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Open File Report 5886

Quaternary Geology of Essex County, Southwestern Ontario

1994

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ONTARIO GEOLOGICