (buried) of the Beaver Valley. To the west is a bedrock surface dissected by valleys and depressions. The valleys were preferred sites of deposition yet the are precursors of the present Saugeen River and its tributaries. The disorganized nature of this bedrock surface is attributed to the underlying Salina Formation which consists of easily-eroded soft shales and evaporite deposits which may have formed cavities and collapsed at depth.

Separating these two distinct bedrock terrains is a break in slope along the Guelph-Salina contact dipping west at approximately 50 feet per mile (9.5 m per km)(Figure 4). The face probably represents the regional dip of the Guelph Formation as the regional dip of the Paleozoic strata averages 25 to 40 feet per mile (4.8 m to 7.6 m per km) (Liberty and Bolton 1971). This scarp however, coincides approximately with the Singhampton Moraine and may have been an influence (aiding compressive flow) on the location of the moraine.

Figure 4. Cross-section of bedrock topography and drift thickness in the Durham area. Vertical exaggeration is V:H. = 1:70



QUATERNARY GEOLOGY

Quaternary geology involves the study of deposits and earth-forming processes of the great ice age and recent times. The underlying bedrock together with the glacial and glacially related processes have combined to determine the landscape and soil strata of the Durham area. These soils are mainly glacial deposits (late Quaternary age) as recent or post-glacial processes have not altered the Durham landscape extensively.

The chapter begins with a general discussion of the relationship between bedrock geology, glacial processes and the resultant drift. A brief account of the glacial activity in the area provides a conceptual framework against which the sequence or stratigraphy of the soil (strata) can be related.

Pattern of Drift Thickness

The general pattern of drift deposits reflects the bedrock topography of the Durham area. Although regular thickness of drift covers the east part of the map area, variable drift thicknesses (from 8.21 m (25-200 ft.) are more characteristic of the western part of the map area (Figure 4 and Map P.1837). Drift is thinnest along the courses of the Saugeen River and its main tributaries where bedrock may be exposed. The thickest accumulations of drift follows a belt northeast from Mount Forest (Highway 6 and south edge of the map) to west of Flesherton: this belt includes the Singhampton Moraine and has drift up to 61 m (200 ft.) thick. The position of this thicker drift straddles the face of the bedrock escarpment. Thus the Guelph Formation dip-slope face may have been partially responsible for protracted deposition occurring in this position as glacial ice was retarded (compressive flow) by the scarp as it quarried the Salina Formation to the west.

Summary of Glacial Activity

The glacial activity and past environmental conditions in the Durham area are summarized in Table 2. The oldest glacial deposits recorded in the Durham area are about 24,000 years old. Ice advanced into the area to deposit Catfish Creek Till during the main late Wisconsinan advance (Nissouri Stadial). During this time Catfish Creek ice moved strongly from the north and northeast (Western Grenville provenance) through the Southern Ontario peninsula, finally halting in Ohio. Coarse-grained till was produced from this advance because good subglacial drainage was affored by bedrock and outwash substrates. As the Catfish Creek ice mass melted back, drainage was blocked and a series of lakes formed in Southern Ontario, at levels well

TABLE 2 GLACIAL ACTIVITY AND DRAINAGE CONDITIONS

ICE SHEET	ACTIVITY	TEXTURE OF TILL	SUBSTRATE	SOURCE AREA LOCAL	DRAINAGE
Neustadt?	Surge or sediment flow	Silty,clayey	Lacustrine	Saugeen Valley	Blocked
Elma	Minor Advance Mainly retreat	Sandy	Outwash; Bedrock	East of Georgian Bay (Reworked W Grenville)	Ice-covered or Open
Tavistock	Moderate Advance plus sediment flow at ice margin	Clayey,silt	Lacustrine	East of Georgian Bay (Reworked W Grenville)	Blocked
Catfish Creek	Major through-flow	Coarse Sandy	Outwash Bedrock	East of Georgian Bay (W. Grenville)	Open

NOTEt Listed in order of youngest to oldest.

above the existing Great Lakes starting approximately 305 m a.s.l. Consequently, Tavistock ice re-advanced from a limited retreat position attained during the Erie interstadial, and, passed over lacustrine substrates. These lacustrine sediments were frozen onto the base of the ice and then deposited as sediment gravity flows and basal till to produce the fine-grained Tavistock till. Although, Elma ice represented only a moderate advance to the southeast in the Durham area, it seemed to remain active long enough (and due to compressive flow) to deposit an abundance of sandy silt till under conditions of extended ice cover. The source area for this sediment is similar to that deposited by Catfish Creek ice. Neustadt diamicton (till?) represented deposition from a small ice surge along the valley of the Saugeen River, lubricated by water and fine-grained lake sediments or deposition from ice-marginal sediment gravity flow.

Stratigraphy of Glacial Deposits

The principal methods of assembling the stratigraphy or sequence of glacigenic deposits in southern Ontario is to trace mappable till units from site to site. This involves recognizing the genesis and various physical characteristics for each till. Table 3 summarizes the various field properties used to map the tills in the Durham area and vicinity. Table 4 summarizes the deposits themselves as well as their stratigraphic position.

Appendix A summarizes some of the important sections and boreholes which were subdivided on the basis of the above properties.

Laboratory analyses are used to supplement the field data. These data are summarized in Table 5 and Figure 6 and listed in full in Appendix B. Textural classifications are those established by Elson (1961).

Table 6 compares regional data for the Catfish Creek Till.

Older Drift

The oldest sediment in the area consists of 9 m of lacustrine clay, silt and fine sand, underlying Catfish Creek Till. The lowest four metres are rhythmically banded silt and clay with fine sand partings. These comprise 1 to 5 cm thick couplets or bands. This becomes a massive silt to clay unit, rhythmically banded near the base and massive with the occasional sand layer near the top.

These sediments represent a local proglacial lake environment which was created by Catfish Creek ice as it advanced into the area and blocked drainage down the Saugeen River. This relationship has only been observed in the vicinity of the South Saugeen River west of Landerkin.

TABLE 3 SUMMARY OF FIELD PROPERTIES FOR DIFFERENTIATING TILLS IN THE DURHAM AREA.

TILL	COLOUR[1]	STONINESS[2]	TEXTURE	STRUCTURE	CONSISTENCY	CONTINUITY	STRATIGRAPHIC POSITION	ORIGIN
NEUSTADT	dark yellowish brown(10YR5/4)	1%	Clayey-silt	blocky	firm	Saugeen River Valley	overlies fine lacustrine sediments	flow till or debris flow
ELMA	light yellowish brown (10YR6/4 10YR5/4)	very stoney, 25-50%	sandy silt	fissile	soft to friable	patchy near Maple Lane Moraine	overlies Tavistock Till	mainly lodgement, seme flow till
TAVISTOCK	brown (dark yellowish brawn) (10YR4/3) (10YR4/4)	stone-poor 2-5%	silt	blocky	stiff	only found southeast of Holstein	may overlie fine lacustrine sediments	lodgement same flaw till
CATFISH CREEK	yellowish brown (10YR5/4)	very stoney, up to 50%	sandy silt	massive	extremely hard	may form continuous deposition with Elma Till	occurs on bedrock or coarse stratified sediments	lodgement and basal melt-out

oxidized, dry colour determined from Munsell colour chart.
Weight percent, greater than 4nm.

NOTE: Detailed sections are listed in Appendix A.

TABLE 4 SUMMARY OF LATE QUATERNARY DEPOSITS AND EVENTS IN THE DURHAM AREA

AGE	TIME STRATIGRAPHIC UNIT	ROCK STRATIGRAPHIC UNIT	DEPOSIT OR EVENT	MATERIAL	MORPHOLOGIC EXPRESSION
Recent			modern alluvium	gravel, sand silt, clay	present day floodplain
			bog and sand	peat, muck marl	closed depression
Late Wisconsinan	Port Bruce Stadial	Neustadt drift	lacustrine deposits	fine sand silt, clay	small, level areas
			Neustadt till	silt till	thin ground moraine
			lacustrine deposits	silt, fine sand	low level areas
			outwash	gravel, sand	braided- channel system, kame terraces, valley train, river terraces;
			ice-contact stratified drift	silt, sand gravel, some till	kames, end moraines, kame deltas, eskers
		Elma Drift	Elma Till	stoney, sandy silt) silt till	drumlins, fluted ground moraine
		Tavistock Drift	Tavistock Till and debris flows	clayey silt; silt till	ground moraine
	Erie Interstadial		lacustrine deposits	clay, silt	buried
	Nissouri Stadial	Catfish Creek Drift	Catfish Creek Till	stoney, sandy silt till	ground moraine (mainly buried)
			lacustrine deposit	massive to banded silt, clay	buried lake plain

Catfish Creek Till

Distribution

The Catfish Creek Till (deVries and Dreimanis, 1960) is a very distinctive till which can be traced over large areas of Southern Ontario. It consists of a very hard, stoney, sandy silt till with a massive structure and yellowish brown oxidized colour (10YR 5/4).

This till can be traced (on the ground) from the type area near Lake Erie (Dreimanis and deVries, 1960), to Guelph (Karrow 1968) and to Orangeville (Cowan, 1976). The Tavistock Till overlies the Catfish Creek Till from the Orangeville Moraine to the Durham area and this was an aid in the accurate tracing and correlation of the Catfish Creek Till.

Catfish Creek Till outcrops at the surface in the extreme southeast corner of the map sheet, and is also present along the banks of the South Saugeen River where it underlies two younger till units. The till varies in thickness from at least 5 to 10 m, although it could be greater in the northwest. Thicker exposures unequivocally proving the presence of Catfish Creek Till in the north and northwest portion of the Durham area are missing. Catfish Creek Till has been mapped however, to the northwest as far as Southampton (Sharpe, 1979) in the Chesley-Tiverton area where it represents a continuous deposit; Catfish Creek Till to Elma Till. Correlation further north to Thornbury, where it overlies organic deposits dated at 31,500 ± 1,000 c^{*4} years (BGS-182AS) and 36,000 c^{14} years (GSC-2053), has been suggested by Burwasser (1974). Detailed work by Pinch (1979), confirms the correlation of Catfish Creek Till to the Thornbury area.

The lower contact of this till sheet is not well exposed but locally it shows a sharp change from lacustrine sediments at the one site observed. The upper contact is sharp in the southeast where lacustrine sediments again overlie. In the northwest, the contact is gradational to Elma Till as continuous ice presence and deposition appears to have controlled the transition.

Lithology

Catfish Creek Till is coarse textured (up to 50% > 2 mm) and rich in dolostone: the pebble lithology has a limestone to dolostone ratio of 0.1 (Table 5). The till matrix is a sandy silt (37% sand, 49% silt). The calcite to dolomite ratio in the silt-clay fraction is 0.3. This lithologic character is due to a strong ice advance from the north and northeast across Silurian dolostone bedrock.

The heavy minerals show a predominance of red to purple garnets supporting the concept of ice flow from the north.

Based on three heavy mineral analyses of fine sand (total garnet of 13% and a purple/red ratio of 0.7) a source area from the western Grenville Province is also suggested (Gwyn, 1971). This result is similar to that for other nearby areas (Gwyn, 1976; Cowan, 1979; Gwyn and Dreimanis, 1979). The trace element values are similar to those reported by Warren and Delavault (1961) for dolostone rocks above the Niagara escarpment. The higher values for Cu and Zn (Closs, 1979) suggest a possible influence from Georgian Bay shales.

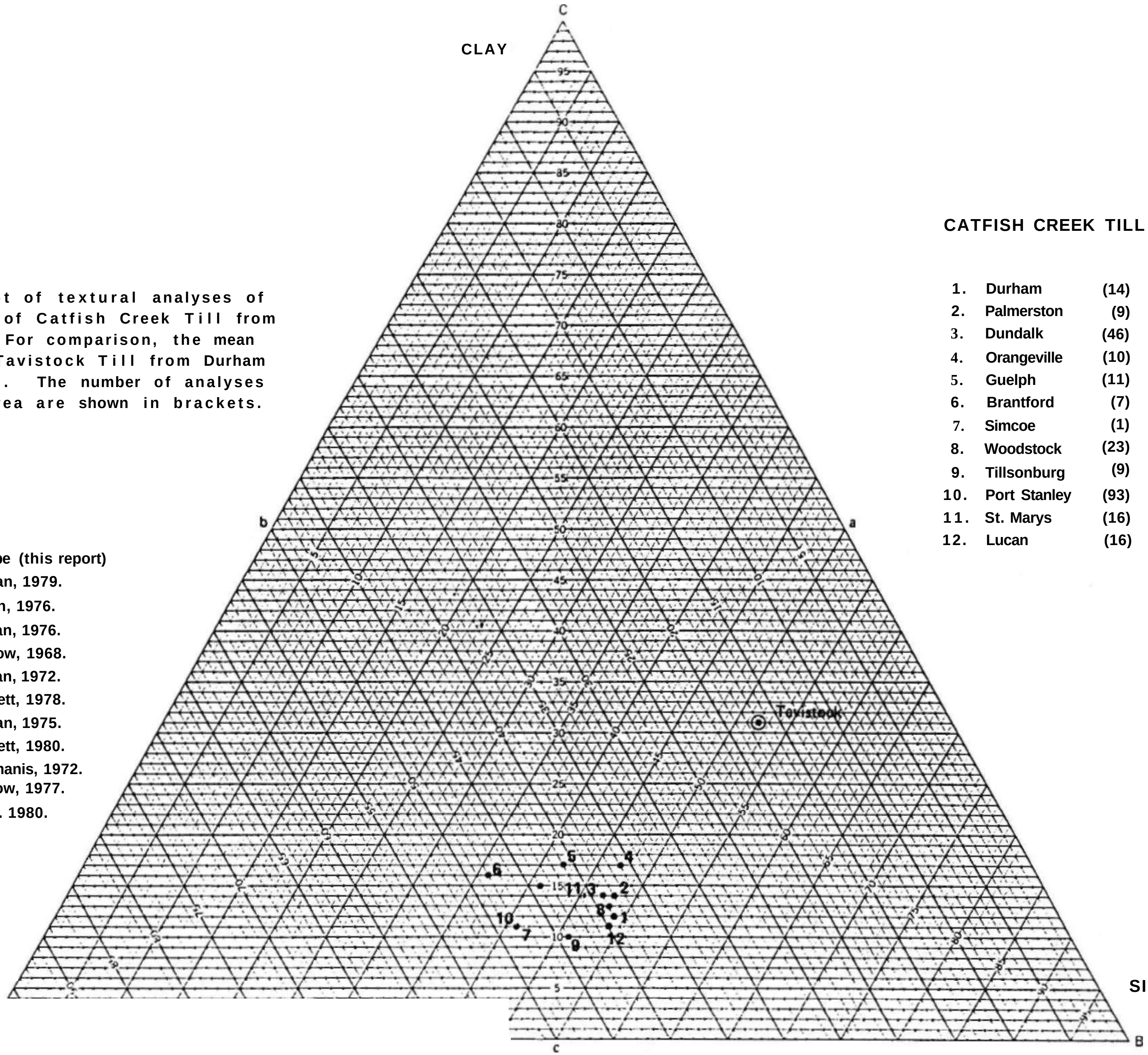
Environment of Deposition

The lithologic properties listed are very similar to those reported for Catfish Creek Till in adjacent areas (Figure 5, 6). The textural uniformity of Catfish Creek Till over such a large area (Figure 5) is striking and implies very uniform load characteristics in the base of the advancing glacier. The coarseness and uniformity of this till suggests a strong ice movement through the lake basins under well drained conditions, (some local ponding may exist). This provided either an apron of coarse outwash material (or bedrock) which was subsequently eroded and incorporated by the advancing ice. The coarseness of the till allowed subglacial drainage during subsequent deposition, resulting in extremely dense, overconsolidated till. The characteristics and extent of this till have important resource and engineering implications.

Figure 5.
Ternary plot of textural analyses of the matrix of Catfish Creek Till from 12 areas. For comparison, the mean value for Tavistock Till from Durham is included. The number of analyses for each area are shown in brackets.
Source:

1. Sharpe (this report)
2. Cowan, 1979.
3. Gwyn, 1976.
4. Cowan, 1976.
5. Karrow, 1968.
6. Cowan, 1972.
7. Barnett, 1978.
8. Cowan, 1975.
9. Barnett, 1980.
10. Dreimanis, 1972.
11. Karrow, 1977.
12. Sado. 1980.

CLAY



SAND

SILT

CATFISH CREEK TILL

1. Durham (14)
2. Palmerston (9)
3. Dundalk (46)
4. Orangeville (10)
5. Guelph (11)
6. Brantford (7)
7. Simcoe (1)
8. Woodstock (23)
9. Tillsonburg (9)
10. Port Stanley (93)
11. St. Marys (16)
12. Lucan (16)

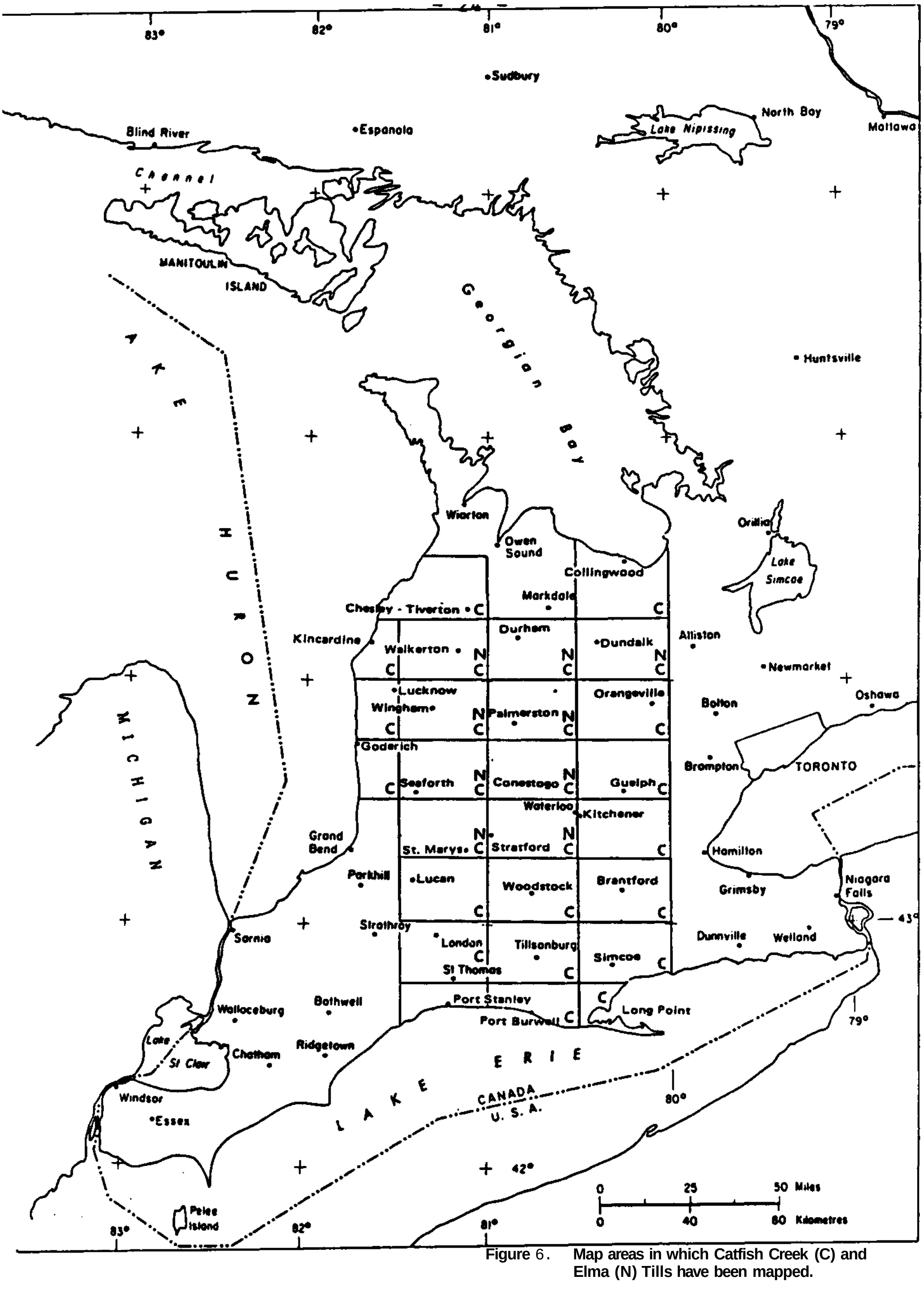


Figure 6. Map areas in which Catfish Creek (C) and Elma (N) Tills have been mapped.

The very uniform texture, density, coarseness and strong parallel fabric of the Catfish Creek Till implies deposition at the base of a free-draining moving glacier by a lodging process over upland and interflure settings. Locally, in basins or valleys different modes of deposition occur (Evenson et al 1977; Gibbord 1980).

Tavistock Till

In the Durham area the Tavistock Till is a brown (10YR 4/3) gritty, silt to clay silt till with 2-5% clasts (Table 3). The till is soft to compact and weathers with a blocky to columnar-jointed pattern.

Extent

Tavistock Till was formally named in the Stratford area (Karrow, 1974), although it has been correlated* with various tills across southwestern Ontario (Figure 6, 8). In Durham, Tavistock is a very thin till, typically a few metres thick but only 1 m thick in places. It outcrops at the surface in the southeast corner of the sheet and

Tavistock Till had previously been called "northern till" in the Guelph area (Karrow, 1068) and till "C" in the Stratford Conestoga area (Karrow, 1971). Cowan (1975) correlated the Zorra till in the Woodstock area and the gritty clayey silt till west of the Orangeville moraine (Cowan 1976) as the Tavistock Till. To the east, in the Dundalk area, Gwyn (1976) mapped Tavistock Till to the Orangeville Moraine; while to the west. Cowan (1974) had observed it in the subsurface at Wingham. Recently it has been traced as far south as London in the Lucan area (Sado, personal communiation Feb. 1979) and possibly as far southwest as Sarnia (Fitzoerald 1979).

underlies Elma Till southeast of the Singhampton Moraine. Tavistock Till has not been found northwest of Holstein or approximately the position of the Singhampton Moraine.

Lithology

The lithology of Tavistock Till strongly reflects the underlying dolostone bedrock (Table 5). The limestone to dolostone ratio is 0.1 in the pebble grade and the calcite to dolomite ratio is 0.5 in the silt and clay fractions. The heavy minerals in the sand fraction, particularly the garnet ratio of less than 1.0 and moderate percent garnet (12%) indicate a Western Grenville source area (east of Georgian Bay, Figure 6) Gwyn and Dreimanis (1979). Tavistock Till has higher vlaues of trace elements than the other tills in the area. This reflects the affinity of trace elements to fine-grained sediments. The fine texture may also be responsible for the reddish hue of Tavistock Till, derived from local red Salina shale or Queenston shale from Georgian Bay.

The composition of the Tavistock Till is similar to that of Catfish Creek Till (Table 5 and Figure 7): the pebble fractions are identical with regard to the limestone: dolostone ratio at 0.1. Total carbonate contents (< 74 mm) are lower in Tavistock Till (50%) than Catfish Creek Till (69%); the difference is explained by the finer texture of Tavistock Till (Figure 8) and the fact that older tills

uu	lexture					Pebble Lithology							Carbonate3			Heavy Minerals		Atterberg LimitB				Trace Elements						
	No. of Samples	Clay	Silt	Sand	Hd (u)	No. of Samples	Lime-stone	Dolo-stone	Chert	Clastic	Precam-brian	Limestone Dolostone	No.,r Samples	lotal	Calc/ Dolo-stone	* Heavies	s Magnetica	No. or Samples	Liquid Limit	Plastic Limit	Index or Plasticity	NO. or Samples	Cu	Zn	Ni	Pb	Cr	Ba
Neustadt	5	18	67	15	13	-	-	-	-			-	5	50.8	0.5	2.3	16.8	4	20	15	5	5	21	40	15	-	39	-
Elma	44	13	50	37	41	18	10	83	0	1	6	0.1	44	58.9	0.3	2.1	15.3	13	15	14	1	8	24	41	11	10	33	251
Taviatock	23	31	52	17	9	9	8	83	a	i	S	0.1	23	50.3	0.5	2.1	12.8	12	25	15	10	6	30	61	19	21	52	288
Cutfiah Creek	14	12	49	39	43	4	7	82	0	1	8	0.1	14	68.7	0.3	1.9	13.3	non-plastic				3	17	33	7	10	24	220

IABLE 5. SUMMARY Or PR0PERIIES Of IILLS IN DURHAM

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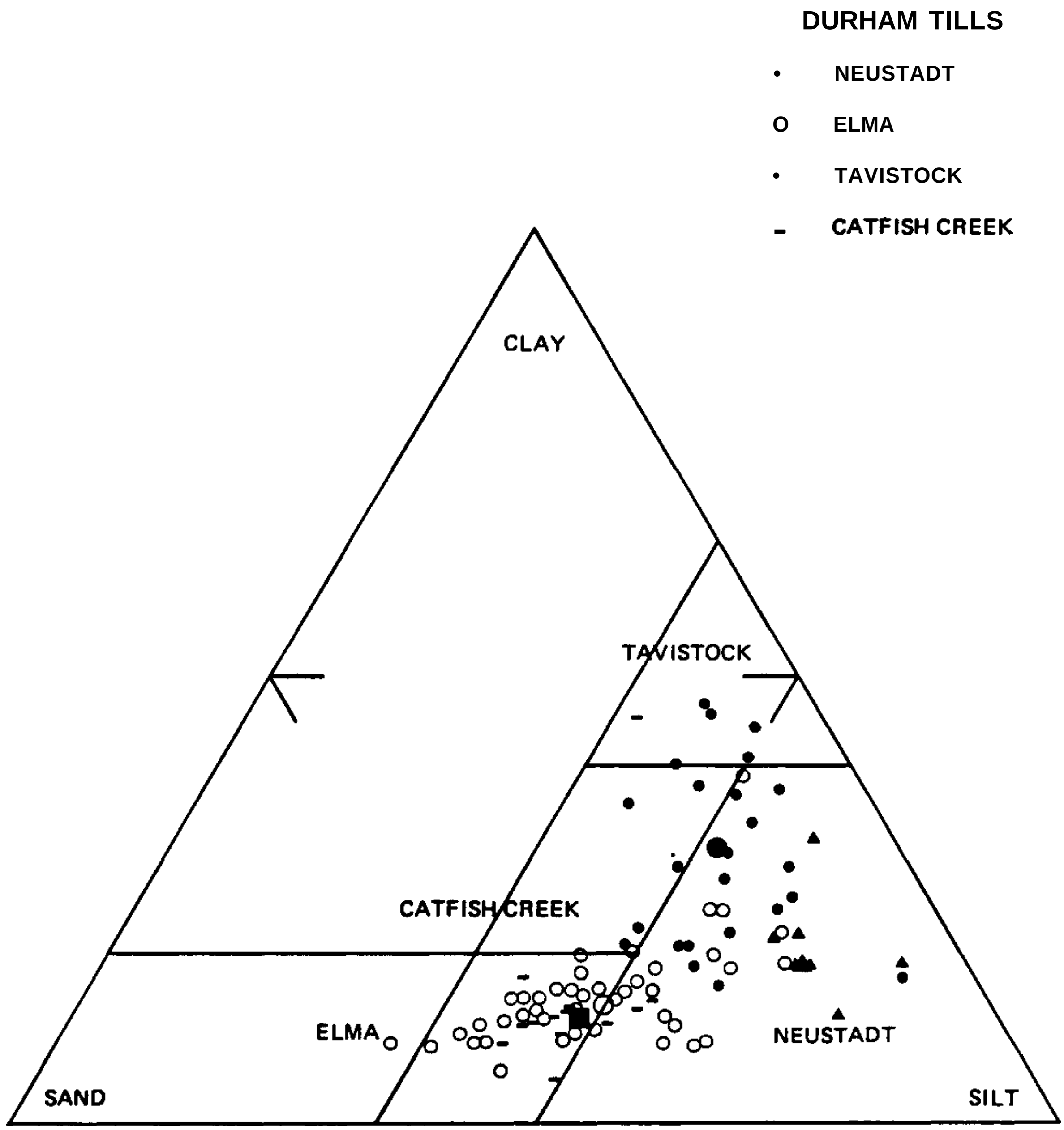


Figure 7 Ternary plot of textural analyses of the matrix of tills in the Durham area.

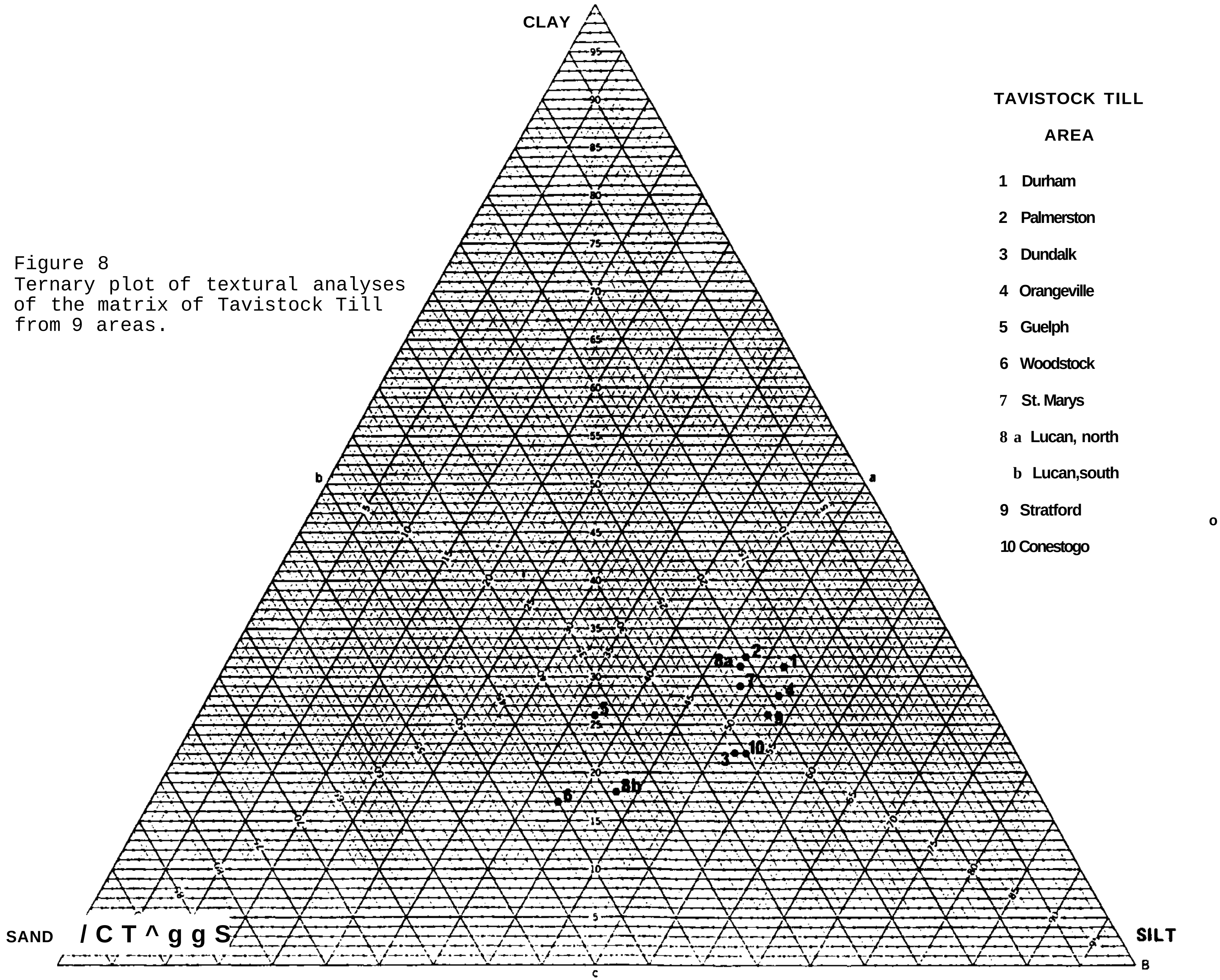
cover the carbonate bedrock. The calcite to dolomite ratio is marginally higher in Tavistock Till (0.5) compared to Catfish Creek Till (0.3); this is attributed to the effect of large lacustrine areas which may introduce calcite from the southwest by way of dispersion in the proglacial lakes. More simply, calcite may show an affinity for finer grain sizes•

However, texturally there is a radical change between Tavistock and the older Catfish Creek Till which represents a change in substrata (Figure 7 and Table 5) or position of deposition. Tavistock Till incorporated fine lacustrine sediments (31% clay) while Catfish Creek Till comprises outwash and eroded bedrock material (only 12% clay).

Environment of Deposition

Tavistock Till is considered to represent the glacial reworking (freezing-on) of ponded fine-grained lacustrine sediments and in places (Photo 4) shows a transition: laminated waterlain till from massive basal till. The fine-grained lacustrine origin is regionally characteristics of Tavistock Till although it tends to be sandier at its margin where it has overriden (or is interbedded with) glaciofluvial or glaciolacustrine sands (e.g. Guelph, Woodstock and south Lucan, Figure 8, 9). These characteristics for Tavistock Till suggest that a large lake, or a series of lakes (Cowan, 1979) (deep enough in

Figure 8
Ternary plot of textural analyses of the matrix of Tavistock Till from 9 areas.

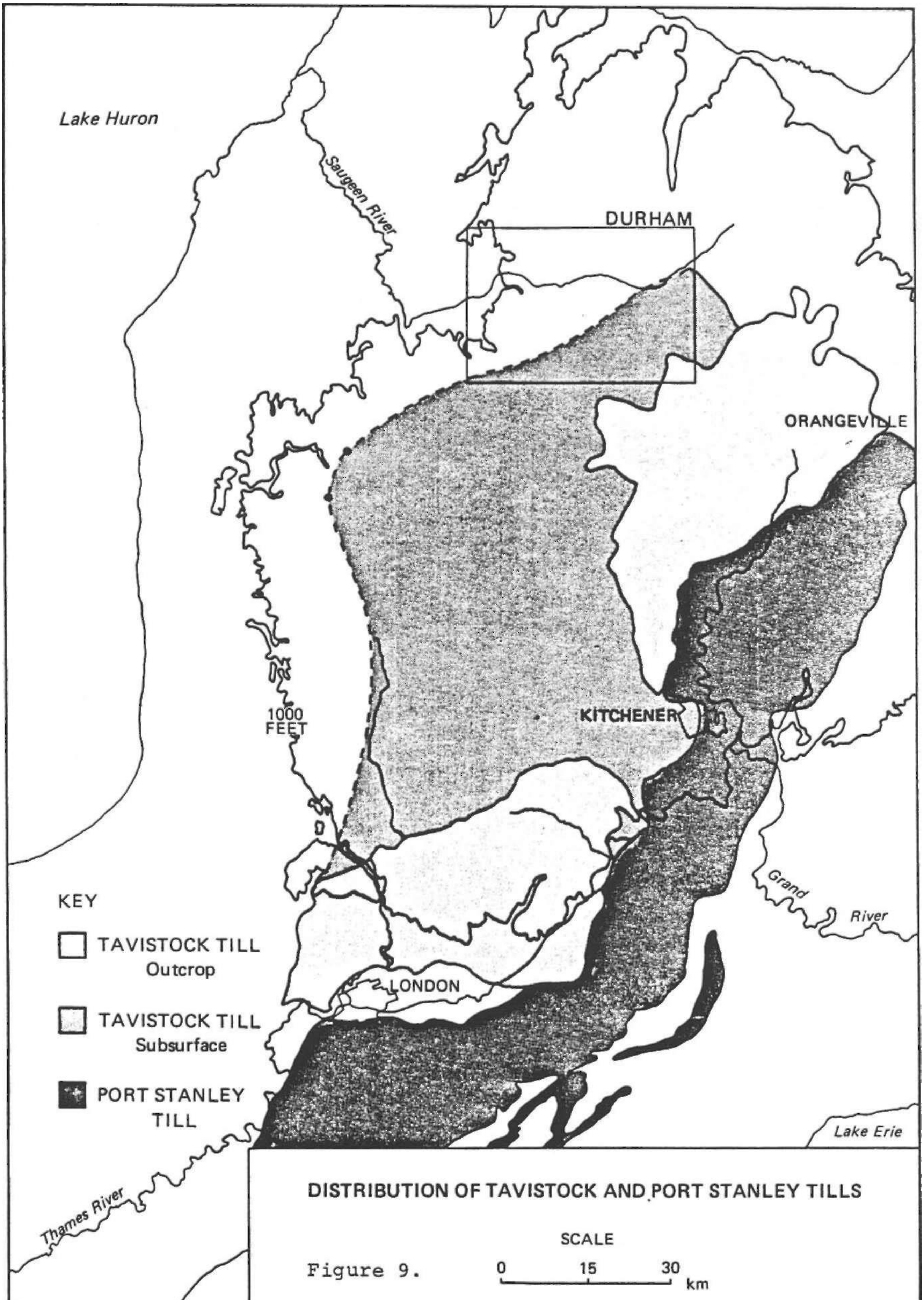


which to deposit fine-grained lacustrine material) existed in front of the advancing Port Bruce Stadial ice or the retreating Missouri Stadial ice. The position of the Singhampton Moraine is the approximate northwest limit of Tavistock Till in the Durham area and this is the approximate western shoreline of these lakes. Figure 9 shows the total distribution of Tavistock and the possible limits of preceding lakes. A corollary of this understanding is that the western margin also represents a retreat position for the Erie Interstadial, a more restricted ice-distribution interpretation than previously held (e.g. Dreimanis 1977).

Source Areas

The Western Grenville provenance present in Tavistock drift also indicates that the Tavistock ice may have been reworking the Catfish Creek drift as the Tavistock ice moved from the northwest to the southeast (Figure 7).

Cowan (1979) has evidence (flutings and provenance relationships) for the Tavistock Till being deposited by ice moving from the northwest to the southeast i.e. from Georgian Bay. The dolomite content and distribution of fine-grained till in the Durham area supports that direction of ice movement. Tavistock Till is considered to be the major deposition, as glacial ice moved from Georgian Bay during the Port Bruce Stadial (Terasmae et al 1972; Karrow



DISTRIBUTION OF TAVISTOCK AND PORT STANLEY TILLS

Figure 9.

1974). In the Palmerston area to the south. Cowan (1979; Figue 7), has shown Tavistock Till to be the main member of a series of three tills of similar composition. However, these fluctuations in the main Port Bruce are not present in the Durham area. Tavistock Till has been shown to be approximately equivalent in age to the Port Stanley Till (Figure 9) by Cowan (1976, 1979) and Karrow (1974).

A alternate explanation is that Tavistock till is superglacial facies equivalent of the Catfish Creek (i.e. they have identical lithological properties except for particle size)• The finer texture of the Tavistock may simply be due to ice-marginal sedimentation during the melt book of Catfish Creek ice.

Elma Till

Distribution

Elma Till was first described as till "N" (Karrow, 1971) and then given its formal name from Elma Township, Perth County (Karrow, 1974). From there it has been traced to the north and west (Fig. 6). In the Durham area, Elma Till covers three different regions. The Teeswater drumlin field northwest of the Maple Lane Moraine forms a discontinuous till plain. The Maple Lane Moraine itself forms the most definite outer margin of Elma Till where up to 10 m of basal till may exist. Beyond this, the till is very thin (1 to 2m) and discontinuous to the southeast corner of the area where, Elma Till forms the Dundalk till plain. In this outer zone the till originated as flow or melt-out units from a thin, melting ice sheet.

Lithology

Elma Till consists of loose and fissile, light yellowish brown (10YR6/4), sandy silt till which is moderately stoney (10 to 15% but may be up to 50%). Where it is not weathered, the till is compact and grey brown (10YR5/2). At depth, it is very dense and can only be distinguished from Catfish Creek Till where Tavistock Till intervenes. Elma Till has a silty facies south of Ayton where it incorporated ponded silts and shale from the Salina Formation.

The lithology of Elma reflects its origin. It mainly consists of a fluted lodgement or basal till derived from the base of the glacier. Thus it has a high proportion of locally eroded Silurian dolostone in both the coarse (pebble) and fine (carbonate) fractions (Table 5). The coarseness of the matrix and pebble fractions also indicates erosion and incorporation of local Silurian dolostone.

The minor occurrence of erratics such as limonite, jasper-pebble conglomerates (Lorraine Formation) and red garnets indicates a source area north of Georgian Bay. This indicates englacial or long-transport material.

Ice-directional Indicators

Several features indicate that Elma ice generally moved from northwest to southeast. First, flutings oriented northwest-southeast commonly occur southeast of the Maple Lane Moraine. Second, there are several features oriented perpendicular to ice movement. The Maple Lane Moraine and the Singhampton Moraine both represent important standstills (advance and retreat positions respectively) aligned northeast-southwest. Between these two major moraines, minor moraine ridges composed of till are also oriented northeast-southeast.

The Elma Till is further marked by eskers, which indicate ice flow to the southeast, and by sandy outwash channels, which formed parallel to the ice margin as they drained to the southwest.

Drumlins to the northwest of the Singhampton Moraine (Teeswater drumlin field) show a slightly divergent flow pattern from west of north to northwest.

Glacial Activity

The Teeswater drumlins consist of up to 20 m of stoney sandy till and sand, a thickness of Elma drift which implies a special style of glacial activity. For example, Tavistock Till does not occur in the thick till sequence northwest of the Singhampton moraine. This may indicate sedimentation or continuous occupation of ice since the deposition of Catfish

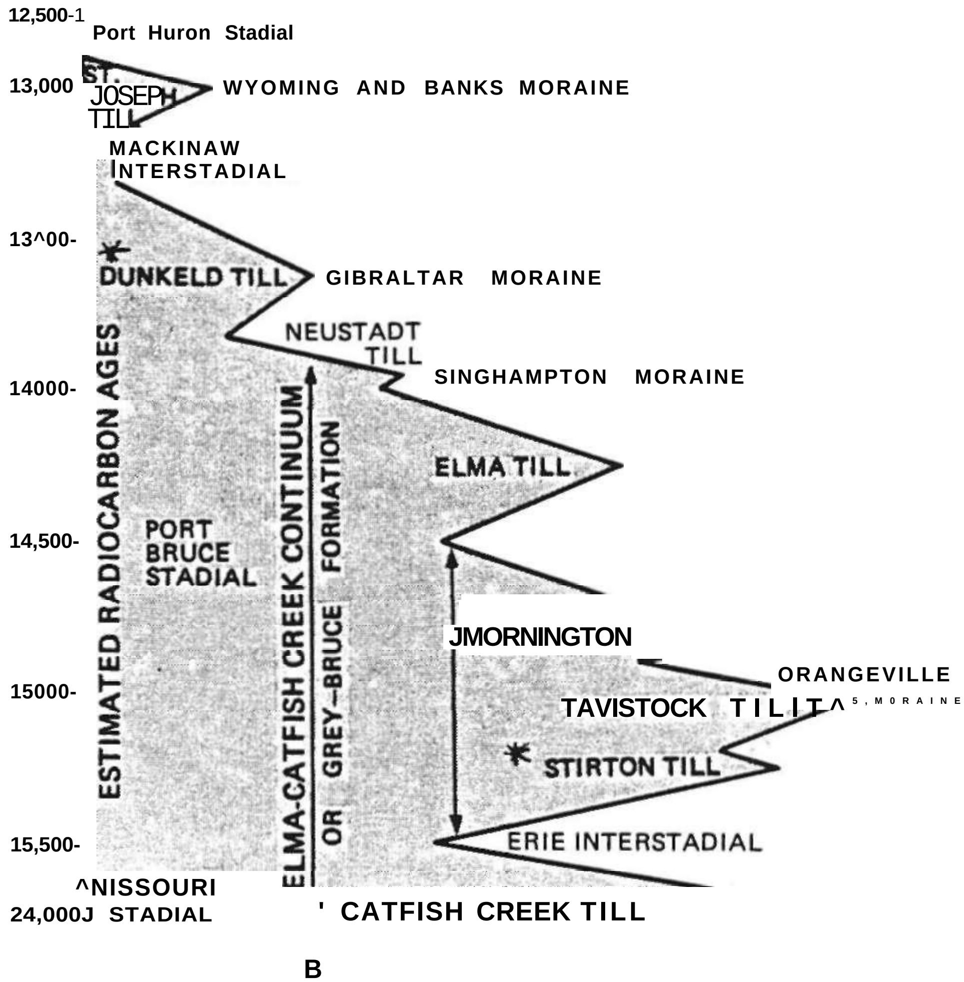


Figure 10 Time-distance plot between Southampton (A) and Orangeville (C). The portion B-C is the area of concern for the Durham area, showing the relationship between the Elma-Catfish Creek continuum and their separate deposits to the southeast. (Modified from Cowan et al 1978). Tills marked by an asterisk (*) are not present in the Durham map area.

Creek Till (through to the deposition of Elma Till). The result is that the ice advance which deposited Elma Till and associated drift may be strictly defined by the area southeast of the Singhampton Moraine, whereas from there to the northwest only the top surface of the coarse textured till represents Elma deposition. The resulting stratigraphy is summarized in the time-distance diagram (Figure 10). Here, Elma Till is defined where it overlies Tavistock Till but it becomes a continuum with Catfish Creek northwest of the inner limit of Tavistock Till. A convenient way to summarize these relationships is to consider the Elma-Tavistock-Catfish Creek Till continuum the "Grey-Bruce" formation in areas where these members cannot be separated.

The lithology of Elma Till is identical to that of Catfish Creek Till (Table 5). The sole exception is that total carbonate values are 10% lower in Elma Till. This lithologic similarity suggests two alternatives: 1) Elma ice travelled over a similar substrate as Catfish Creek ice; or, 2) Elma ice and Catfish Creek ice are one and the same ice body so that the original drift in the ice sheet was deposited by advancing, retreating and fluctuating ice movements. In general, this produced basal till meltout tills and flow tills respectively.

The radical textural change from lacustrine-derived Tavistock Till to coarse-grained Elm Till requires elaboration. Three explanations are feasible yet only one seems probable.

1. The ice front may have retreated far enough to the west (well into the Lake Huron Basin) to allow general drainage of ponded waters, prior to a re-advance over coarser outwash sands and gravel.

2. The ice mass could have melted back to such a degree that massive fragmentation and disintegration took place, allowing coarse sediments to accumulate, prior to readvance.

3. The main load characteristic (coarse debris rather than local fine-textured debris) of the main Lake Wisconsinan ice mass was re-established or maintained, resulting in the deposition of englacial and local debris.

The first two arguments lack stratigraphic evidence for significant retreat prior to deposition of Elma Till (Sharpe, 1977, 1978b). Tavistock Till has not been found northwest of a line between Holstein[1] and Wingham (40 km southwest). Beyond this line, Elma and the older Catfish Creek Till are indistinguishable. Thus, an advance for Elma ice can only be recognized where Tavistock Till separates the two coarse-textured tills. To the northwest of this advance region, I suggest that continuous deposition or ice occupation existed from Nissouri stadial time until late Port Bruce time (Figure 10).

A comparison of stratigraphic evidence for the surrounding area supports the interpretations from Durham concerning Late Wisconsinan time. To the east, in the

Dundalk area, Gwyn (1976) has mapped Elma Till beyond (south) of the Singhampton Moraine. There it is mappable as a unit separate from Catfish Creek Till based on surface geomorphology (drumlin orientation) and physical properties. Northeast of the Singhamton Moraine the correlative of the Elma Till, the Newmarket Till (Gwyn 1972) is considered by Gwyn (1976; Open File 5132 revised) to represent continuous ice presence in the northwest portion of the Dundalk area. In the Collingwood area (Burwasser (1979) has mapped a coarse stoney sandy silt till (Newmarket) resting on bedrock. In this same area near Thornbury, Pinch (1979) correlated a solitary thick sandy silt till sequence (overlying an organic deposit of Middle-Wisconsinan age) as the Newmarket Till. This also implies continuous ice-cover and deposition occurred from Nissouri time on through to late-glacial time when the glacier left the area.

Neustadt till

A thin, silt till covers a small area in the southwest corner of the map area. This till is informally termed the Neustadt till and was first observed by Cowan (1975). The Neustadt till is a yellow-brown (10YR5/4) to brown, silt to clayey silt till. It is blocky in structure and has a low grit and pebble content. The till is reworked lacustrine material deposited in an ice-dammed lake occupying the South

Saugeen River valley. Being of local origin, the lithology composition (e.g. carbonates) of this till is similar to the three older tills in the area (Table 5). Where it is underlain by observed lacustrine material it can be mapped as a separate unit; otherwise, it can have a fine sandy silt texture similar to Elma Till. In other locations the unit appears to be a lacustrine deposit because of its very high silt content. The lack of stratification and the presence of a preferred fabric suggest a till; however, this material could have also originated as a flow-till or debris-flow deposit in a pro-glacial lake.

Summary

The picture that emerges of glacial activity during the Port Bruce Stadial (about 15,000 - 13,500 years age) is one of downwasting glacial ice, relatively thick in and adjacent to the lake basins and correspondingly thin and more active further inland. The stable thick ice allowed a continuous cover or continuous subglacial deposition (Elma-Catfish Creek Till) near the lake basins. Further inland towards the centre of the southwestern Ontario peninsula ("Ontario Island") the ice was thin and the margin was more active depositing a more complex series of till units (Tavistock, Elma, Neustadt).

Glacial Landforms

Ground Moraine

Ground moraine consists of glacial drift (till and stratified drift) deposited directly from glacier ice over the areal extent of glacial cover rather than at its margins as discrete morainic hills or ridges. Most of the ground moraine in Durham consists of basal till deposited by an active glacier. This ground moraine covers about 40% of the map area and has two distinct patterns. Beyond the Singhampton Moraine there is a level to gently undulating fluted basal till surface with weak drumlin forms. This area forms the western portion of the Dundalk till plain (Chapmea and Putnam, 1966) and lies in contrast to the ground moraine northwest of the Singhampton Moraine, where a rolling drumlinized terrain is heavily dissected by meltwater channels. This latter region forms the eastern portion of the Teeswater drumlin field of Chapman and Putnam (1966).

A series of low till ridges occurs parallel to the Maple Lane Moraine. These features, one kilometre wide, several kilometres long and up to 10 m thick are formed of stiff, massive, basal Elma Till. They seem to represent small end moraines which forms have been enhanced by meltwater channels draining either side of the ridges.

Streamlined Forms

Streamlined glacial forms indicate the orientation of ice movement. The most common of these are glacial flutes found southeast of the Maple Lane Moraine. These flutings marks consist of almost imperceptible hollows on the ground (Prest, 1968), about 1 m deep and tens of metres wide. They commonly have a thin veneer of silt and fine sand from glacial meltwaters. These flutes formed during the advance of Elma ice as it eroded the surface of both Elma and Tavistock Tills. The southeast-northwest trend indicates that Elma ice traversed this portion of the Tavistock Till surface without depositing any drift.

Situated northwest of the Singhampton Moraine are drumlins forming the Teeswater drumlin field. They are well formed drumlins often up to 1.5 km in length and 25 m in height. They are composed of stoney sandy silt till which may represent both Elma Till and Catfish Creek Till. The material in the core of the drumlin was thought to be Catfish Creek Till but sand was found in a few exposures. Their present orientation is just west of north to just east of south Whereas drumlins of Catfish Creek Till mapped by Gwyn (1976; OFR 5132) are oriented northeast-southwest. Two possibilities arise here: either the Durham drumlins represent converging flow from Georgian Bay during deposition of Catfish Creek Till or they are younger drumlins formed by the flow during the time of Elma ice.

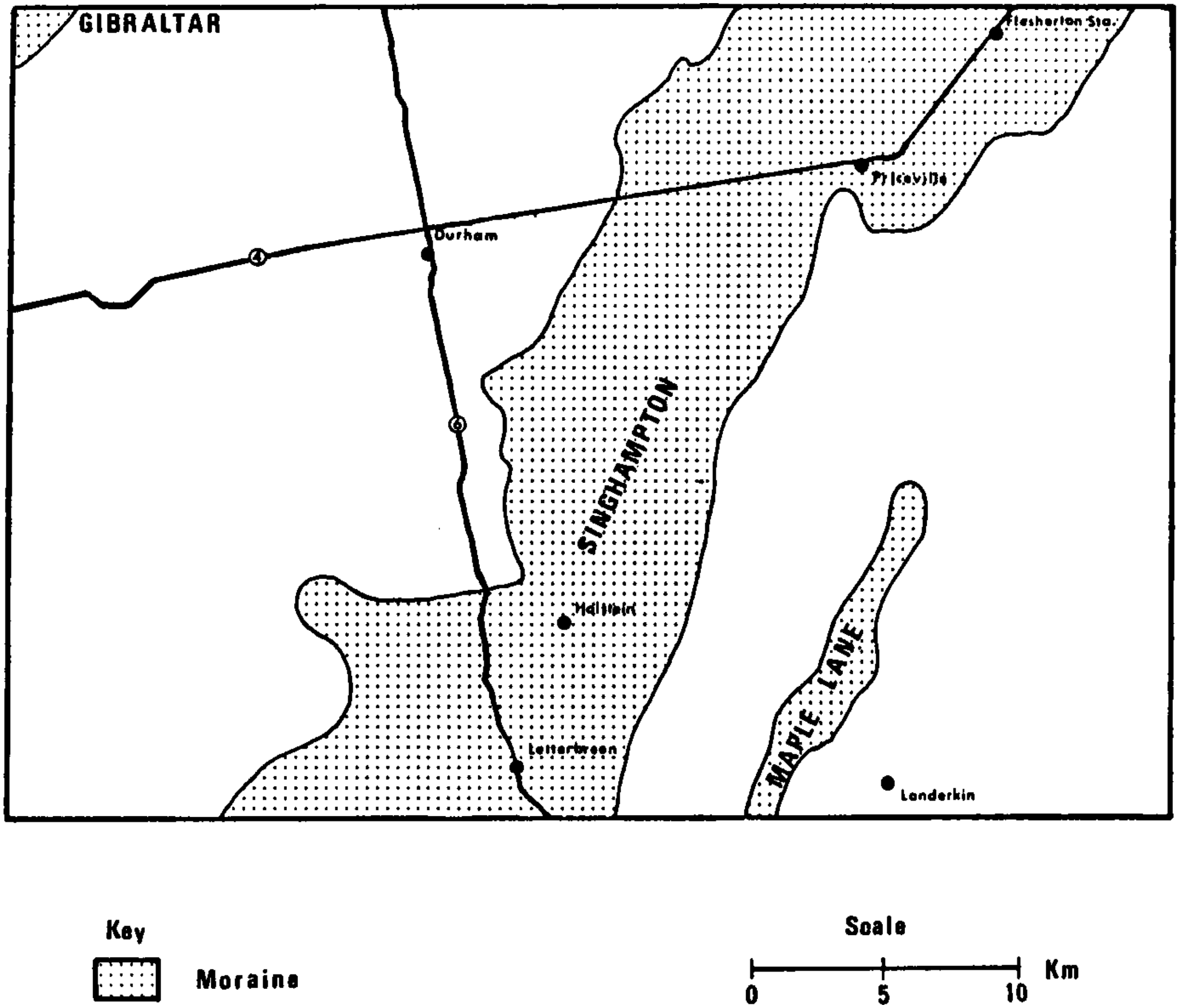


Figure 11   Location of end moraines in the Durham area.

End Moraines

The end moraines in the Durham area formed as recessional moraines or ice-marginal features deposited at the edge of a generally retreating ice front. The three moraines crossing the Durham area are illustrated in Figure 11.

Maple Lane Moraine

The oldest moraine in the area runs west of Landerkin comprising well-formed kame and kettle topography. This moraine continues from Maple Lane to the northeast only as intermittent sandy knobs and was considered by Taylor (1910) to be the extension of the Milverton Moraine traced from 120 km to the south-southwest. Tracing of the Milverton Moraine fades out in the last 20 km or 80 km and thus the new name of Maple Lane seems practical for the Durham area. The correlation offered by Taylor is however, confirmed because the Milverton Moraine and the Maple Lane Moraine are both close to the outer limit of Elma Till. Elma Till actually extends for several kilometres east of the moraine where a thin patchy loose till unit (flow till) recorded a zone of thin ablating ice.

This moraine may represent a minor fluctuation of Tavistock ice which capped some eskers in the Palmerston area with Tavistock Till (Cowan, 1979). More probable though, is the above argument which relates the moraine to deposition of Elma Till.

The moraine consists of sand and gravel originally deposited as outwash by a braided stream flowing to the southwest. These predominantly sandy sediments have been faulted and disturbed near the frequent ice-block depressions which characterise the moraine, southwest of Maple Lane. Thin sandy Elma Till (flow till) caps the moraine occasionally southwest of Maple Lane but from here to the northeast, it forms a more continuous cover which fragments the moraine.

Singhampton Moraine

Correlation

The Singhampton Moraine is the massive expanse of kames, channels and terraces extending northeasterly across the central Durham area. It was first named by Taylor (1913) as he correlated the Singhampton Moraine with the Seaforth Moraine to the southwest. This correlation was changed by Taylor (1939), Chapman and Putnam (1943, 1951, 1966 Figure 11a), yet recent work by Sharpe (1975, 1978) and Feenstra (1975) confirms the original correlation (Figure 12). The orginal correlation is confirmed by:

1. distribution of major outwash channels in Durham and Caledon;

2. a revised correlation of the Port Huron Moraine (Sharpe, 1978);

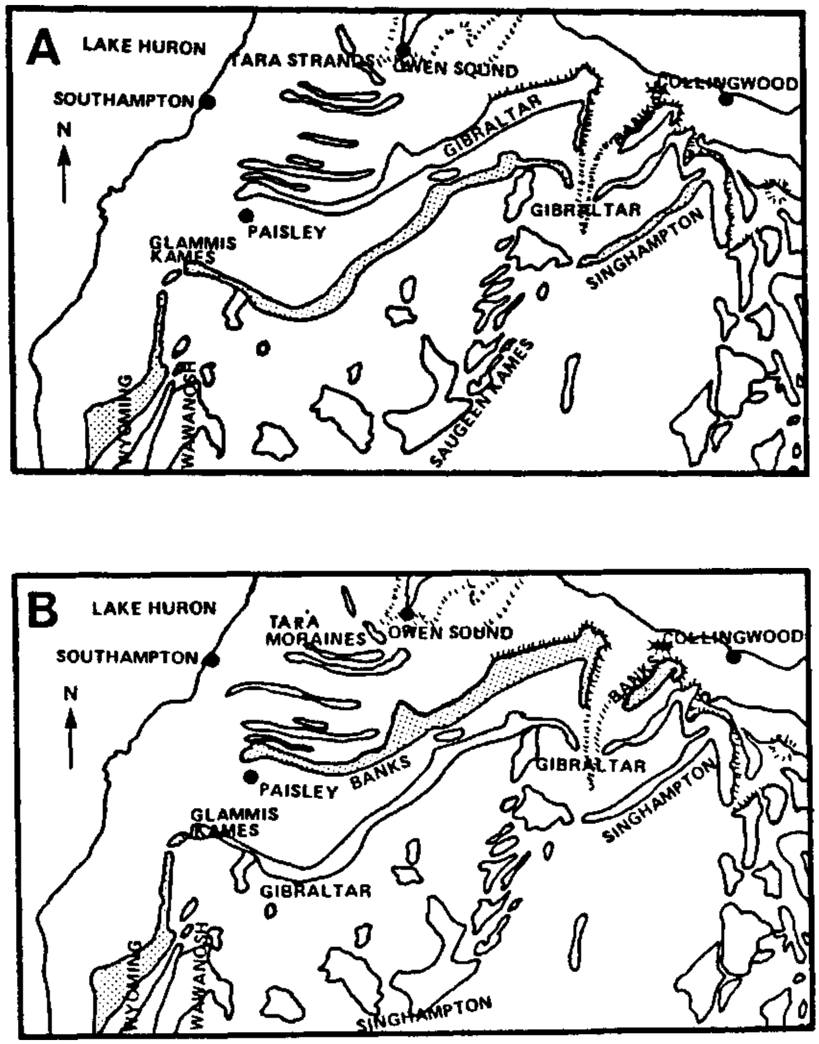


Figure 12 Moraine terminology and correlation of the Port Huron Moraine System: A - after Chapman and Putnam, 1966; B - after Sharpe (1975, 1978) and Feenstra (1975). The patterned area indicates the position of the Singhampton Moraines for each correlation.

3, a revised correlation of the Paris and Gait Moraines (Barnett, 1978, 1979).

The revisions are based on:

1. Major outwash channels fronting the Singhampton and Gilbraltar Moraines (in Durham and Dundalk) are the same as those fronting the Paris and Gait moraines (in Caledon).

2. Younger moraines including the Port Huron Moraine system fit the new position for the Singhampton Moraine i.e. Walkerton Moraine is older than the Port Huron (Cowan et al 1978) and the Banks Moraine is equivalent to the Wyoming (Port Huron) Moraine.

3. A revised correlation of the Paris and Gait moraines provides an independent- check from the Erie-Ontario basins (Barnett, 1978, 1979).

Character and Genesis

Continued sediment accumulation at the ice margin by glacial meltwaters formed the Singhampton Moraine. Early morainic material consisting of kames of lacustine fine sand and silt were eroded by a major network of braided outwash streams which fronted the main mass of the moraine. This kame material is found east of the outwash extending from Priceville to Letterbreen. North of Thistle, the moraine contains gravel and sand deposited as fluvial or fan sediments; whereas south of Thistle including morainic drift west of Highway 6, the moraine again contains a lacustrine

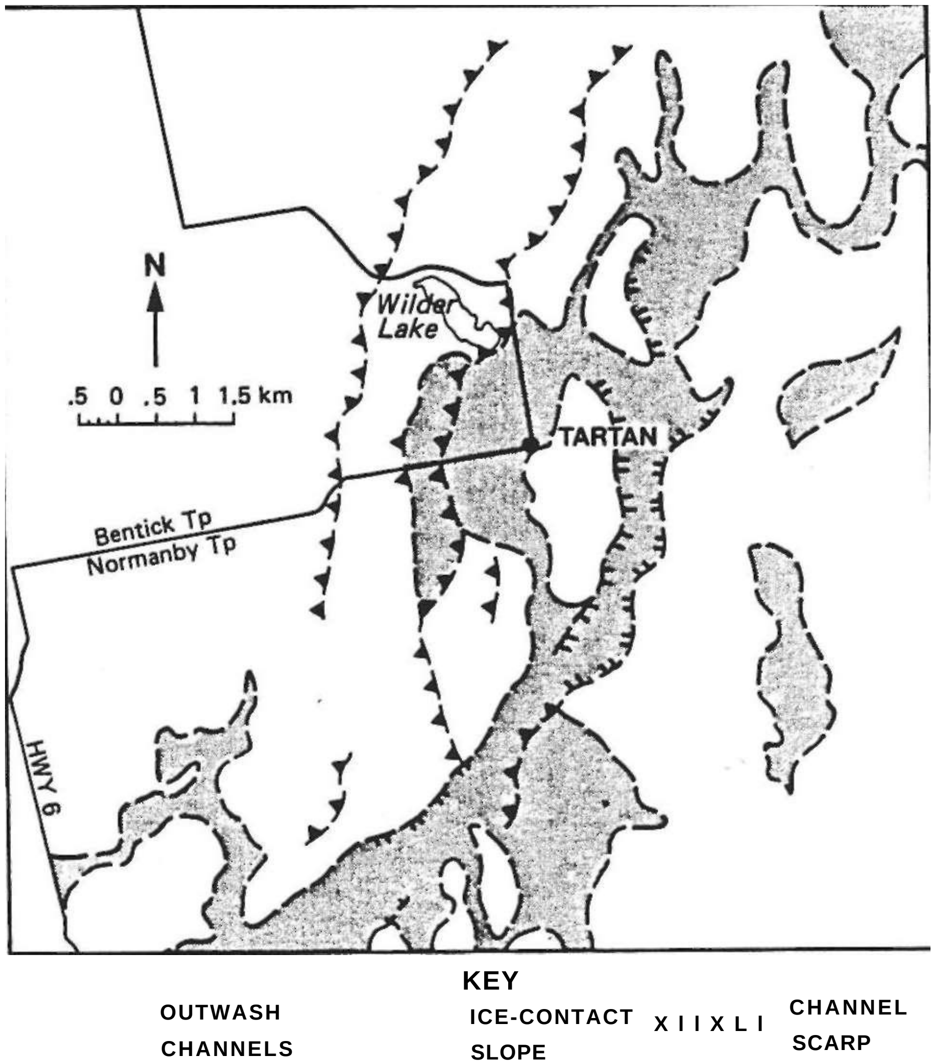


Figure 13 Ice-contact terraces near Tartan about 8 km southwest of the Town of Durham.

fine sand deposit. This lacustrine deposition took place prior to the ice front withdrawing a sufficient distance to allow major drainage. These fine sediments were then dissected by a large braided stream which carried meltwaters and coarse sediment away from a rapidly melting ice margin.

A series of well developed major ice-contact slopes mark the position of the ice margins from which these streams issued. Successive terraces formed (Figure 13) at these positions when the ice supported these outwash systems against higher land to the east. This development is very clearly preserved in the resultant landforms (i.e. ice-contact terraces) such as those near Wilder Lake (Photo 1). As the ice retreated to the west, outwash deposition took place in a more chaotic environment (ice burial) so that terrace forms were not preserved; nevertheless these deposits are coarse gravelly sand.

The above processes have combined to produce some of the most spectacular morainic topography in Southern Ontario (Photo 5) which includes kames, kettles, ice block depressions and blocks of stratified sediment isolated by outwash channels.

Gibraltar Moraine

A small portion of the Gibraltar moraine is included in the extreme northwest corner of the map area (Figure 11) and consists of sandy bouldery drift in very hummocky terrain.

The main influence of this morained position on the area is that a network of thick outwash gravel deposits front the moraine as valley train along the Saugeen River.

The relationship of outwash gravel to the Gibraltar Moraine is also a key in tracing its extent. Taylor (1913) showed this moraine as a correlative of the Wyoming Moraine and thus part of the Port Huron Moraine system. Chapman and Putnam (1943, 1951 1966) named this moraine the Singhampton Moraine (and a Port Huron equivalent; Figure 12a). However, they did not realize that the valley train fronting the Gibraltar Moraine from Markdale to Allen Park is clearly younger than the outwash near Flesherton fronting the next older moraine (Singhampton).

The difficulty which Chapman and Putnam (1966) encountered in tracing this outwash is understandable as great quantities of outwash are associated with both the Singhampton and Gibraltar Moraines. Hence, the depositional regime of rapid ablation at the ice margin, was similar when both moraines were being formed. This realization helped confirm the morainal correlations in the areas and also has important economic implications concerning aggregate resources.

The age of the Gibraltar Moraine is known quite well, compared to other moraines in the area. A basal bog date of 13,500 ± 210 (GSC 1151) years B.P. was obtained from Louise Lake, located immediately in front (south) of the Gibraltar

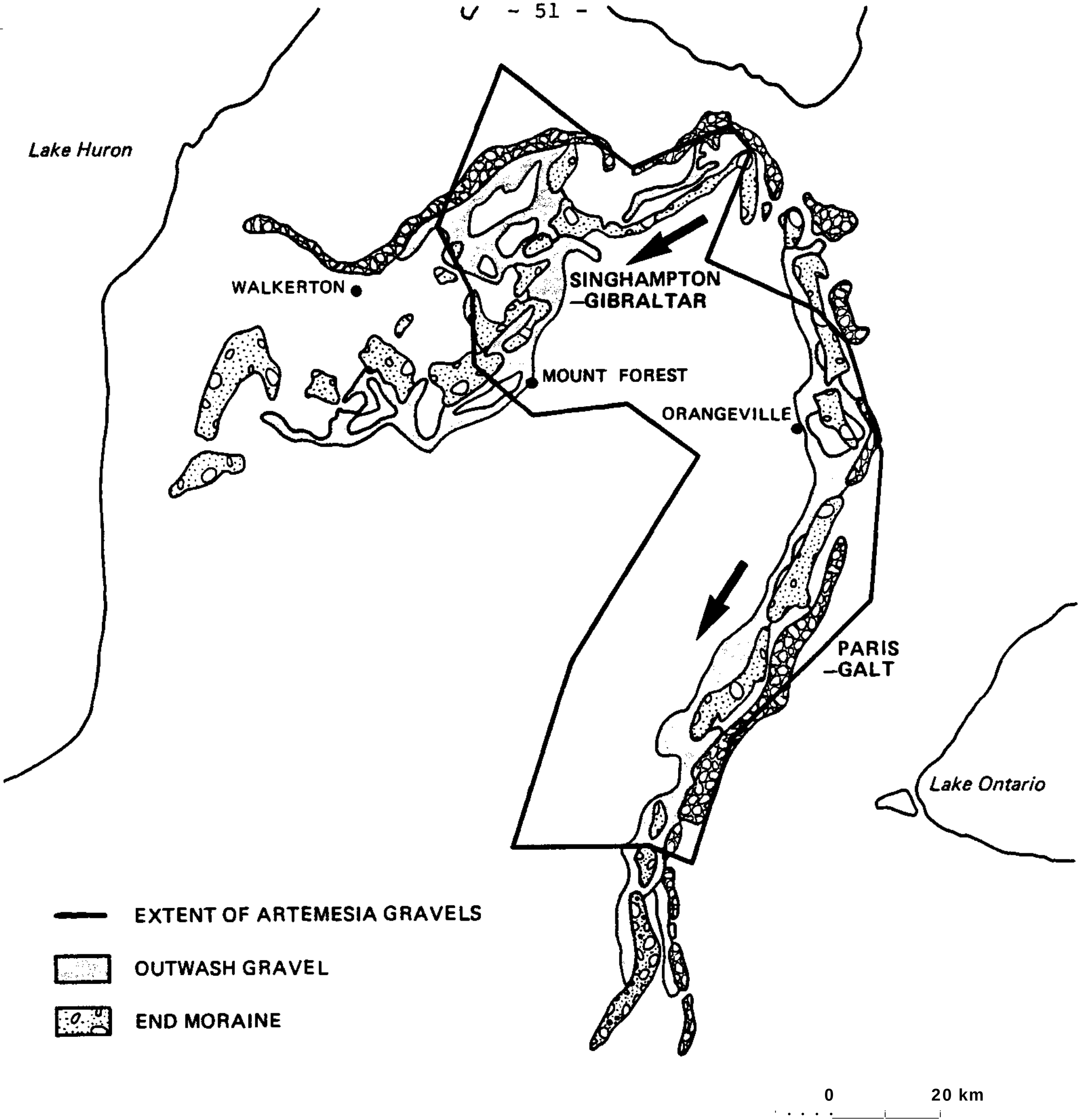


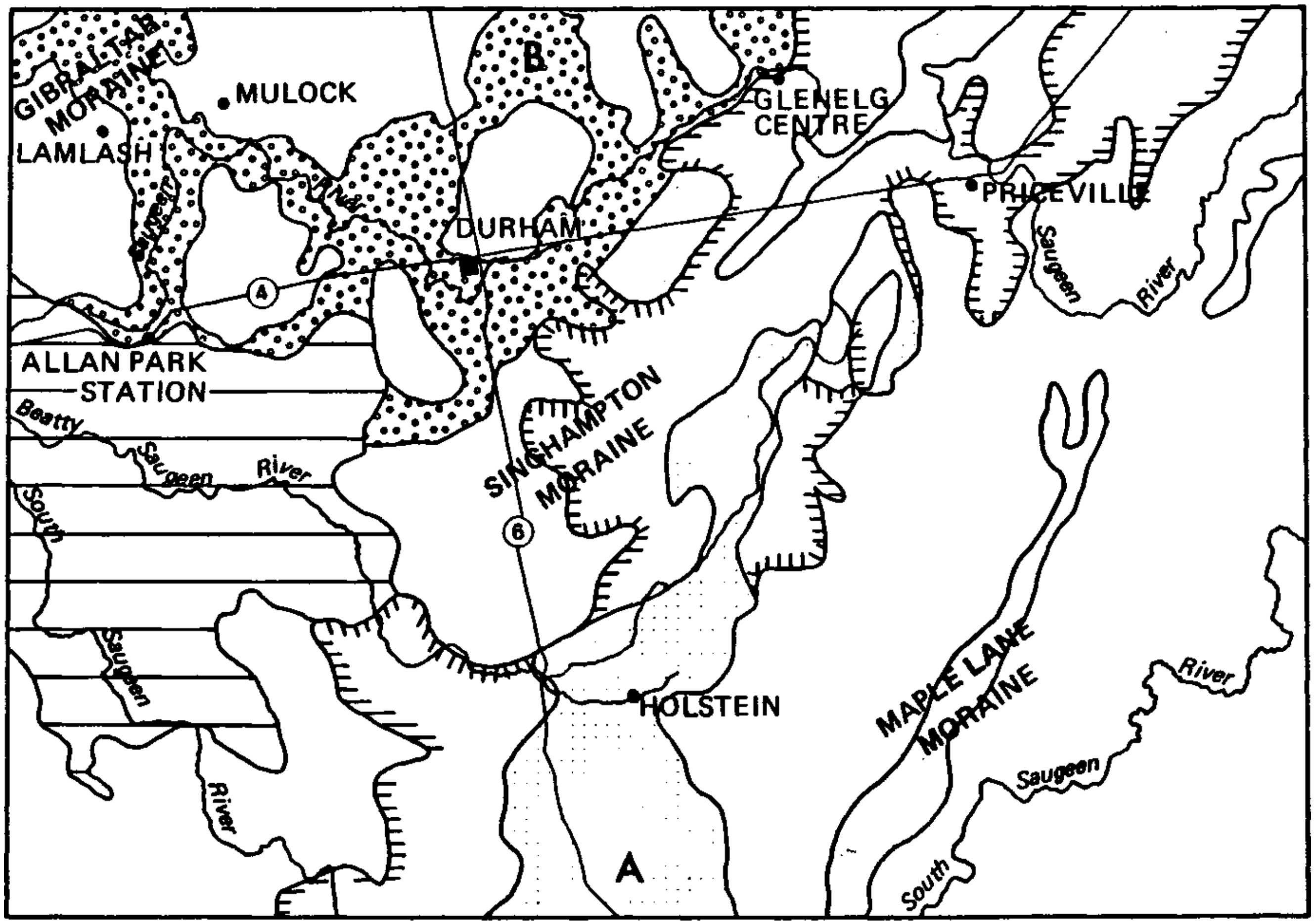
Figure 14 The Artemesia Gravels defined by Logan (1863). Logan's map essentially outlines the whole of the moraine-outwash sequence representing the Singhampton and Gibraltar Moraines and their correlatives to the south, the Paris and Gait Moraines.

Moraine, 3 kilometres north of the Durham area. Karrow and Anderson (1975) considered this date to be too old by 1500 years due to the effect of "old" carbonate. However, the Banks Moraine is the next younger moraine and it is considered to be approximately 13,000 years old (it is now the Port Huron equivalent,(Sharpe, 1978). Since the bog that was dated is beyond the Gibraltar Moraine, an age of 13,500 years B.P. would be the youngest estimate for the age of the moraine. Thus, when the standard error of the date is considered, the date appears to be a valid estimate.

Glaciofluvial Features

Outwash

The outwash deposits of the Durham area were first documented by Logan (1863) as part of a large belt of gravel (the Artemesia gravels) outlined in parts of 37 townships (Figure 14). In Artemesia Township, these gravels comprise the Singhampton and Gibraltar Moraines and their associated outwash trains which Logan correlated to the south to the Paris and Gait Moraines. Logan's map also includes two older features not associated with the outwash; the Orangeville and Waterloo Moraines. He refers to the roundness, coarseness and quantity of these gravel: properties of which will be examined here.



LEGEND

BOUNDARY OF SINGHAMPTON MORAINE

AREA OF PONDING

MAPLE LANE MORAINE

SINGHAMPTON MORAINE

GIBRALTAR MORAINE

Figure 15 The position of the two members of the Artemesia Gravel: Singhampton (Pattern A) and Gibraltar (Pattern B).

Considering Logan's initial mapping and the importance of the deposit, it is here proposed that the major outwash system associated with the Gibraltar and Singhampton moraines be named the Artemesia Gravel. This Formation name would apply to all outwash sand and gravel deposited by meltwaters running westward from Gibraltar and Singhampton while ice built these moraines. Its extension to meltwater flowing south from the above locations as well as those which were deposited by meltwater of the Gait and Paris Moraines is suggested but not discussed here.

Artemesia Gravel

Two members of the Artemesia Gravel occur in the Durham area (Figure 15). First, the outwash gravel associated with the Singhampton Moraine mainly comprises plains, terraces and kame terraces with some channel fill or valley train. There is some tendency for these features to be a function of downstream facies changes. Second, outwash in front of the Gibraltar Moraine mainly forms terraces along the Saugeen River. In addition, a good portion of the Singhampton Moraine itself (see Page 54) consists of outwash sediment (see Photo 5).

Singhampton Member

In the Durham area the Singhampton member extends from Priceville to Letterbreen. The outwash around Priceville contains sheets of generally horizontally bedded cobbly gravel and sand forming a pitted plain. From Thistle southwest to Letterbreen a continuous outwash network occurs in terraces and kame terraces before passing downstream into valley train material. The outwash plain around Priceville and the upstream portion of Thistle-Letterbreen systems are horizontally bedded (Photo 7) showing an absence of foreset bedding which is similar to diffuse gravel sheets formed in upstream reaches (Hein and Walker, 1977). Around Holstein the outwash system is braided and foreset bedding starts to become noticeable although parallel stratification still dominates these cobbly gravelly sediments.

The above geological setting seems similar to the model proposed by Hein and Walker (1977) in gravelly braided streams: upstream areas show crude horizontal stratification and imbrication due to high rates of discharge of coarse gravel. Lower rates of discharge of finer gravel in downstream reaches should lead to more cross-stratification as bed evolution takes place. Other models of braided stream development have been proposed for other locations in this formation (Eynon and Walker, 1974; Fraser 1979).

The Artemesia Gravel fronting the Singhampton Moraine represents upstream proximal facies braided outwash with some stream bar development downstream. The importance of this type of precise environmental interpretation is that predictions about gravel distribution and quality can be made more readily. For example, the outwash system between Flesherton and Letterbreen is not well exposed yet its character seems to be quite comparable to the model of Hein and Walker (1977).

The distribution of gravel can be assessed by other means. The outwash plain around Priceville has a minimum thickness of five metres based on terrace-height estimates along the Saugeen River. The valley train from Thistle to Letterbreen is at least six metres thick and may be up to fifteen metres thick in places. The ice-contact terraces range from ten to fifteen metres in thickness and may be much thicker according to some water well data.

Lithologically the Artemesia Gravels are hard rounded cobbles of dolostone (85%) from the Amabel and Guelph Formations. Limestone (10%) and Precambrian (5%) clasts are present in these gravels in low amounts.

The stone content of these gravels is quite high as they range from 30-70% greater than 2 mm. In some of the valley trains, where lag deposits may have accumulated, hollow-stem auger borings have been stopped by boulders. These coarse lag deposits may prevent a better estimate of gravel reserves being determined in some areas, without the use of special equipment.

Gibraltar Member

The second member of the Artemesia Gravel Formation represents outwash in front of the Gibraltar Moraine extending from north of Glenelg Centre to west of Allen Park Station, passing to the northwest of Durham. A second branch of this system joins the first from directly north of Allen Park Station. This valley train system is defined by a well developed terrace system along the Saugeen and the Rocky Saugeen Rivers. (Photo 8)

This member has thicknesses of gravel up to 20 m in the area west of Durham. The best exposures of these gravels occur at the Durham Stone and Paving Company pit southeast of Durham. Here the outwash consists of crudely bedded and weakly horizontally stratified pebbly to cobbly gravel. These deposits were laid down as thin sheets of gravel on very active, wide, stream-beds typical of proximal braided - outwash systems. In places sandy, trough cross-bedding and ripple-drift cross-stratification are present in (Photo 9) indicating bar formation in the Middle reaches of the outwash system.

The material downstream from the Lamlash-Mulock region becomes quite sandy (only 10-15 gravel content) as opposed to up to about 40 per cent upstream. The lithology of these gravels is high dolostone (90%) with a few per cent limestone and Precambrian.

Meltwater Channels

The above discussion indicates that glacial ice meltwater has had an obviously important influence on the landscape of the Durham area. Outwash deposits have been cut into deeply, (Photo 9) adjacent to the modern streams especially along the Saugeen River and its tributaries, the South Saugeen and the Beatty Saugeen Rivers. Meltwater also deposited terraces graded to a short-lived lake that existed around the Neustadt area at 328 m (1075 feet) elevation.

There is a network of meltwater channels floored with outwash sand and organic material east and west of the Maple Lane Moraine. These channels are parallel to the end moraine crests and probably represent temporary ice-marginal positions where channel erosion took place.

Very active meltwater erosion occurred elsewhere in the area. Excellent fluvial terraces are present at Holstein, Bunessan, Edge Hill, and south of Mulock.

Ice-contact Stratified Drift

The stratified drift located in the end moraines of the area mainly consists of glaciofluvial material derived from proglacial streams. There are many other areas mapped as ice-contact stratified drift possessing characteristics which allow one to identify a specific environment.

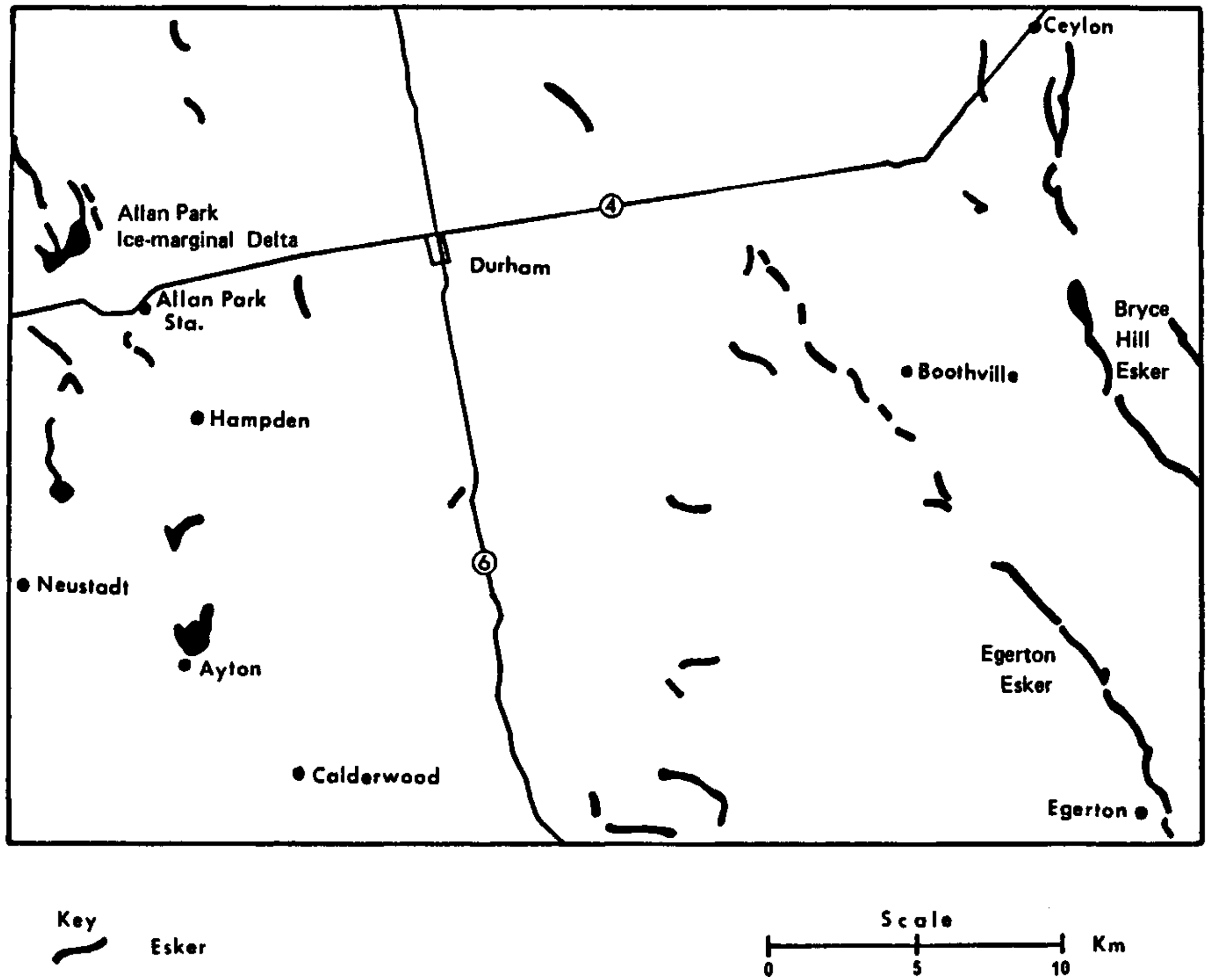


Figure 16 Location of eskers and ice-marginal deltas in the Durham map-area.

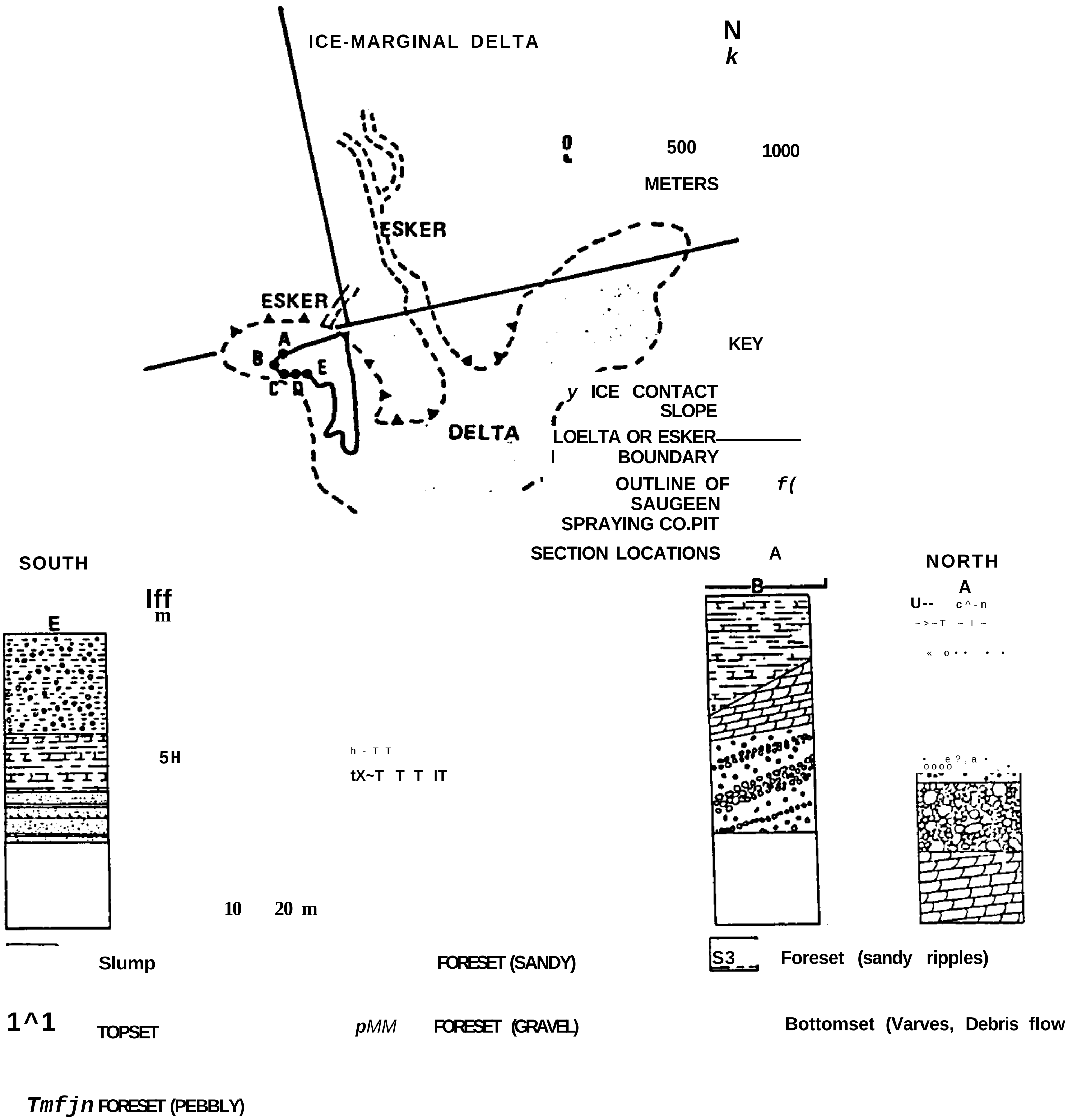


Figure 17 Sedimentary facies exposed in an ice-marginal delta at Allen Park Station.

Ice-marginal Deltas

There are at least five ice-marginal deltas present in the map are (Figure 16). This style of ice-marginal deposition is characteristic of terrain where a melting ice front is "retreating" down a regional slope and ponding meltwater in front of it - a condition which prevails in the area of the Saugeen River drainage area.

The ice-marginal delta at Allen Park Station is extremely well developed (Figure 17) so as to serve as a model for identifying other deltas. These possible deltas are transitional to moraine in their formation Powell (in press) or they appear to be isolated kames. These features are also present in the Chesley area (to the northwest) and the Markdale area to the north.

The ice-marginal delta at Allen Park Station (Figure 17) is almost 2 km wide and 0.5 km long with a height of 35 m. Steep (up to 35°), north-facing, ice-contact slopes form the delta's northern edge whereas the toe slopes gently (15°) south to the Saugeen River. One prominent esker (there are a few minor ones) leads into the north end of the delta and this can be traced for at least 5 km northwards.

The stratigraphy of this delta (Fig. 17) consists of silts and clays overlain by cross-laminated and plane-bedded sands which in turn are overlain by pebbly sands. The sequence represents a classic prograding delta system of bottomset, foreset and topset beds (Jopling and Walker, 1968). Towards the ice-contact slope and close to the esker source area, the lower facies consist of coarse steeply dipping gravel beds. These relationships are well displayed in Photos 11, 12 and in the thesis by Storrison (1979).

The form of various other kame-like deposits in the area (e.g. west of Calderwood; at Ayton; east of Neustadt; north of Neustadt; and, west of Hampden, (Fig. 16) where an esker leads in from the north, is similar to the delta northwest of Allen Park Station. Many of these features are poorly exposed although available pit faces show foreset units and topset bedding of deltaic or fan origin. Therefore by combining the facies associations (Fig. 17) and the kame-like landform at the end of an esker, it is interpreted to be an ice-marginal delta, depositional environment. Recognition of this type of depositional is important economically as more accurate inventories of aggregate resources can then be made. Site development and equipment needs (e.g. crusher) can be planned more efficiently as the sizing of the aggregate can be anticipated by the delta model (see pg. and Fig. 18).

Eskers

Eskers occur commonly in the Durham area and the most prominent are located on the Dundalk till plain. These eskers are oriented northwest-southeast or parallel to ice movement.

The eskers in this area are the beaded eskers of Banerjee and McDonald (1975). This implies a deglaciation environment where the esker stream entered standing water at the glacier terminus. These were short-lived ponds as there is a lack of lacustrine sediments other than the beads themselves, that represent delta formation. The deltaic beads contain mainly sand and pebbly sand whereas the esker ridges contain coarser sandy gravel. The Egerton esker, passing east of Egerton (Chapman and Putnam, 1951) has the above characteristics for its full length northwest to the area west of Boothville. Here it parallels a flat-topped ice-contact deposit containing mainly outwash gravel - this indicates that the depositional environment had changed to one of river activity rather than lake activity.

The larger esker passing east of Hopeville is continuous with the Bryce Hill Esker (Gwyn, 1976). It continues for 42 km from where it heads near Ceylon in the Singhampton Moraine southeastward through the Dundalk area to Camilla in the Orangeville map area. The lithologic data on these eskers is included in the Economic Geology section of this report.

Cowan (1979) reports that the eskers in the Palmerston area south of the Durham area relate to two ages (or episodes) of till deposition. The possibility exists that the Egerton esker had its beginning during the retreat of Tavistock ice from the area. With Elma ice having covered the whole area, it is feasible to think of the main esker formation in the Durham area as occurring during the recession of the Elma ice.

Crevasse Fillings

Crevasse fillings are short, linear ridges of sand, gravel and till which reflect the filling of surface fractures with washed sediment from the ice sheet. They form a subparallel system of low (5 m) ridges southeast of Bunessan. They indicate wasting of the glacier in place, and more of these features probably exist in the area because of the available ice-contact stratified drift.

Glaciolacustrine Sediments

Although glaciofluvial sediments dominate the landscape of the Durham area, glaciolacustrine sediments are important locally in some areas. The most prominent is the area around Neustadt which has a large area of clayey soil and fine sand. Fine-grained lacustrine sediments (clayey silt) occur up to 11 m thick, exposed in a river cut on the South Saugeen River. The fine sand facies however, has only been seen to be a few metres thick. These deposits originated as outwash sediments that fed into a lake that occupied a surface below 1075 feet a.s.l. This lake was held up by ice which built an ice-marginal delta northwest of Allen Park Station. Where outwash streams entered this small lake, (4 km west of Orchard; 6 km southwest of Durham) small pebbly sandy deltas have formed.

Other small areas of lacustrine material, mainly silts are sparsely scattered on the Elma Till surface east of the Singhampton Moraine. The largest of these areas occurs 6 km east of the Singhampton Moraine. . These small pondings formed as ice blocked drainage to the Saugeen River and to the Beaver Valley.

Recent Sediments

Bog and Swamp Deposits

There are few bog deposits in the Durham area due to the porous nature of the surficial cover. Nevertheless, bogs do occur in three main areas: on the level surface of the Elma Till, in small kettle-holes within the Singhampton and other moraines; and along wide, flat portions of former outwash channels. The bogs on the Elma Till surface tend to be broad features several metres thick and may have lacustrine silt or fine sand on the bottom. The bogs in kettle holes are small but quite deep, possibly 5 m or more. Organic sediment in former outwash channels are generally thin and they rest on outwash gravels. The shallowness of bogs in the Durham area leave little potential for their economic development.

Alluvium

Much of the alluvium in the Durham area is coarse, gravelly material as the present day streams are found on the floor of former wide outwash river systems. Terraces of this recent gravelly alluvium are well displayed along the Saugeen River, particularly the South branch. These deposits can be interbedded with wood debris (Photo 14) and at these sites, they preserve a history of flooding and base-level changes (lake levels) that need to be studied in detail. Karrow (1978) discusses the nature and occurrence of these terraces for the area bordering Lake Huron.

GEOLOGICAL HISTORY

This section on geological history focuses attention on the glacial activity which was responsible for the various soils deposited in the Durham area. Deposits mapped in the Durham area are all Late Wisconsinan in age. Figure 9 illustrates the history of Late Wisconsinan ice movement in the Durham area. Stratified drift (varied silt and clay) occurs beneath Catfish Creek Till just south of the area in the Palmerston area (Cowan 1979). These sediments are most likely related to local proglacial pond sedimentation prior to Catfish Creek ice advancing through the area.

Catfish Creek Till was deposited in Durham by Late Wisconsinan ice which moved across the area as a major advance from the northeast and continued through the southwestern Ontario peninsula to the southwest. This till is a very coarse-textured unit and this implies that Catfish Creek ice advanced through the area under conditions of free drainage with deposition of coarse outwash material. This deposition took place during the Nissouri Stadial approximately between 24,000 and 16,000 years ago when ice moved as far south as southern Ohio and Indiana (Dreimanis and Goldthwait, 1973).

The Erie Interstadial (16,000 to 15,000 years ago) marked an ice-free period in the southeast corner of the map including the Holstein area. The rest of the area was ice covered. The presence of this ice blocked normal drainage down the Saugeen River system and resulted in the deposition of varved clay and silt deposits in the southeast portion of the Durham area. A series of lakes existed during this interval (in front of this ice-retreat position) extending from Dundalk to London and perhaps further to the southwest (Fitzgerald, 1979). The evidence near Holstein provides the most precise northerly ice position during the Erie Interstadial and differs markedly from previous interpretations (Dreimanis and Goldthwait, 1973; Dreimanis, 1977).

Ice advancing from this retreat position reworked lacustrine sediments while it deposited the Tavistock Till, the first and most extensive of several similar tills deposited during the Port Bruce stadial (Cowan, 1979). This advance deposited Tavistock Till between Holstein and Orangeville where it built the Orangeville Moraine (Cowan, 1976). Ice melted back from here to the central portion of the Durham area prior to readvancing to slightly beyond the Maple Lane Moraine while laying down the Elma Till sheet. The similarity of this till to Catfish Creek and the limited time available during the Port Bruce Stadial (15,000 to 13,500 BP) suggests that a major reorientation of the ice did not take place at this time, but, that a relatively minor readvance of. the ice occurred.

Another very minor advance is represented in the valley of the Saugeen River by the Neustadt till. Glacial ice moved quickly or surged along the valley reworking lacustrine clays and silts. Alternately ice-marginal (debris flow) sedimentation was active.

The glacial activity in the Durham area was one of continued presence of glacial ice from about 23,000 years B.P. (Nissouri stadial) through to the 13,500 years ago (Port Huron time). The chronology is similar to that proposed for the Beaver Valley region, near Heathcote northeast of Durham (Pinch, 1979).

Before the glacier left the area a series of ice-marginal deltas were deposited between Neustadt and Allan Park Station. The best developed delta is at Allan Park Station where the ice straddled and blocked the Saugeen River. The small lake created has varved clays indicating a duration of less than fifty years. Several small deltas were deposited by outwash streams entering this lake. The lake drained when ice left the area around 13,500 year ago.

From the time of formation of the Singhampton Moraine through to the formation of the Gibraltar Moraine in the extreme northeast corner of the map extensive deposits of sand and gravel were laid down especially as outwash stream deposits. A series of the terraces developed along the Saugeen River as a result of these outwash systems and as a result of base level changes at Lake Huron associated with post-glacial lake levels.

Recent events in the area involved reworking of gravel as coarse alluvium along the modern streams and slow organic deposition along the abundant channel courses and in ice-stagnation depressions.

ECONOMIC GEOLOGY

Sand and Gravel Resources

Some of the largest gravel resources in Ontario lie in and adjacent to the Durham area. Logan in his 1863 report on the Geology of Canada mapped out the Artemesia Gravel (Fig. 14) - a vast sand and gravel formation deposited as glacial outwash systems in front of the Singhampton-Gibraltar and Paris-Gait moraines (Fig. 14). The significance of this relationship was also recognized by Taylor (1913) but was not generally followed up by other workers.

The southern extension of the formation forms the massive resources in the Durham area. These resources are conservatively estimated at several billion tonnes for the Durham area alone. The abundance of these aggregate resources should provide the local municipalities with sufficient planning opportunities to ensure the utilization of enough of this material to meet future future aggregate demands•

Aggregate extraction in the Durham area is controlled under the Pits and Quarries Control Act. Presently, twenty-five properties have been licenced for extraction. During field investigation, permanent processing operations existed on two of these properties and over 140 pits were identified. These two commercial operations are described below whereas the other main pits of the area are listed in Appendix B. Map P.1835 (back pocket) shows the distribution of sand and gravel and ranks the deposits as to their commercial potential.

The results of this survey plus some additional field work by E.V. Sado were combined to produced general estimates of the gravel resources of Artemesia (Sado, 1976a), Bentinck (Sado, 1976c), Glenelg (Sado, 1976b), Egremont (Sado, 1976e), Normanby (Sado 1976d) and Proton Townships. Subsequently, and following the collection and processing of additional data. Aggregate Resources Inventory Papers (ARIP) were published for these same townships^.

Durham Stone and Paving (80)^

This operation, located on lots 60, 61 and 62, concession 2, EGR, Glenelg Township, Grey County, has 182 acres of reserves remaining of 300 acres licensed under the Pits and Quarries Control Act*»

^ARIP No. 73, Artemesia Township
ARIP No. 82, Bentinck Township
ARIP No. 83, Glenelg Township
ARIP No. 85, Egremont Township
ARIP No. 84, Normanby Township
ARIP No. 51, Proton Township.

^Numnber refers to location on map (back pocket).

*Data supplied by Owen Sound District Office of the Ministry of Natural Resources.

The pit occurs in an outwash stream deposit laid down by an earlier and larger Saugeen River flowing to the south and southwest. Meltwaters from the receding ice front formed a series of terrace levels along the present branches of the Saugeen River. The deposit is generally 5 m thick and probably rests on bedrock in the northeast portion of the property. It has 0.5 m of topsoil and overburden. This pit has been in operation for several years and was previously described by Hewitt and Karrow (1963).

The deposit consists of massive to weakly stratified gravel (60-70% gravel) beds consisting of rounded to sub-ropunded dolomite. In places the deposit may consist predominantly of fine aggregate which occurs as troughs of cross-stratified sands interbedded with pebbly gravel. These sandy lenses are more prominent in the marginal areas away from the coarse deposits of main-channel flow but they affect less than 25% of the whole deposit.

Less than 5 percent of the gravel exceeds 10 cm while up to 60% is greater than 2.5 cm. Only a small percentage of fines (less than No. 200 mesh) and oversize material (greater than 10 cm) affect this deposit due to the good overall size sorting by high velocity streams.

The operation comprises crushing, screening and washing activities for a permanent hot-mix plant. A full complement of crushed, fine and coarse aggregate products are also available up to 19 mm (3/4 inch) stone.

This operation is typical of the potential for commercial operations that are possible from similar outwash deposits flanking the Saugeen River and its tributaries.

Saugeen Spraying Company (6)

The pit, owned by Victor Arnett, is located in lots 9 and 10, concession I, NDR, Bentinck Township. This operation occurs on the west flank of a large ice-marginal delta that was build into a glacial lake that stood at 328 m a.s.l. The distribution of fine and coarse aggregate in this deltaic form is influenced by the depositional environment in which the sediments were deposited. Sandy deposits up to 10 m thick generally occur around the lakeward perimeter (see Fig. 17, Page 67) of the feature on the south and west sides. Coarse cobbly gravel (approximately 2 m in thickness) underlies these sands especially towards the ice-contact slope or the north side of the feature. Towards the eastern edge of the property the material consists of steeply dipping beds of coarse cobbly gravel and sand (up to 12 m thick) deposited by a high energy stream (stream from an esker tunnel) entering the lake. As the lake level fell upon glacial retreat a i m cap of pebbly gravel and sand was formed atop the feature. Figure 17 and page 67 can be consulted for more details concerning the formation of this unique feature. This delta is unique in that it has a very well preserved form. The recognition of this form is important in locating similar deposits in the area.

The types of products produced from the pit are closely associated with the geological origin of the site. Fine aggregates, such as brick sand, are obtained from the perimeter of the delta whereas the coarse aggregates particularly road gravel are extracted from the central portions of the delta. In general, the supply of each of these aggregate materials is very predictable in this type of deposit (Fig. 18).

The aggregate extracted from this pit is processed through a portable crusher, and a permanent screening and washing plant which is located at the south end of the property.

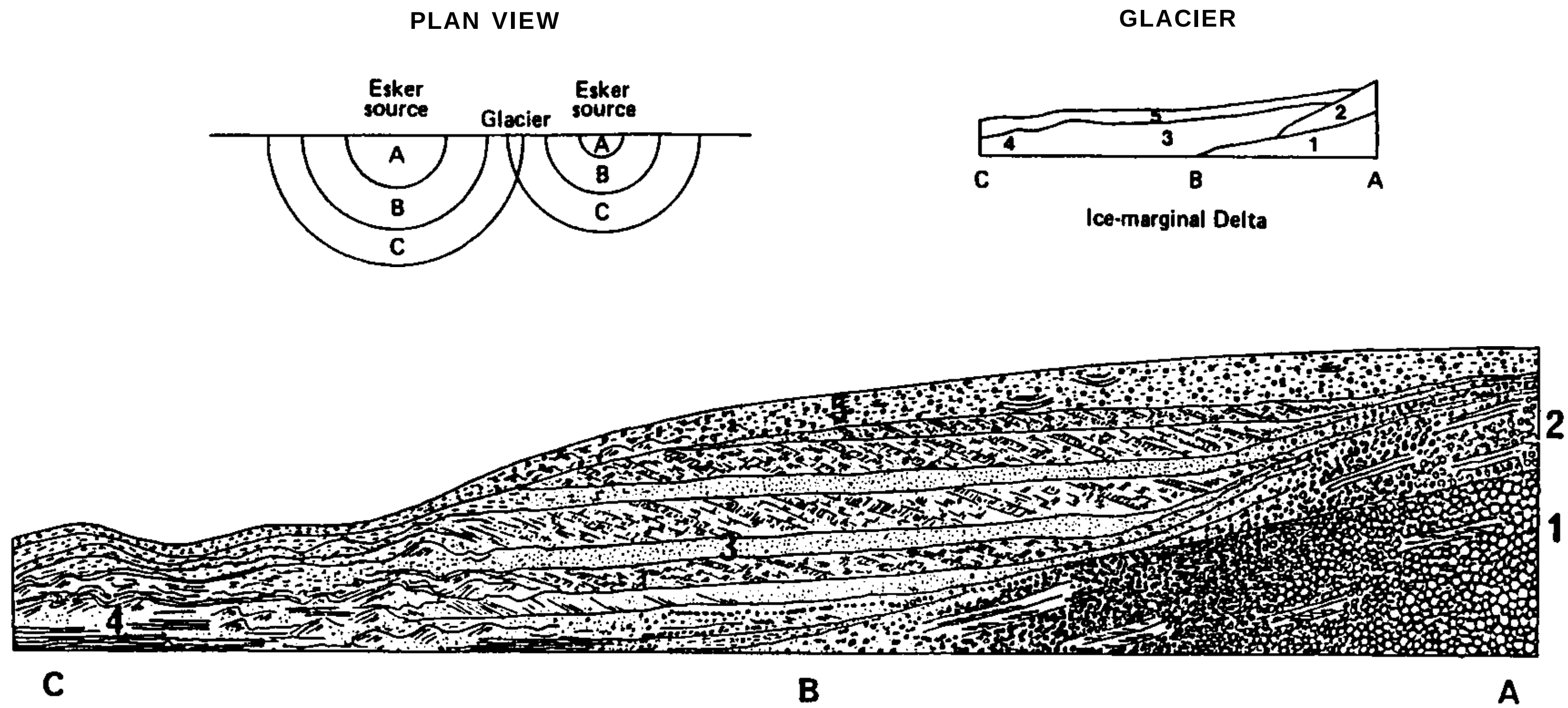


Figure 18 Schematic diagram of an ice-marginal delta lobe for aggregate potential.

	Delta Environment	Lithology	Aggregate Use
1)	Gravelly foreset beds	cobbly gravel	granular base, sub-base clear and coarse
2)	Gravelly sand foreset beds	gravelly sand	granular base and sub-base
3)	Sandy foreset beds	sand	fine aggregates
4)	Bottomset beds	sand, silt, clay	(common fines)
5)	Topset beds	pebbly sand	granular sub-base

Quality of aggregate and percentage of crushable material decreases as one goes from A to C

Engineering Geology

The engineering potential of the soil materials of the Durham area are summarized in Table The most significant engineering aspects of the soils in the Durham area relate to their resource potential. Supplies of construction materials for road construction and maintenance, bed material for drains and other building purposes are available in lareg quantities in all areas except Proton township.

The porous nature of most of the soils in the Durham area means that the area is a large groundwater recharge area. The area is also good for groundwater supply as indicated by the local streams which run high all summer long. The Guelph Formation is even more important for a larger and more stable water supply and most farm wells in the area established in this stratum.

[D]The reader is cautioned that the comments provided related only in a very general way to the geological unit in question. Geological units can vary significantly over short distances.

The engineering use to which a particular sit is put, should only be determined after a site specific investigation.

I ABLE 6 ENGINEERING SIGNIFICANCE Of GEOLOGIC UNI IS

GEOLOGICAL UN11/ ENGINEERING USE	BEDROCK GUELPH	SALINA	ELMA[1]	TILL TAVISTOCK[2]	CATFISH CREEK[3]	GLACIO-fLUVlAL	GLACIO-LACUSTRINE	ICE CONTACT DRIFT	ALLUVIUM	ORGANIC MATERIAL
Resource Potential										
Sand and Gravel	Poor	Poor	f air	Poor	fair	Excellent	Poor	Excel lent	Good-fair	Poor
Crushed stone	fair	Poor	(fill		(fill)					
Goundwater	Good	Poor	fair	Poor	fair	Good-fair	Poor	Good	Good-f air	Poor
Light Construction Conditions										
Excavation	Blasting	Shovel	Good	fair (Water)	Local Blasting	Good	fair	Good	fair	Poor
f oundat ion	Excellent	fair	Good	Good	Good		Good	Good	Poor	Poor
Grading	Difficult	Difficult	Good	fsir	Good	Good	fair(wet)	fair(steep)	Poor	Poor
Material Re-uae	Rockfill	Salt, gypsum	Good (Base-course)	fair	Good	Good	fair (CLay-lining)	Good	Aggregate	Peat
Waste Disposal Suitability										
Septic Systems	Very Poor (karstic)	fair-Poor	Good	Good	Poor	Poor	Good	Poor	Poor	Poor
Landfill	Very Poor	Poor	f sir	Good	fair	f air	Good	f ai r	Poor	Poor
Lagoona	Poor	Tair	Good	Good	fair	Poor	Good	Poor	Poor	Poor
Waste Disposal	Good (Salina)	Good					fair-Good	Poor	Poor	

[1] lest data for Elma lill N = 50; W_e - 10

[2] lest data for Tavistock Till N = 25; W_o = 15; W = 15; Wj = 25.

'[3] lest data for Catfish Creek lill N = 100; W_n = 10

Where N is the penetration resistance value; W_o is the natural **Muter** content; Wp is the plastic limit and Wj is the liquid limit.

REFERENCES CITED

Banerjee, I. and McDonald, B.C.
1975: Nature of Esker Sedimentation, p. 132-154, *in* Glaciofluvial and glaciolacustrine sedimentation edited by A.V. Jopling and B.C. McDonald, Special publication No. 23, Society of Economic Paleontologists and Mineralogists, 320 p.

Barnett, P.J.
1978: Quaternary geology of the Simcoe area, southern Ontario; Ontario Division of Mines, G.R. 162, 74p.

1979: Glacial Lake Whittlesey: the probable ice frontal position in the eastern end of the Lake Erie basin. Canadian Journal of Earth Sciences, Volume 16, p.568-574.

1980: Quaternary geology of the Tillsonburg area, southern Ontario; Ontario Geological Survey, O.F.R. 5308, 130p.

Burwasser, G.J.
1974: Quaternary geology of the Collingwood-Nottawasaga area, southern Ontario; Ontario Division of Mines, Preliminary Map P.919, Geological Series, scale 1:50 000. Geology 1973.

Chapman, L.J. and Putnam, D.F.
1943a: The moraines of southern Ontario; Transactions of the Royal Society of Canada, Volume 37, Section IV, p.33-41.

1943b: The Physiography of Southwestern Ontario, Scientific Agriculture, Volume 24, No.3, p.101-125.

1949: The recession of the Wisconsin glacier in southern Ontario: Transactions of the Royal Society of Canada, Volume 43, Series 3, p.23-52.

1951: The Physiography of Southern Ontario; University of Toronto Press, 284p.

1966: The Physiography of Southern Ontario; University of Toronto Press, 2nd ed., 386p.

Closs, G.
1979: A preliminary report on the trace element geochemistry of Upper Ordovician rocks of central southern Ontario; Ontario Geological Survey, Open File Report 5268, 26p.

Cowan, W.R.
1972: Pleistocene Geology of the Brantford Area, southern Ontario; Ontario Department of Mines, Industrial Mineral Report 37, 66p.

1974: Quaternary geology, Wingham (40P/14) and Lucknow (40P/13) areas, southern Ontario: p.189-191 in Summary of Field Work, 1974, by the Geological Branch, Ontario Division of Mines, MP 59, 206p.

1975a: Quaternary geology of the Woodstock area, southern Ontario, Ontario Division of Mines, GR 119, 91p.

1975b: Quaternary geology of the Walkerton area (41A/3) Bruce and Grey Counties; p.111-112 In Summary of Field Work, 1975, by the Geological Branch, Ontario Division of Mines, MP 63, 158p.

1976: Quaternary geology of the Orangeville area, southern Ontario; Ontario Division of Mines, GR 141, 98p.

Cowan, W.R.
1979: Quaternary geology of the Palmerston area, southern Ontario; Ontario Geological Survey, Report 187, 64p.

Cowan, W.R., Karrow, P.F., Cooper, A..J. and Morgan, A.V.
1975: Late Quaternary stratigraphy of the Waterloo-Lake Huron area. Southwestern Ontario; p.180-222 in Geological Association of Canada, Field trips Guidebook Part B, 330p.

Cowan, W.R., Sharpe, D.R., Feenstra, B.H. and Gwyn, Q.H.J.
1978: Glacial geology of the Toronto-Owen Sound area, p.1-16, guidebook, Toronto '78 edited by A.L. Currie and W.O. Mackasey, Geological Associaton of Canada, 361p.

deVreis, H. and Dreimanis, A.
1960: Finite radiocarbon dates of the Port Talbot Interstadial deposits in southern Ontario: Science, June 10, volume 131, No.3415, p.1738-1739.

Dreimanis, A.
1961: Tills of Southern Ontario; p. 80-96 in Soils of Canada, edited by R. Leggett, Royal Society of Canada, Special Publication No. 3, 240 p.

Dreimanis, A.
1962: Quantitative Gasometric Determination of Calcite and Dolomite by Using Chittick Apparatus; Journal of Sedimentary Petrolory, volume 32, No.3, p.520-529

1972: Surficial Geology, Port Stanley (401/11), (west half); Geological Survey of Canada, O.F.R. 85.

1977: Late Wisconsin glacial retreat in the Great Lakes region. North America. Annals of the New York Academy of Sciences, 298, p.70-89.

Dreimanis, A., and Karrow, P.F.
1972: Glacial History of the Great Lakes-St. Lawrence Region, the Classification of the Winsconsin(an) Stage and its Correlatives; p.5-15, in Section 12 (Quaternary Geology), 24th session International Geological Congress, 226p.

Dreimanis, A., and Goldthwait, R.P.
1973: Wisconsin Glaciation in the Huron, Erie and Ontario Lakes; p.71-106, in Geological Society of America Memoir 136, edited by R.F. Black, R.P. Goldthwait and H.B. Willman, 334p.

Evenson, E.B., Dreimanis, A., and Newsome, J.W.
1977: Subaquatic flow tills: a new interpretation for the genesis of some laminated till deposits, Boreas, volume 6, p. 115-133.

Eynon, G. and Walker, R.G.
1974: Facies relationships in Pleistocene outwash gravels southern Ontario: a model for bar growth in braided rivers; Sedimentology, volume 21, p.43-70.

Frazer, J.Z.
1979: Derivation of a quantitative lithofacies depositional model for the Caledon outwash - a Pleistocene braided stream deposit. Unpublished M.Sc thesis. University of Toronto, 317p.

Feenstra, B.H.
1975: Quaternary geology of the Markdale area (41A/7), Grey County: p.116-118 in Summary of Field Work, 1975, by the Geological Branch, Ontario Geological Survey, ed. Milne, V.G., D.F. Hewitt, K.D. Card, and J.A. Robertson, Ontario Division of Mines, Map 63, 158p.

Fitzgerald, W.D., Janicki, E., and Storrison, D.J.
1979: Quaternary geology of the Sarnia-Brights Grove area, southern Ontario; Ontario Geological Survey Preliminary Map P.2222, scale 1:50,000.

Gillespie, J.E. and Richards, N.R.
1954: Soil Survey of Grey County; Report No. 17 of the Ontario Soil Survey, 79p.

Gibbord, P.
1980: The origin of stratified Catfish Creek Till by basal melting; Boreas, v.9, p.71-85.

Gwyn, Q.H.J.
1972: Quaternary geology of the Dundalk area, southern Ontario; Ontario Department of Mines and Northern Affairs, Preliminary Map P 727, Geological Series, scale 1:50,000, Geology 1971.

1976: Quaternary geology of the Dundalk area, southern Ontario; Ontario Division of Mines, Open File Report 5132, 119p.

Gwyn, Q.H.J, and A. Dreimanis
1979: Heavy Mineral assemblages in tills and their use in distinguishing glacial lobes in the Great Lakes region. Canadian Journal of Earth Sciences, volume 16, No. 12, p.2219-2235.

Hein, F.J. and Walker, R.G.
1977: Bar evolution and development of stratification in the gravelly braided Kicking Horse River, British Columbia; Canadian Journal of Earth Sciences, volume 14, p.562-570.

Hewitt, D.F. and Karrow, P.F.
1963: Sand and gravel in Southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151p.

Hewitt, D.F. and Cowan, W.R.
1969: Sand and Grave in Southern Ontario 1967-1968; Ontario Department of Mines, Industrial Mineral Report 29, 105p.

Hoffman, D.W., Matthews, B.C. and Wickland, R.E.
1964: Soil associations of southern Ontario; Ontario Soil Survey Report No. 30, 21p.

Jopling, A.V. and Walker, R.G.
1968: Morphology and origin of ripple-drift cross lamination, with examples from the Pleistocene of Massachussets; Journal of Sedimentatary Petrology, Volume 38, p.971-984.

Karrow, P.F.
1968: Pleistocene geology of the Guelph area; Ontario Department of Mines, GR 61, 38p.

1971: Quaternary geology of the Stratford-Conestoga area; Geology Survey of Canada, Paper 70-34, lip.

1974: Till stratigraphy in parts of southwestern Ontario Geological Society of America Bulletin, Volume 85, p.761-768.

1977: Quaternary geology of the St. Mary;s area, southern Ontario, Ontario Division of Mines, GR 148, 65p.

1978: The relationship of valley terraces and glacial lake levels east of Lake Huron, Ontario, Canada; Geological Society of America, North Central Section, Abstract with programme, Ann Arbor, Michigan, p.258.

Karrow, P.F., Ben-Tahir, I., Steele, D.B. and Morrison, W.D.
1965: Durham Sheet, Bedrock Topography Series, Ontario Division of Mines Preliminary Map P.305, scale 1:50,000.

Karrow, P.F. and Anderson, T.W.
1975: Palynological study of lake sediment profiles from southwesten New Brunswick: Discussion, Canadain Journal of Earth Sciences, Volume 12, p.1808-1812.

Karrow, P.F., Cowan, W.R., Dreimanis, A., and S.N. Singer
1978: Middle Wisconsinan stratigraphy in southern Ontario, p.17-17, guidebook, Toronto '78 edited by A.L. Currie and W.O. Mackasey, Geological Association of Canada, 361p.

Keele, J.
1924: Preliminary report on the clay and shale deposits of Ontario; Geological Survey of Canada, Memoir 142, 176p.

Leverett, F. and Taylor, F.B.
1915: The Pleistocene of Indiana and Michigan and the history of the Great Lakes; United States Geological Survey, Monograph 53, 529p.

Liberty, B.A. and Caley, J.F.
1969: Geology, Bruce Peninsula area, Ontario; Geological Survey of Canada, Map 1194A, scale 1:257,440. Geology (1940-1958).

Liberty, B•A. and Bolton, T.E.
1971: Paleozoic geology of the Bruce Peninsula area, Ontario; Ontario Geological Survye, Memoir 360, 163p.

Logan, W.E.
1863: Superficial geology; p.886-930 in Report on the geology of Canada. Geological Survey of Canada, Report of Progress to 1863, p.983. Accompanying Atlas published 1865, 42p.

Miall, A.D.
1977: A review of the braided river depositional environment; Earth Science Reviews, volume 13, p.1-62.

1978: Lithofacies types and vertical profile models in braided river deposits: a summary; A.D. Miall, editor. Fluvial sedimentology, Canadian Society of Petroleum Geologists, Memoir 5, p.597-604.

Pinch, J.J.
1979: Sedimentology and Stratigraphy of Wisconsinan deposits in the McKittrick site and Beaver River George, Clarksburg, Ontario. Unpublished M.Sc thesis. University of Western Ontario, 103p.

Powell, R.D.
in press: A model for sedimentation by Tidewater Glaciers, International Glaciological Society, Symposium on Glacier Beds, Geilo, Norway.

Prest, V.K.
1970: Quaternary Geology of Canada; p. 676-764 in Geology and Economic Minerals of Canada, R.J.W. Douglas, editor, 838p.

Putnam, D.F. and Chapman, L.J.
1943: The Drumlins of Southern Ontario in p.75-87, Transaction of the Royal Society of Canada, Section IV, p.75-90.

Sado, E.V.
1976a: Granular Aggregate Inventory of Artemesia Township, Grey County, Ontario; Ontario Division of Mines, Open File Report 5165, 18p.

1976b: Granular Aggregate Inventory of Glenelg Township, Grey County, Ontario; Ontario Division of Mines; Open File Report 5166, 19p.

1976c: Granular Aggregate Inventory of Bentinck Township, Grey County, southern Ontario; Ontario Division of Mines, Open File Report 5167, 24p.

Sado, E.V.
1976d: Granular Resources of Normanby Township, Grey County, Ontario; Ontario Division of Mines, Open File Report 5168, 16p.

1976e: Granular Aggregate Inventory of Egremont Township, Grey County, Ontario; Ontario Division of Mines, Open File Report 5169, 18p.

Sharpe, D.R.
1975: Quaternary geology of the Durham area (41A/2), Grey County; p.113-115 in Summary of Field Work, 1975, by the Geological Branch, Ontario Division of Mines, MP 63, 158p.

Sharpe, D.R.
1978: A revised correlation of the Port Huron Moraine system in southern Ontario; Geological Society of America, Abstracts with Programs, Volume 10, p.284.

Sharpe, D.R. and Broster, B.E.
1977: Quaternary Geology of the Durham area, southern Ontario; Ontario Geological Survey, Preliminary Map P.1556, scale 1:50,000.

Sharpe, D.R. and Broster, B.E.
1978: Sand and Gravel Resources of the Durham Area, Grey County, Southern Ontario; Ontario Geological Survey of Preliminary Map P.1835, Geological Series, scale 1:50,000. Geology 1975.

Sharpe, D.R. and Clue, Jack
1978: Bedrock Topography of the Durham area, Southern Ontario; Ontario Geological Survey, Map p.1836, Bedrock Topography Series, scale 1:50,000. Compilation 1977, 1978.

Sharpe, D.R. and Edwards, W.A.D.
1979: Quaternary Geology of the Chesley-Tiverton Area, southern Ontario; Ontario Geological Survey, Preliminary Map P.2314, Geological Series, scale 1:50,000. Geology 1976, 1977: stratigraphic drilling, 1978.

Storrison, D.J.
1978: A paleoenvironmental reconstruction of an ice-marginal delta northwest of Durham, Ontario; Unpublished B.Sc. thesis, University of Toronto, 117p.

Taylor, F.B.
1897: Moraines of Recession and Their Significance in Glacial History, p.421-465. Journal of Geology, 1897, (July-August) 54p.

1909: Field Work on the Pleistocene Deposits of Southwestern Ontario, p.103-111. Geological Survey of Canada, Summary Report, 1909.

1910: Field Studies on the Pleistocene deposits of Southwestern Ontario, p.164-167, Geological Survey of Canada, Summary Report, 1909.

1912: Pleistocene Deposits of Southwestern Ontario, p.262-268. Geological Survey of Canada, Summary Report, 1911.

1913: The Moraine Systems of Southwestern Ontario, Transactions of the Canadian Institute, Volume 10, p.1-23.

1939: Correlatives of the Port Huron Morainic System of Michigan in Ontario and Western New York; American Journal of Science, Volume 237, No.6, p.375-388.

Terasmae, J., Karrow, P.F. and Dreimanis, A.
1972: Quaternary Stratigraphy and Geomorphology of the Eastern Great Lakes Region of Southern Ontario; Guidebook, Excursion A42, 24th International Geological Congress, Montreal, 75p.

Warren, H.V. and Delavault, R.E.
1961: The lead, copper, zinc and molybdenum content of some limestones and related rocks in Southern Ontario; Economic Geology, volume 56, No. 7, p.1265-1272.

APPENDIX A

Measured Quaternary Sections and Borehole Logs

1. Measurement in metres from the surface down with approximate accuracy of .1 m due to variations in thickness•
2. Elevations in feet (metres) at top of section.
3. Sections and boreholes are shown on Figure 19and the NTS grid references refer to Durham map sheet 41A/2 which is contour in feet. see Map 1, back pocket.

Section 1016 G.R. 288728 Elevation 1500 ft (457 m)

A:	0-2 m	Elma Till: loose, fissile sandy silt, sand lenses.
	2-6 m	Tavistock Till: blocky, brown, clayey silt till.

Section 1384 G.R. 128713 Elevation 1175 ft (358 m)

A:	0-1.5 m	Elma Till: loose, stratified, yellowish brown sandy silt.
B:	1.5-3.5m	Stratified fine sand with silt and silt clay, wet.
C:	3.5-6.0m	Elma Till: loose, yellowish sandy silt; reddish clay-silt block, slumped.
D:	6.0-7.0m	Tavistock Till: stoney, clay silt, reddish brown•

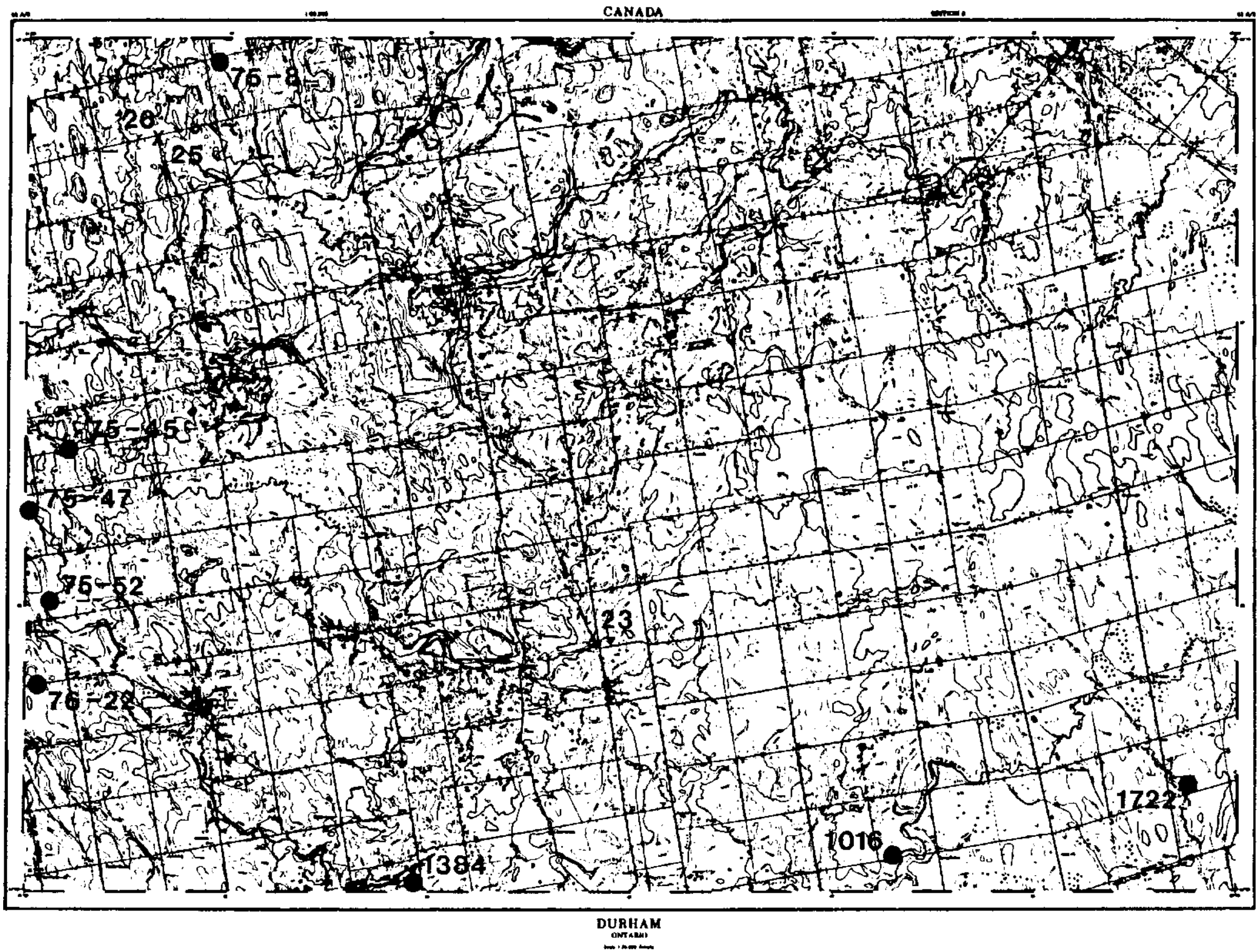


Figure 19   Location of Measured Sections (•) and Boreholes (X)

Section 1722 G.R. 383751 Elevation 1500 ft (472 m)

A: 0-1 m Elma Till: loose, yellowish brown, sandy silt till (Sample 1722N).

B: 1-3 m Tavistock Till: laminated, water laid reddish brown clayey silt till, to massive, basal till (Sample 1722T).

C: 3-5 m Catfish Creek Till: very stiff, yellow brown stoney sandy silt (Sample 1722CC-2).

Section 75-8 G.R. 062988 Elevation 1150 ft (351 m)

A: 8m Elma-Catfish Creek Till: massive, stoney silty sand, fissile at surface, block stiff at base.

Section 75-45 G.R. 013860 Elevation 975 ft (297 m)

A: 0-3-5 m Medium, white-grey sand with some stone.

B: 3.5-9.5m Elma Till: yellowish brown sandy silt, very stiff blocky (Samples 75-45-A, B).

C: 9.5-11.0m Faintly stratified to massive clayey silt and the fine infrequent stone; gradational into above till.

Section 75-47 G.R. 002843 Elevation 890 ft (271 m)

A: 0-.3 m Silty fine sand, organic-rich at top.

B: .3-1 m Pebbly sand with common shells (modern ostracods).

C: 1-1.5 m Organic material, logs, branches.

D: 1.5-1.6m Pebbly, cobbley gravel.

E: 1.6-2.6m Grey, stoney sandy silt til, common Salina Formation.

Section 75-52 G.R. 006808 Elevation 950 ft (290 m)

A: 0-3 m Massive, yellowish brown, fine sand.

B: 0-5 m Laminated, grey fine sand with silt.

C: 5-15 m Massive, light brownish grey, clayey silt till, stone-poor; Neustadt till?

Section 76-22 G.R. 004784 Elevation 1090 ft (332 m)

A: 0-2 m Neustadt till: yellowish brown, blocky, silt clayey silt.

Borehole 23 (Holstein) G.R. 51898798 Elevation 1350 ft (411 m)

A: 0-8 m Outwash gravel: pebbly to cobbly, rounded with good sand lenses.

B: 8-10 m Tavistock Till: brown, clayey silt till.

C: 10-13 m Catfish Creek Till: very dense, stoney, sandy silt till.

- hole terminated, too dense to procede.

Borehole 16 (Lamiash) G.R. 50428958 Elevation 975 ft (279 m)

A: 0-5 m Outwash: cobbly to pebbly gravel.

B: 5-12 m Medium sand, minor gravel, water table at 10 m mark.

C: 12-22 m Laminated silt and clay to mainly massive silt and clay.

- terminated as gravel zone had been passed.

Borehole 25 (Saugeen River) G.R. 50438953 Elevation 960 ft (293 m)

A: 0-15 m Interstratified medium sand and poorly sorted gravel.

B: 15 m Guelph Formation dolostone.

APPENDIX B

Till analyses (sample locations are plotted on Map back pocket)•

1. Except for pebble lithologies, all laboratory analyses were carried out by the Geoscience Laboratories of the Ontario Geological Survey.
2. Sand-silt boundary is 62.5/* ; silt-clay boundary diameter is ***2^l\.***
3. Pebble counts were done on 1 - 4 cm fraction.
4. Carbonate analysis were done on -200 mesh (74**/4)** fraction using Chittick Apparatus.
5. Heavy mineral separations were done on the -60 to +120 mesh (250 to ***125*** fraction using tetrabromoethome (S.G.= 2.96).
6. Till identification: CC - Catfish Creek Till; D - Neustadt Till; E - Elma Till; T - Tavistock Till.
7. Samples located outside the area are indicated by letters opposite sample numbers: P - Palmerston, W - Walkerton, O - Orangeville.

APPENDIX B

ocet ion	U U	Grid Reference	IEX1URL (Matrix) Sand K	Silt \	Clay S	H	PEBBLE LI1H0L0GV Lime-stone	Dolo-Btone	Chert	Clastic	Precam-brian	Limestone Dolostone	CARBONATES				HEAVY MINERALS Heavies	Magnetics	1RACE ELEMENTS	AIIERBURG LIMIIS Liquid Limit	Plastic Limit	Index of Plasticity
HP)	I	5328/8565	38.0	46.8	15.2	5							0.1	3.6	30.0	33.0	2.6	9.6		31	18	13
2(P)	1	5328/B565	31.0	52.B	16.2	B							0.6	20.7	33.9	54.6	2.0	11.3		20	13	7
3	N	5032/8892	13.0	47.4	39.6	35							0.3	13.3	42.3	55.6	2.3	14.5		14	14	0
4	N	5032/8892	10.5	50.5	39.0	43							0.3	14.7	42.1	56.8	2.3	18.1		too sandy		-
5	N	5103/8991	11.0	39.4	49.6	63							0.1	7.3	55.3	62.6	1.8	12.1		too sandy		-
6	1	5013/8825	16.5	76.9	6.6	11							0.6	18.1	34.1	52.9	2.5	11.1		19	15	4
7	N	5129/8973	13.8	43.8	42.4	48							0.3	16.2	56.1	72.3	1.5	18.2		13	13	1
B	CC	5189/8798	-	-	-	-																
9	CC	5189/8798	-	-	-	-																
10	N	5051/8776	12.0	43.0	35.0	-	-	-		-	-	-	0.2	10.1	51.1	61.2	2.3	13.5		14	12	2
11	I	5240/8720	22.0	49.2	28.8	14	5	67		1	7	.1	0.4	13.6	35.0	48.6	2.4	22.2		18	14	4
12	I	5344/8737	34.0	54.2	11.8	4	-	-		-	-	-	0.7	19.5	29.5	49.0	1.8	11.8		24	15	9
13	I	5264/8719	29.0	48.4	22.6	8	-	-		-	-	-	0.6	18.0	30.4	48.4	2.6	8.4		23	13	10
14(0)	T	Orangeville	24.0	61.4	14.6	13	-	-		-	-	-	0.07	2.4	33.9	36.3	2.4	9.6				
15(0)	1	Orangey tile	27.5	54.5	18.0	8	-	-		-	-	-	0.6	19.7	33.1	52.6	1.6	10.3				
16(0)	1	Orangeville	15.5	60.3	24.2	25	-	-		-	-	-	0.3	16.6	51.7	68.3	1.3	12.8				
17	I	5257/8755	41.0	50.4	8.6	3	3	88		-	9	.03	0.6	19.6	32.3	51.9	1.9	14.3		30	17	13
18	1	5284/8587	21.5	5B.1	20.4	12	-	-		-	-	-	0.4	16.3	36.5	52.8	2.1	9.7				
19	I	5335/8758	44.5	49.1	6.4	2	10	85		-	5	.1	0.8	20.4	24.7	45.1	ᔕ	11.0		29	18	11
20	T	5212/8763	36.0	41.0	23.0	5	14	71		1	14	.2	0.5	13.6	27.9	41.5	2.2	13.0		24	15	9
21	I	5384/8751	20.0	49.2	31.8	27	7	89		-	4	.1	0.4	17.0	43.2	60.2	1.6	17.0				
22	•I	5384/8751	46.0	44.0	10.0	2	9	89		-	3	.1	0.5	14.5	28.3	42.8	1.8	13.6		32	19	13
23	1	5384/8751	47.0	43.0	10.0	2	1	-		-	-	-	0.6	20.4	36.5	56.9	2.2	10.3				
24	?	5237/8747	37.0	50.8	12.2	5	10	77		3	. 10	.1	0.6	16.5	26.0	42.5	1.8	9.7				
25	N	5337/8751	19.5	4B.5	32.0	24	-	-		-	-	-	0.5	19.8	38.8	58.6	1.8	12.2				
26	N	5286/8727	14.0	43.2	42.8	48	14	84		-	2	.2	0.2	9.5	48.6	58.1	1.5	10.9		- too sandy		0
27	N	5274/8769	19.0	57.8	23.2	IB	-	-		-	-	-	0.4	14.0	39.0	53.0	1.8	13.2				
2a	N	5330/8790	17.4	52.8	30.2	34	11	85		1	a	.1	0.4	14.7	42.5	57.2	1.6	12.0				
29	N	5364/8848	14.5	51.1	34.4	35	≅	89		1	2	.1	0.09	4.6	48.8	53.4	2.0	15.0				
30	N	5399/8816	11.8	44.8	43.4	48	12	84		1	3	.1	0.07	3.7	57.8	61.5	1.8	17.4				
31	N	5381/8851	14.4	50.6	35.0	38	12	83		1	4	.1	0.2	12.1	48.8	60.9	1.8	13.9				
32	N	5291/8830	10.4	49.2	40.4	46	20	67		2	11	.3	0.2	7.9	48.8	56.7	2.0	16.5				
33	N	5282/8719	17.0	45.6	37.4	38	a	83		-	9	.1	0.3	16.1	46.3	62.4	2.0	15.2				
34	N	5209/8912	10.2	38.4	51.4	66	-	-		-	-	-	0.3	15.2	56.1	71.3	2.0	19.6				
35	N	5257/8755	15.2	45.0	39.8	39	-	-		-	-	-	0.4	18.4	41.5	59.9	2.0	16.4		13	12	1
36	N	5257/8755	24.0	56.2	19.8	7	-	-		-	-	-	0.4	14.7	40.0	54.7	2.2	21.9				
37	N	5257/8755	24.2	54.8	21.0	14	-	-		-	-	-	0.5	16.4	36.7	53.1	2.4	17.3				
38	N	5384/8751	16.0	52.2	31.8	27	10	82		-	8	.1	0.4	14.4	34.8	49.2	1.9	20.5				

APPENDIX B

Location	till	Grid Reference	Sand \	Silt %	Clay S	M	Lime-stone	Dolo-StoiH	Chert		Clastic	Precam-brian	Limestone Dolostone					S Heavies	% Magnetics		Liquid Limit	Plaatic Limit	Index of Plasticity	
			1EX1URE (Hatnx)				PEBBLE L1IH0L0GY							CARBONATES				HEAVY MINERALS		TRACE ELEMENTS	AT TERBURG LIMITS			
39	N	5188/8814	8.5	36.0	55.5	80	5	88			1	6	.1	0.2	9.5	50.9	60.4	2.3	12.5	- - - -	14	13	1	
40	N	5295/8943	15.1	48.9	36.0	35	-	-			-	-	-	0.3	11.6	45.9	57.5	2.8	18.0		16	14	2	
41	N	5295/8943	45.0	50.2	4.8	5	-	-			-	-	-	0.6	19.7	31.0	50.7	2.6	9.1	- - - -	30	11	19	
42	N	5234/B995	12.5	48.9	38.6	42	9	88			-	3	.1	0.3	15.2	58.5	73.7	1.2	11.8	- - - - -				
43	N	5295/8939	14.5	47.3	38.2	40	8	88			1	3	.1	0.2	10.1	56.1	66.2	1.3	12.1					
44	N	5347/8990	12.0	56.6	31.4	30	-	-			-	-	-	0.5	15.2	32.3	47.5	2.0	19.7	- - - -	17	15	2	
45	N	5305/8967	17.5	60.1	22.4	17	-	-			-	-	-	0.2	12.7	52.2	64.9	1.5	21.1	- - - -	17	13	4	
46	N	5008/8712	9.1	48.3	42.6	45	-	-			-	-	-	0.05	3.0	56.4	59.4	2.4	14.8					
47	N	5024/8803	19.9	45.1	35.0	19	-	-			-	-	-	0.1	6.3	46.1	52.4	3.3	10.6					
4B	N	5D25/8805	9.0	58.4	32.6	29	-	-			-	-	-	0.1	6.1	44.6	50.7	2.3	15.8	-	too sandy			
49	N	5067/8988	15.4	46.0	38.6	40	9	85			-	2	.1	0.4	17.3	46.3	63.6	1.8	13.7					
50	N	5175/8943	9.0	40.1	50.9	66	10	84			2	4	.1	0.1	5.7	56.1	61.8	2.3	16.4					
51	N	5086/8952	14.0	41.2	44.8	51	10	77			6	7	.1	0.3	15.9	50.9	66.8	2.0	16.7					
52	N	5086/8952	13.0	44.0	43.0	47	12	81			3	4	.1	0.3	17.0	45.9	62.9	2.4	19.5					
53	N	5012/8860	15.0	53.6	31.6	22	-	-			-	-	-	0.4	15.3	35.8	51.1	2.8	18.4	- - - -	15	14	1	
54	N	5012/8860	11.0	57.8	31.2	33	9	79			-	12	.1	0.2	7.8	40.2	48.0	2.0	16.7	- - - -	16	14	2	
55	I	5332/8902	29.5	66.3	4.2	6	-	-			-	-	-	0.1	4.32	32.5	36.8	2.9	5.1	- - - -	28	19	9	
56	D	5008/8811	17.0	76.0	7.0	a	-	-			-	-	-	0.6	20.3	31.4	51.7	2.0	13.6	- - - -	18	14	4	
57	CC	5264/8719	11.0	43.6	45.4	52	16	71			-	13	.2	0.3	14.5	49.7	64.2	2.1	15.5	- - - -	too sandy		-	|
58	cc	5400/8712	13.5	47.5	39.0	40	12	84			1	3	.1	0.3	15.7	50.1	65.8	1.8	13.3	- - - -	17	13	4	
59	CC	5118/8718	5.0	49.9	45.1	53	-	-			-	-	-	0.1	6.1	53.4	59.5	2.1	7.2	-	too ssndy		-	^
60	I	5243/8706	-	-	-	-	-	-																
61	CC	5243/8706	14.0	54.4	31.6	32	-	-	-	-		-	-	0.3	13.2	43.2	56.4	1.7	15.4	-	too sandy		-	I
62	CC	5234/8699	15.0	45.6	39.4	40	15	77	-	-		8	.2	0.3	14.2	45.7	59.9	2.1	12.1					
63	CC	5255/8717	11.5	51.2	36.8	42	12	80	1	-	1	6	.2	0.2	11.1	50.7	61.a	1.8	14.3					
64	CC	5384/8751	11.4	44.3	44.3	50	1	-	-	-		-	-	0.2	13.2	57.6	70.8	1.8	13.B	- - - - -				
65	CC	5384/8751	12.0	44.2	47.8	52	-	-	-	-		-	-	0.2	13.4	57.4	7.08	1.7	16.1	-	too ssndy			
66	CC	5290/8729	10.0	47.6	42.2	48	-	-	-	-		-	-	0.2	8.8	52.0	60.8	1.8	13.7	-	too ssndy			
67	CC	Orangeville	12.0	45.4	42.6	47	-	-	-	-		-	-	0.3	14.8	57.4	72.2	1.7	12.3					
68	N	5049/8985	12.0	44.0	44.0	49	13	78	-			9	.2	0.3	14.6	47.B	62.4	2.1	14.7	-	too sandy			
69	D	Halkerton	21.0	62.2	16.8	9	-	-	-	-		-	-	0.6	18.4	29.3	47.7	2.7	16.9	- - - -	22	16	6	
70	N	5307/8828	9.0	62.2	28.8	35	-	-	-	-		-	-	0.3	13.1	37.5	50.6	1.9	13.7	- - - - -				
71	N	5257/8755	6.0	43.8	50.2	63	4	91	-	-		5	.04	0.2	10.4	49.4	59.8	2.4	14.6					
72	CC	5400/8712	9.0	42.5	48.5	56	-	-	-	-		-	-	0.3	13.7	49.0	62.7	2.3	12.5	- - - - -				
73	CC	5400/8712	12.8	46.9	39.3	42	-	-	-	-		-	-	0.3	13.3	52.4	65.7	1.7	11.3					
74	1	5243/B706	37.5	54.7	7.8	4	7	B1	-	-		12	.1	0.3	16.3	30.2	54.2	2.3	6.9	- - - -	25	16	9	
75	N	5046/8B40	8.4	61.2	30.4	26	-	-	-	-		-	-	0.3	13.6	40.7	54.2	2.3	12.6					
76	I	5243/8306	20.0	54.5	25.5	17	-	-	-	-		-	-	0.6	19.7	33.7	53.4	2.1	11.4	- - - - -				

APPENDIX B

Location	Till	Grid Reference	TEXTURE (Matrix) Sand	Silt s	Clay	M	PEBBLE L IIHOLOGV Lime-stone	Dolo-stone	Chert	Clastic	Precam-brian	Limestone Dolostone	CARBONATES				HEAVY MINERALS Heavies	Magnetics	I RACE ELEtCNTS				AT TERBURG LIMITS Liquid Limit	Plastic Limit *	Index of Plasticity
77	T	5243/8706	40.4	43.6	16.0	3.4	-						0.9	23.7	27.9	51.6	2.3	. 13.2	-	-	-	-	-	-	-
78	I	5243/8706	17.5	56.5	26.0	14							0.5	18.1	38.5	56.6	2.3	10.2	-	-	-	-	-	-	-
79	I	5243/8706	25.7	61.7	12.6	10							0.5	16.9	36.7	53.6	1.7	14.8	-	-	-	-	-	-	-
80	I	5189/8798	29.0	46.0	25.0	8.0	-						0.6	20.4	32.7	53.1	0.7	31.2	-	-	-	-	-	-	-
BMP)	CC	5147/8712	13.0	47.0	40.0	3B	-	-	-	-			0.4	15.5	43.2	58.7	2.4	12.8	-	-	-	-	-	-	-
82(P)	CC	5234/8706	13.0	53.5	33.5	34							0.5	18.4	41.3	59.7	1.7	12.9	-	-	-	-	-	-	-
83(H)	D	4998/8783	18.0	66.0	16.0								0.59	17.7	34.8	52.5	2.2	18.6	22	36	14	J7	18	15	3
84(W)	D	4998/8783	18.0	67.0	15.0	-							0.51	17.5	73.9	51.4	2.2	15.4	21	40	15	40	18	16	2
85	D	5005/8784	12.0	73.0	15.0								0.4D	13.7	34.6	48.3	2.5	17.5	22	40	16	41	21	17	4
B6(P)	CC	5147/8712	13.0	47.0	40.0	JB							0.36	15.5	43.2	58.7	2.4	12.8	14	30	6	26	-	-	-
87(P)	CC	524 J/8706	13.0	53.5	33.5	34							0.45	18.4	41.3	59.7	1.7	12.9	16	36	6	27	-	-	-
BB(P)	T	5243/8706	20.0	54.5	25.5	17							0.59	19.7	33.7	53.4	2.1	11.4	19	46	13	40	-	-	-
89(P)	I	5147/8712	40.4	43.6	16.0	3.4	-						0.85	23.7	27.9	51.6	2.3	13.2	21	50	17	47	-	-	-
90(P)	I	5147/8712	17.5	56.5	26.0	14							0.47	18.1	38.5	56.6	2.3	10.2	16	36	9	33	-	-	-
91(P)	N	5075/8714	18.0	65.0	17.0	14							0.36	13.9	39.2	53.1	2.8	12.9	18	46	13	37	-	-	-
92	N	5384/8751	11.5	41.5	47.0	53							0.44	19.3	43.8	63.1	1.9	14.9	19	48	9	25	-	-	-
93	N	5394/8987	12.0	44.5	43.5	51							0.53	18.3	34.8	53.1	2.4	11.2	32	56	10	34	-	-	-
94	N	5316/8837	21.0	63.5	15.5	12							0.58	19.3	33.3	51.6	1.7	12.8	23	48	14	39	-	-	-
95	N	5023/8828	9.1	41.1	49.8	63							0.10	4.28	43.8	48.1	2.9	13.1	21	34	10	32	-	-	-
96(W)	N	5188/8869	9.0	32.0	59.0	105	-	-					0.26	15.4	58.7	74.1	2.1	16.1	too coarse				-	-	-
97	D	4997/8765	21.3	64.7	14.0	8.5	-						0.73	21.8	29.7	51.5	2.4	12.8	20	45	14	38	24	15	9
98	D	5007/8808	33.0	60.6	6.4	9	-	-			-			-	-	-	1.8	16.7	too coarse				-	-	-
99	N	5375/8961	28.8	59.6	11.6	5.2	-	-	-				0.94	19.4	20.4	40.1	1.5	8.7	26	63	20	51	22	17	5
too	CC	5040/8768	20.0	76.0	4.0	8	-	-					0.69	20.4	29.7	50.1	4.0	12.7	20	42	13	36	22	17	5

APPENDIX C

Pits are located by property number on Map in back pocket.

Descriptive data for gravel or sand pits visited during the field survey.

NOTES:

1. Estimated or inferred resources include the area immediately surrounding a pit. Resources are indicated as follows:

   Small (S) less than 1.5 million tonnes;
   Medium (M) 1.5 to 5.0 million tonnes;
   Large (L) more thatn 5.0 million tonnes.

2. Pits are numbered on an alphanumeric system by county, township, concession and lot. For townships crossed by Highway 4 and 6, the concession designator N and S, and E and W, refer to concessons which are adjacent to the Durham N, SDR (Highway 4) and the Garafraxa Road (E, WGR); (Highway 6) respectively.

3. Pebble lithologies are for 1 - 4 cm sized pebbles.

Property Number	Location: Township	Location: Concession	Location: Lot	Owner or Operator	Overburden (m)	Thickness Reported (m)	Thickness Observed (m)	Reserves Estimated*	Composition: % Stone (estimated)	Composition: % Sand (estimated)	Composition: % Stone >2.5 cm	Composition: % Stone >10 cm	Maximum Boulder (cm)	Origin of Deposit	Carbonates: Limestone	Carbonates: Dolostone	Carbonates: Chert	Clautics: Sandstone	Clautics: Siltstone	Clautics: Shale	Pre-cambrian: Felsic	Pre-cambrian: Mafic Metamorphic	Sample Number	Quartzite	e
1	Artemeu la	2S	29	-	-	-	4	S	15	65	10	1	25	Esker											
2	-	3H	156	-	1	-	5.5	U	20	80	5	.4	20	Ice-contact	-	-	-	-	-	-	-	-	-	-	-
3	Bentinck	1H	21	-	-	3	a	M	10	90	7	1	100	Ice-cont act	9	81	-	-	-	-	5	>	-	-	-
4	-	IS	50	-	-	2	3	U	50	50	30	20	60	Outwash	13	86	-	-	2	-	1	*	-	-	-
5	-	1S	61	-	-	5	3	U	40	60	34	16	25	Outwash	B	90	-	-	-	-	-	2	-	-	-
6a	-	2N	37	Fritz Baily	-	a	10	U	40	60	24	16	45	Ice-contact	4	92	-	-	-	-	2	1	-	1	-
7	-	2S	40	-	1.5	5	6	U	40	60	24	8	25	Ice-cont act	6	92	-	-	-	-	1	1	-	-	-
a	-	2M	46	-	-	-	3	U	30	70	6	1.5	30	Out wash											
9	-	2	55	-	5	7	6	U	60	40	30	12	25	Outwash	a	83	-	-	3	-	3	3	-	1	-
10a	-	3N	45	-	-	10	2	u	50	50	30	10	15	Ice-contact											
10b	-	3N	45	-	2	-	a	u	10	90	9.5	.5	5	Ice-cont act											
11	-	5	25	Elmer Szabo	1	5	4	11	50	50	30	15	20	Eaker	12	85	-	-	-	-	2	-	-	-	-
12	-	6	24	Calvin HacDonald	.5	5	4	u	50	50	-	-	25	Ice-cont act	9	84	-	-	-	-	3	6	-	-	-
1i	Bentinuk	8	21	-	-	3	3	u	50	50	-	-	10	Outwash	9	85	-	-	1	-	2	2	-	1	-
14	-	B	29	-	-	-	1	u	50	50	25	10	30	Eaker	6	83	-	-	-	-	5	6	-	-	-
15	Town of Durham	-	-	-	-	5	4	u	5f)	50	30	20	25	Outwash	9	83	-	-	-	-	2	5	-	1	-
16	Egremont	IE	2	Pr it chard	-	6	8	S	1	99	1	-	5	Outwaah	10	86	-	-	-	-	-	4	-	-	-
17	-	1E	15	-	-	-	10	H	50	50	25	5	40	Outwash											

Property Number	Lacat ion			Owner or Operator	Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Estimated Reserve*	Compos it ion					Origin of Deposit	PEBBLE L1IH0L0CY (PERCENI)										
															Carbonates			Clast ics			Pre-cumbrisn				
	IoHnBhiP	Concession	Lot						Stone (Estimated)	Sand (Estimated)	Stone >2.5 cm	Stone >10 cm	Maximum Boulder (cm)		Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Felsic	Metamorphic Mafic	Sample Number	Qu8e	Iilite
18	-	IE	18	-	.5	5	4	S	75	25	48	11	20	OutwaBh	8	B7	-	-	-	-	1	3	-	1	-
19	-	IE	19	Heaney #1	-	5	6	S	50	50	25	35	20	OutHash											
20	-	IE	20	-	-	3	8	S	50	50	20	2	20	OutMash											
21	-	IE	24	-	-	-	3	L	50	50	25	1	20	OutMash											
22	-	2E	21	-	2	3	7	U	-	-	-	-	-	Ice-cont act	-	-	-	-	-	-	-	-	-	-	-
23	-	2E	34	-	-	5	5	L	70	30	35	7	20	OutMash	5	86	-	-	-	-	4	5	-	-	-
24	-	2	40	-	-	-	8	L	60	40	27	3	50	OutMash											
25	-	2	41	-	-	-	6	L	60	50	27	2	25	OutMash											-
26	Egremont	3	7	-	-	6	7	U	25	75	10	2	1.5	Ice-contact	7	89	-	-	-	-	1	3	-	-	-
27		3	19	-	.5	-	8	U	30	70	9	3	60	Ice-contact	8	78	-	-	1	-	2	10	-	1	-
28	-	3E	23	-	2	3	4	S	15	85	10	5	50	Ice-contact	5	84	-	-	-	-	2	9	-	-	1
29	-	3E	24	-	-	5	4	U	60	40	24	3	20	Ice-contact	7	91	-	-	-	-	-	1	-	1	-
30	-	3E	32	-	-	3	6	M	50	50	20	2	20	OutHash	6	84	-	-	-	-	1	9	-	-	1
31	-	3	49	-	-	-	6	U	50	50	17	2	20	Ice-cont act	14	73	-	-	-	-	3	10	-	-	-
32	-	3	56	-	-	-	12	L	40	60	10	10	25	Ice-contact	14	73	-	-	-	-	6	7	-	-	-
33	-	3	57	-	-	-	2	U	35	65	14	1	10	Outwash											
34 a	-	JL	64	a) Hoffman	2	B	7	U	10	90	1	-	40	Esker	7	86	-	-	-	-		6	-	-	-
34b	-	-	-	-	-	-	6	U	60	40	30	6	40	Esker											

Property Number	Location: Township	Concession	Lot	Owner or Operator	Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Reserves Estimated*	Composition: Stone (estimated)	Sand (estimated)	% Stone >2.5 cm	% Stone >10 cm	Maximum Boulder (cm)	Origin or Deposit	Pebble Lithology (Percent): Carbonates: Limestone	Dolostone	Chert	Clastics: Sandstone	Siltstone	Shale	Pre-cembrian: Felsic	Mafic Metamorphic	Sample Number	Qua...e	e
35	-	6	1	Herv Reeves	-	6	10	L	15	85	4	1	20	Esker	14	78	-	-	-	-	3	2	-	3	-
36		6	5	-	-	4	5	S	30	70	9	1	-	Eaker	5	85	-	-	1	-	3	4	-	2	-
37		7	13	Lloyd Harria	1	3	4	S	15	90	-	-	40	Ice-contact	9	85	-	-	-	-	2	4	-	-	-
38		7	15	William Watson	2	3	a	S	2D	BO	5	0	25	Ice-cont act	18	77	-	-	-	-	3	2	-	-	-
39	Egremont	7	16	-	-	6	3	U	5	95	4	1	-	Ice-contact											
40	-	a	A	Harry Bye	1	2	-	S	5	95	1	-	-	Eaker											
41	-	a	A	-	-	-	10	L	40	60	10	10	25	Esker	11	80	-	-	-	-	1	8	-	-	-
42	-	8	3	Hewitt	-	5	5	U	10	90	5	1	-	Eaker											
43	-	10	7	Isaac Horst	-	-	8	S	30	15	12	-	8	Esker	-	-	-	-	-	-	-	-	-	-	-
44	-	10	17	Wayne Coulson	-	5	7	H	15	85	4	1	30	Ice-contact	19	71	-	-	-	-	4	6	-	-	-
45	-	12	10	Ken Pal lei tie	-	-	8	S	25	75	10	5	40	Ice-cont act											
46	-	12	22	George Green	-	5	6	U	50	50	25	2	50	Ice-cont act	28	69	-	-	-	-	-	3	-	-	-
47	-	14	16	Elmer Echlin	1	-	6	S	70	30	28	2	25	Ice-cont act	a	73	-	-	1	-	9	8	-	-	-
48	-	14	27	George Dyce	-	5	3	U	15	85	3	1	20	Ice-cont act	18	77	-	-	-	-	3	2	-	-	-
49	-	15	27	-	-	-	7	S	50	50	20	5	30	Esker	7	89	-	-	-	-	3	1	-	-	-
50	-	16	6	Leonard Ecclea	-	4	12	L	35	65	24	10	70	Esker	5	80	-	-	-	-	9	5	-	1	-
51	-	17	25	-	-	5	2	S	35	65	12	3	20	Ice-cont act	16	72	-	-	-	-	3	9	-	-	-
52	-	19	5	Clarence Caldwell	-	3	3	L	35	65	10	3	70	Ice-cont act	6	87	-	-	1		-	6	-	-	-

Property Number	Location			Owner or Operator	Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Estimated Reserve	Composition					Origin of Deposit	PEBBLE LITHOLOGY (PERCENT)								Sample Number	Quartzite	e
	Township	Concession	Lot						% Stone (estimated)	% Sand (estimated)	% Stone >2.5 cm	% Stone >10 cm	Maximum Boulder (cm)		Carbonates: Limestone	Carbonates: Dolostone	Chert	Clastics: Sandstone	Clastics: Siltstone	Clastics: Shale	Pre-cambrian: Felsic	Pre-cambrian: Metamorphic Mafic			
53	Egremont	19	22	-	-	-	4	H	60	40	30	9	40	Esker	12	78	-	-	-	-	4	6	-	-	-
54	-	20	18	-	-	-	8	S	50	50	20	5	75	Esker	4	87	-	-	-	-	4	5	-	-	-
55	-	21	6	-	-	3	3	L	50	50	30	2	15	Outwash	-	-	-	-	-	-	-	-	-	-	-
56	-	21	11A	-	-	3	2	U	35	65	11	1	15	Ice-contact	5	89	-	-	-	-	1	4	-	1	-
57	-	21	17	-	-	3	12	L	75	25	45	7	20	EBker											
58	-	21	17	-	-	5	15	M	80	25	56	8	40	Ice-contact											-
59	-	22	A	-	1	10	14	M	50	60	20	2	40	Ice-cont act	13	78	-	-	-	1	4	4	-	-	-
60	-	22	11	-	1	3	8	L	50	60	25	37	50	Ice-contact	3	90	-	-	-	-	1	4	-	2	-
61	-	22	11	-	-	5	2	U	50	50	-	-	-	Ice-cont act	-	-	-	-	-	-	-	-	-	-	-
62	-	22	19	-	-	3	8	L	60	40	30	6	30	Ice-contact											
63	-	22	27	-	-	-	5	U	5	95	2	-	-	Ice-contact	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	4	H	30	70	15	1	20	OutwBsh											-
65	Glenelg	IS	6	-	-	-	7	U	70	30	35	11	25	Outwash											
66	-	IS	6	-	-	-	7	U	65	35	39	13	20	Outwash											
67	-	1S	6	-	-	-	4	D	70	30	53	3	15	Outwash											
68	-	1N	9	Amett	2	-	10	L	20	80	4	1	50	Outwash	4	B9	-	-	-	-	2	5	-	1	-
69	-	IE	19	-	-	-	10	II	50	50	25	5	40	Outwash	-	-	-	-	-	-		-	-	-	
70	-	1S	28	-	-	2	3	M	35	70	14	-	35	Qui wash	11	77	-	-	-	1	3	7	-	-	

Property Number	Location: Township	Location: Concession	Location: Lot	Owner or Operator	Average Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Area Reserve Estimated*	Composition: % Stone (estimated)	Composition: % Sand (estimated)	Composition: % Stone >2.5 cm	Composition: % Stone >10 cm	Composition: Maximum Boulder (cm)	Origin of Deposit	Pebble Lithology (Percent): Carbonates: Limestone	Carbonates: Dolostone	Carbonates: Chert	Clastics: Sandstone	Clastics: Siltstone	Clastics: Shale	Precambrian: Felsic	Precambrian: Mafic Metamorphic	Sample Number	Quartzite	e
71	-	IS	33	-	-	7	4	U	20	80	7	2	30	Ice-contact	4	95	-	-	-	-	-	1	-	-	-
72	-	IS	40	-	-	7	6	S	5	95	-	-	-	Ice-contact	12	84	-	-	-	-	1	3	-	-	-
73	-	2S	6	-	-	-	4	S	50	60	20	1	25	Outwash											
7a	-	2	6	-	-	-	2	U	40	60	12	-	5	Outwash											
75	-	2H	7	-	-	-	-	U	20	80	5	2	25	Ice-contact	B	B1	-	-	-	-	4	7	-	-	-
76	-	2	33	-	10	-	10	H	30	70	18	6	60	Ice-contact	9	80	-	-	-	-	4	7	-	-	-
77	-	2	39	-	-	-	3	M	40	60	12	1	15	Outwash											
78	-	2	43	Pratt	-	-	3	U	20	80	-	-	-	Ice-contact											
79	-	2E	59	-	-	-	6	M	40	65	14	B	80	Outwash											
80	-	2E	59	-	-	-	6	H	40	60	14	4	80	Outwash	4	88	-	-	-	-	-	7	-	1	-
81	-	2	60 61 62	Durham Stone and Paving	-	-	5	S	60	40	IB	6	40	Outwash											
82	-	3	1	-	-	3	3	U	60	40	24	9	-	Ice-contact											
BJ	-	J	1	-	-	2	7	S	50	50	17	2	50	Outwash	5	84	-	-	-	-	-	3	5	2	-
84	-	}	1	-	-	-	10	L	75	25	7.5	7	15	Outwash											
85	-	3	10	3.D. Weir	-	3	B	U	65	35	16	6	35	Outwash											
86	-	JN	21	-	-	2	10	U	60	40	36	24	70	Ice-contact	11	84	-	-	-	-	1	3	3	1	-
87	-	3E	J9	-	-	3	5	M	40	60	16	30	20	Outwash											
88	-	J	62	-	-	-	-	U	15	90	-	-	20	Ice-contact											

	Location								Composition						PEBBLE LItHOLOGY (PERCENI)										
															Carbonates			Clastics			Pre-cambrian				
Property Number	Township	Concession	Lot	Owner or Operator	Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Estimated Reserves*	Stone (estimated)	Sand (estimated)	Stone >2.5 cm	Stone >10 cm	Maximum Boulder (cm)	Origin of Deposit	Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Felsic	Mafic Metamorphic	Sample Number	Quartzite	Illite
89	-	3	64	-	-	2	5	U	20	80	6	1	15	Ice-contact	-	-	-	-	-	-	-	-	-	-	-
90	-	3	70	-	-	2	5	H	40	60	16	-	10	Outwash	5	74	-	-	-	-	3	5	-	1	-
91	-	4	10	-	-	5	5	S	30	70	7.5	3	25	-	7	86	-	-	-	-	2	3	-	1	-
92	Glenelg	4	27	-	-	-	5	M	40	60	12	.8	20	Outwash	-	-	-	-	-	-	-	-	-	-	-
93	-	5	1	-	-	8	9	L	50	50	10	10	80	Eaker	12	79	-	-	-	-	2	7	-	1	-
94	-	6	13	-	-	-	7	M	50	50	20	35	20	Outwash	-	-	-	-	-	-	-	-	-	-	-
95	-	15	25	-	-	3	3	H	40	65	16	-	8	Outwash terrace	4	87	-	-	-	-	2	5	-	2	-
96	-	-	-	-	-	-	5	0	40	60	8	2	15	Outwash	4	90	-	-	-	-	1	5	-	-	-
97	-	-	-	-	-	-	8	_	10	90	3	1	15	Outwash	7	82	-	-	-	-	5	4	-	1	1
98	Normanby	1W	1	M. Granby	-	5	5	M	30	70	9	1	35	Outwash											
99	-	1H	16	Dickson #1	-	7	6	U	25	75	7	1	30	-	6	87	-	-	-	1	-	5	-	-	-
100	-	2W	3	-	-	-	-	U	20	80	-	-	-	Deltaic											-
101	-	3	57	-	5	-	6	U	50	50	30	15	20	Ice-contact	4	87	-	-	-	-	3	6	-	-	-
102	-	9	13	Pfefer	-	4	4	U	40	60	28	12	10	Kame											
103	-	9	14	-	-	4	4	U	30	70	21	3	8	Kame	9	80	-	-	1	-	1	7	1	-	1
104	-	10	31	Elmer Fisher	-	5	9	U	40	60	32	25	25	Kame	8	89	-	-	-	-	-	3	-	-	-
105	Normanby	12	19	-	1	7	6	U	40	60	32	16	20	Kame	5	57	-	-	-	29	2	7	-	-	-
106		13	25	Normandy Iwp.	-	8	12	U	40	70	30	16	18	-	9	87	-	-	-	-	1	3	-	-	-

Property Number	Location			Owner or Operator	Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Estimated Reserve	Composition					Origin or Deposit	PEBBLE LITHOLOGY (PERCENT)								Sample Number	Quartzite	e
	Township	Concession	Lot						Stone (est'd)	Sand (est'd)	Stone >2.5 cm	Stone >10 cm	Maximum Boulder (cm)		Carbonates: Limestone	Dolostone	Chert	Clastics: Sandstone	Siltstone	Shale	Precambrian: Felsic	Metamorphic Mafic			
107	-	14	7	Normandy Two	-	2	2	U	50	50	25	15	8	lerrace	4	81	-	-	-	4	-	10	-	-	-
108	-	16	9	Alim Starrier	1	-	4	U	60	40	42	18	12	-	10	86	-	-	-	-	1	1	-	-	-
109	-	17	a	-	-	-	8	U	40	60	34	16	12	Kame	12	79	-	-	-	-	3	6	-	2	-
110	-	18	19	Brand	-	5	5	U	30	70	27	4	12	-	6	85	-	-	-	-	2	7	-	-	-
111	-	-	-	-	5	-	14	U	30	70	26	6	12	-											
112	Proton	1	14	a	-	-	10	M	50	50	20	10	50	Esker	9	81	-	-	-	-	-	10	-	-	-
	-	-	-	b	-	-	8	M	5	95	-	-	10	-											
113	-	2	13	-	-	6	9	M	5	95	-	-	80	-	11	87	-	-	-	-	2	1	-	-	-
114	-	2	13	-	-	-	9	S	40	60	16	1	20	Esker	15	80	-	-	-	-	1	3	-	1	-
115	-	3	12	-	-	-	10	U	75	25	30	7	-	Esker											-
116	-	3	13	-	-	-	10	L	50	50	20	5	20	Esker	18	76	-	-	-	-	-	4	-	2	-
117	-	6	8	-	-	-	5	U	20	80	6	-	15	Esker	7	80	-	-	1	-	6	6	-	-	-
118	-	7	8	-	-	-	15	L	50	50	25	10	40	Esker	16	79	-	-	2	-	1	2	-	-	-
119	-	9	6	-	-	-	7	L	40	60	10	2	40	Esker	8	82	-	-	3	-	-	7	-	-	-
120	-	10	3	-	-	-	6	U	40	60	12	1	20	Buried Esker	14	73	-	-	-	-	3	10	-	-	-
121	-	11	21	-	-	-	7	U	50	50	30	10	40	Esker	12	79	-	-	1	-	2	6	-	-	-
122	-	13	17	-	-	-	12	L	35	65	12	2	40	Esker	18	73	-	-	2	-	2	1	-	-	-
123		14	15	a west	-	-	12	L	50	50	17	5	35	Esker	20	77	-	-	-		1	2	-	-	-

Property Number	Location: Township	Location: Concession	Location: Lot	Owner or Operator	Overburden (m)	Reported Thickness (m)	Observed Thickness (m)	Estimated Reserves*	(estimated) % Stone	(estimated) % Sand	% Stone >2.5 cm	% Stone >10 cm	Maximum Boulder (cm)	Origin or Depoait	Csrbonstea: Limestone	Csrbonstea: Dolostone	Csrbonstea: Chert	Clastics: Sandstone	Clastics: Siltstone	Clastics: Shale	Pre-cambrian: Felsic	Pre-cambrian: Mafic Metamorphic	Sand Sample Number	Quartzite	e
	Proton	14	15	b weat	-	-	9	L	35	65	12	3	30	Esker											-
124	-	15	3	-	-	-	6	U	20	80	8	1	25	Ice-contact	13	82	-	-	1	-	1	3	-	-	-
125	-	17	14	-	-	-	7	M	40	60	16	4	40	Esker	10	87	-	-	-	1	1	1	-	-	-
126	-	19	21	-	-	-	6	U	5	-	-	-	-	Ice-contact	-	-	-	-	-	-		-	-	-	-
127	H. Luther	-	-	-	-	-	B	S	50	50	12	2	25	Esker	15	82	-	-	-	-	1	2	-	-	-

* S-small, M-medium, L-large, U-unknown.

Photo 1. Ice-contact terrace (kame terrace) in Singhampton Moraine near Widder Lake.

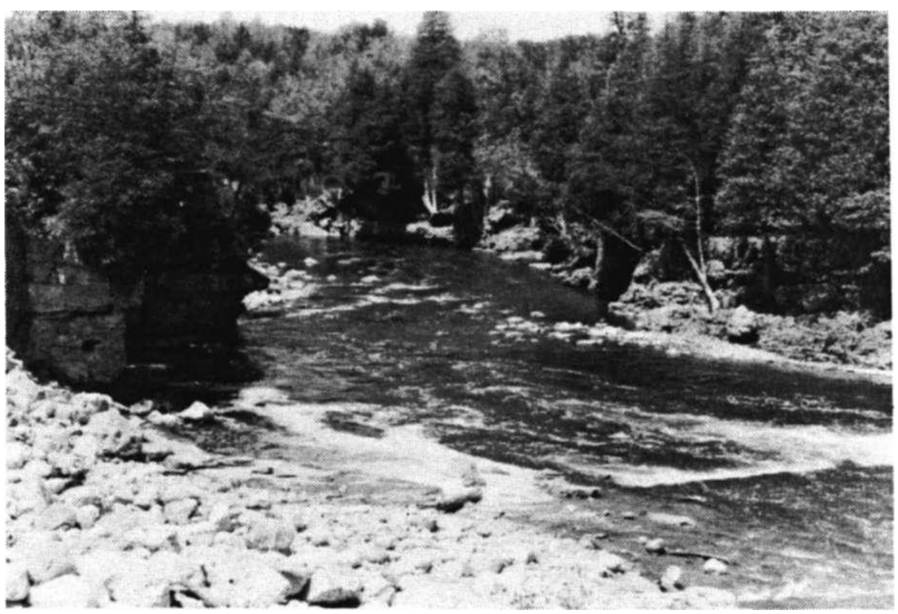


Photo 2. Guelph Formation shale and dolostone on the Saugeen River.

Photo 3. Salina Formation shale and dolostone on the South Saugeen River.

Photo 4. Laminated (waterlain?) Tavistock Till resting upon stoney massive (lodgement) Catfish Creek Till.

Photo 5. Pitted outwash forming part of the Singhampton Moraine near McWilliams.

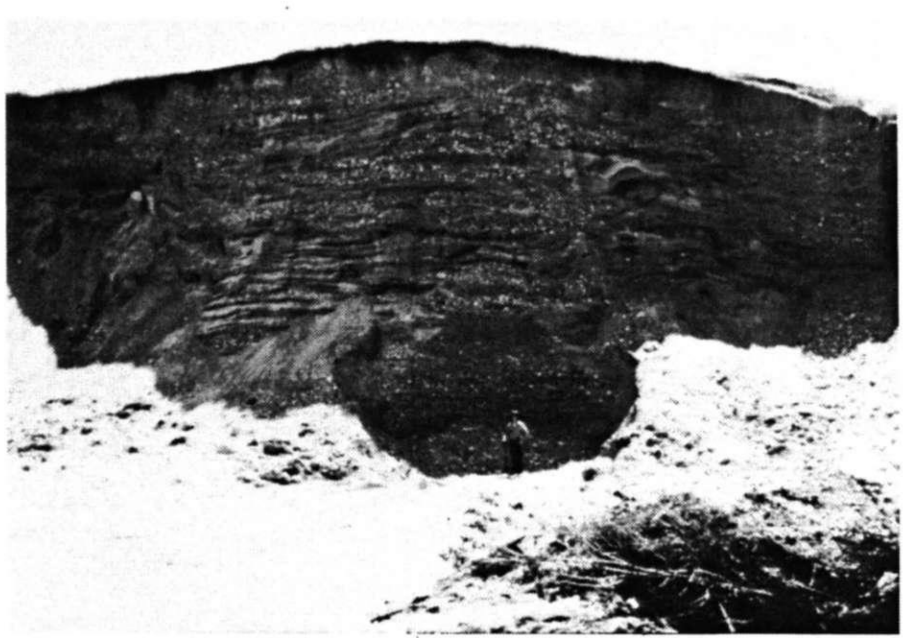


Photo 6. Braided-stream character of the core of the Singhampton Moraine.

Photo 7. Terraced gravel along the Saugeen River; horizontally bedded outwash deposition, representative of a proximal facies diffuse gravel sheet.

Photo 8. Sandy cross-channel deposition downstream in the Artemesia Gravel, Singhampton Member.

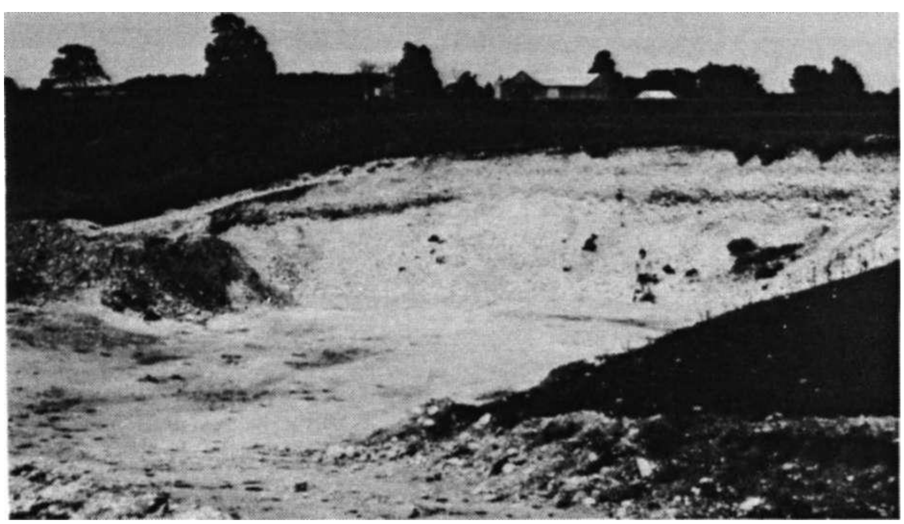
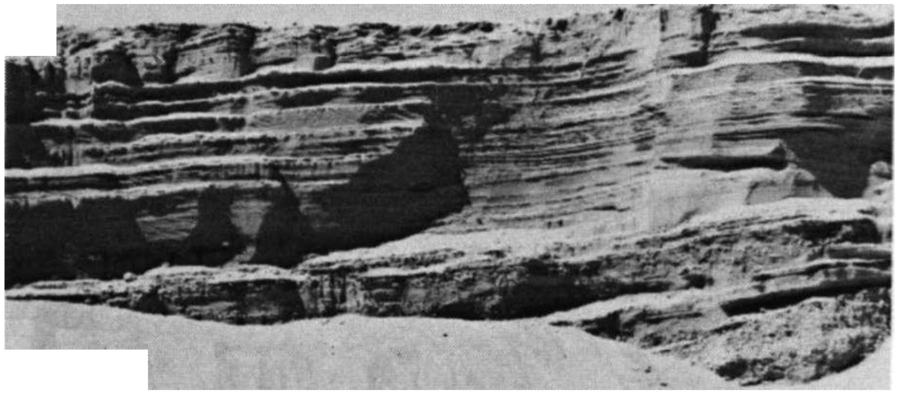
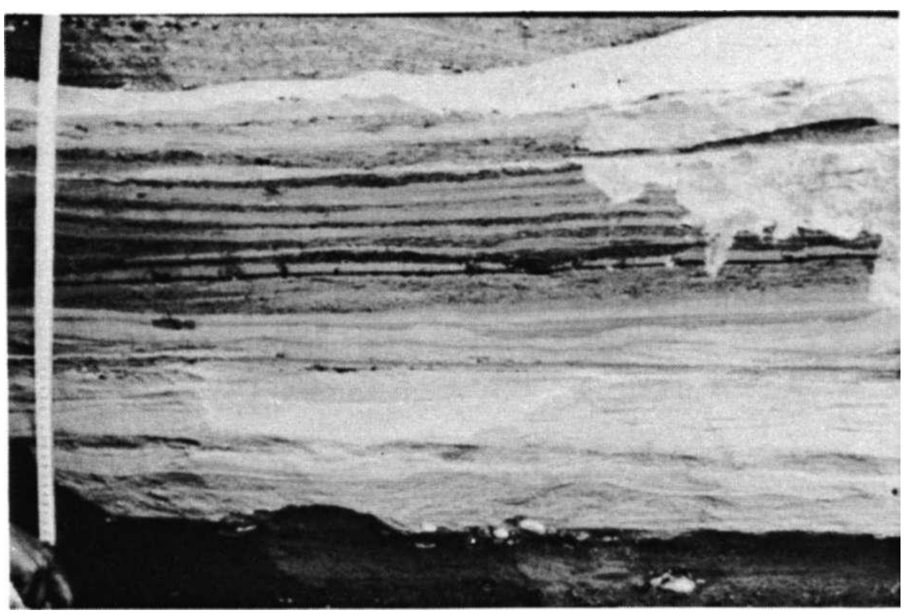


Photo 9. Outwash gravel deeply cut by meltwater channel.



Facies relationships of the Allen Park Station ice-marginal delta, coarser topset beds out into the finer foreset beds.



Bottomset beds consisting of ripple-drift cross-laminated fine sand grading up into banded silt sand.

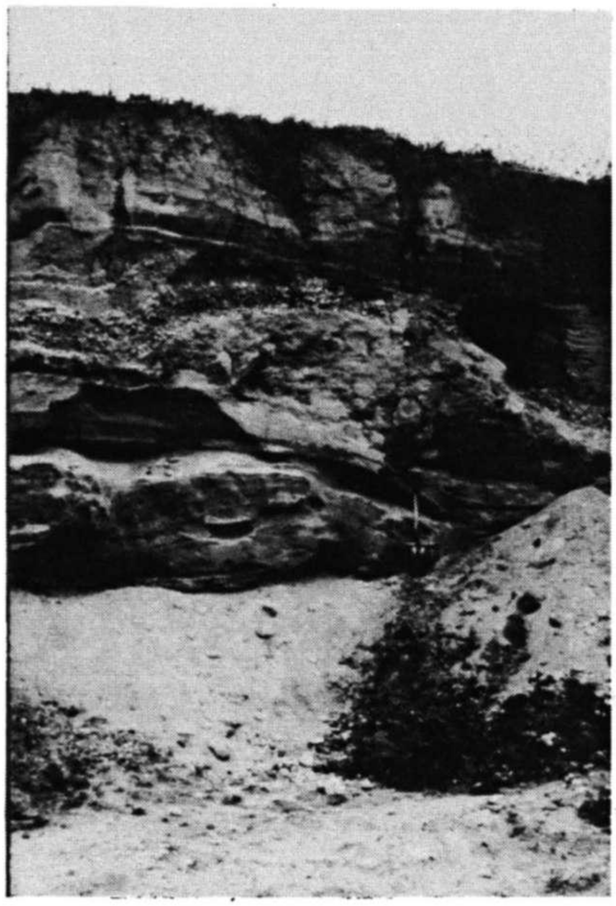


Photo 12. Variable sediment characteristic of esker deposits.

Photo 13. Recent fluvial deposits (including wood) along the Saugeen River.

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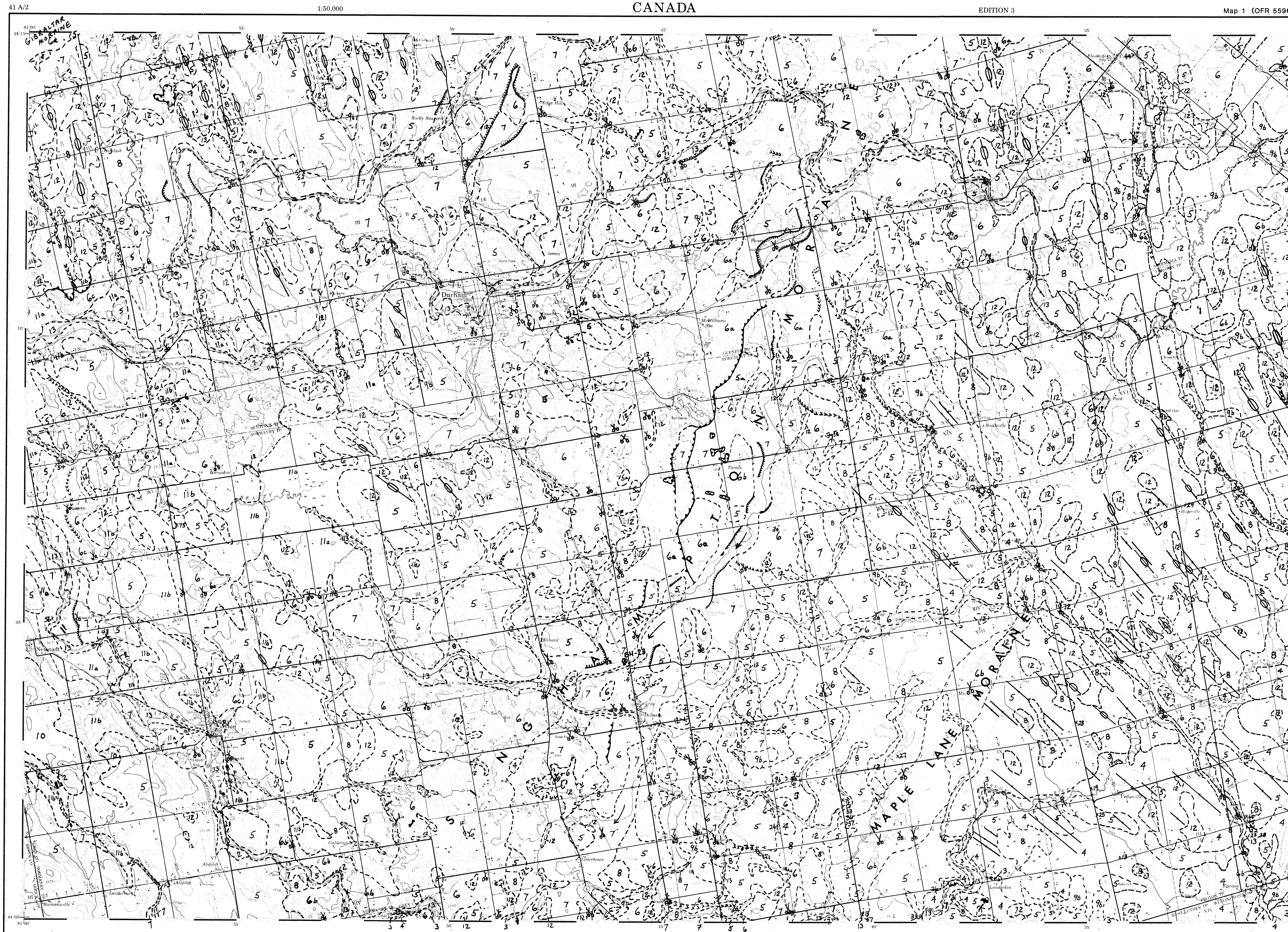
41 A/2 | 1:50,000 | CANADA | EDITION 3 | Map 1 (OFR 5596) 41 A/2



LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT

13	Alluvium: mainly gravel with sand and silt
12	Bog deposits: muck, peat, marl

PLEISTOCENE
Late Wisconsinan

11	Glaciolacustrine sediments: 11a Medium to fine sand 11b Clay and silt with some fine sand
10	Silt till
9	Glaciolacustrine sediments: 9a Fine sand 9b Silt and clay
8	Glaciofluvial outwash sand
7	Glaciofluvial outwash gravel and gravelly sand
6	Ice-contact stratified drift: undifferentiated sand, gravel and silt 6a Mainly gravel 6b Mainly sand or silt 6c Sand and gravel (ice marginal deltas)
5	Elma Till: stoney, sandy silt till 5a Ablation facies, very sandy and loose
4	Tavistock Till: stiff, silt to clayey silt till
3	Catfish Creek Till: hard, stoney, sandy silt till

UNCONFORMITY

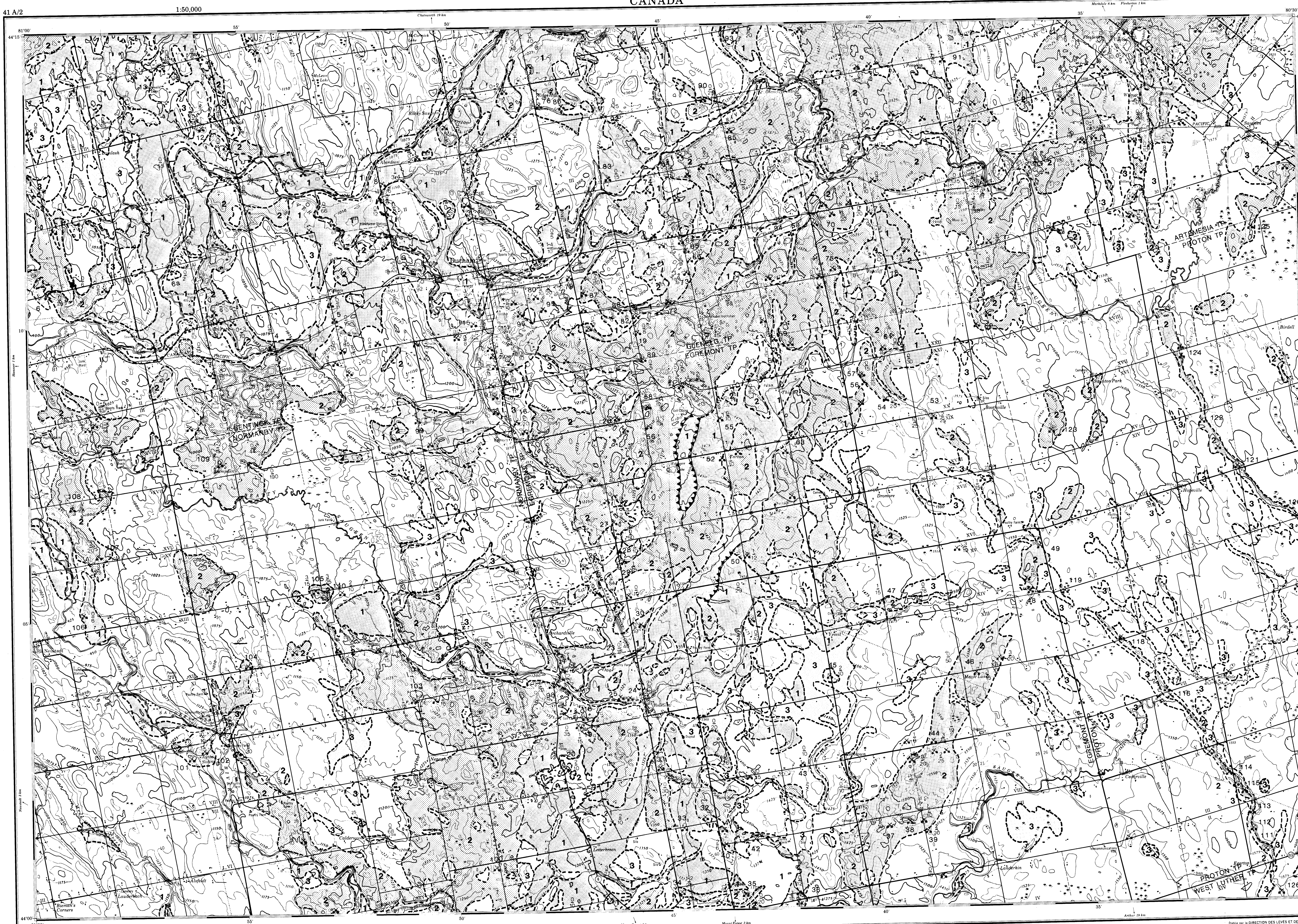
PALEOZOIC
SILURIAN

2	Salina Formation: dolostone and shale
1	Guelph Formation: dolostone

SYMBOLS

- Geological boundary (observed or interpreted)
- Terrace escarpment, fluvial
- Ice-contact slope
- Kettle hole
- Glacial fluting
- Drumlin
- Crevasse filling
- Esker; direction of flow known
- Meltwater channel with direction of flow indicated
- Sand or gravel pit
- X23 Sample site
- Borehole site

41 A/2 1:50,000 CANADA EDITION 4 Map 2 (OFR 5596) 41 A/2



LEGEND

1 Good prospecting target: area underlain by outwash gravel; high probability of finding an economic deposit.

2 Moderate prospecting target: area underlain by ice contact stratified drift; good probability of locating an economic deposit yet prospecting and development costs may be high.

3 Poor prospecting target (sand): area underlain by outwash or lacustrine sand; low probability of locating an economic deposit due to thin patchy distribution and low stone content.

SYMBOLS

- Sand or gravel pit.
- × $\frac{3}{15}$ Water well site indicating thickness (in feet) of unusable material over reported thickness of gravel and sand.
- Geological boundary, approximate.
- Ice contact slope
- 122 **Location of sand/gravel pits (see report)**

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Roads:	Routes:
hard surface, all weather	pavée, toute saison (dual highway / 2 chaussées séparées; more than 2 lanes / plus de 2 voies)
hard surface, all weather	pavée, toute saison (2 lanes / 2 voies; less than 2 lanes / moins de 2 voies)
loose or stabilized surface, all weather	gravier, aggloméré, toute saison (2 lanes or more / 2 voies ou plus; less than 2 lanes / moins de 2 voies)
loose surface, dry weather	de gravier, temps sec
unclassified streets	rues hors classe
cart track	de terre
trail, cut line or portage	sentier, percée ou portage

FOR COMPLETE REFERENCE SEE REVERSE SIDE POUR UNE LISTE COMPLÈTE DES SIGNES, VOIR AU VERSO

DURHAM
ONTARIO

Scale 1:50,000 Échelle

Miles 1 0 1 2 3 Milles
Metres 1000 0 1000 2000 3000 4000 Mètres
Yards 1000 0 1000 2000 3000 4000 Verges

CONVERSION SCALE FOR ELEVATIONS ÉCHELLE DE CONVERSION DES ÉLÉVATIONS

Metres 30 20 10 0 50 100 150 200 250 300 Mètres
Feet 100 50 0 100 200 300 400 500 600 700 800 900 1000 Pieds

CONTOUR INTERVAL 25 FEET
Elevations in Feet above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection

ÉQUIDISTANCE DES COURBES 25 PIEDS
Élévations en pieds au-dessus du niveau moyen de la mer
Système de référence géodésique nord-américain, 1927
Projection transverse de Mercator

Établie par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DE L'ÉNERGIE, DES MINES ET DES RESSOURCES. Mise à jour à l'aide de photographies aériennes prises en 1976. Vérification des ouvrages en 1976. Renseignements à jour en 1976.

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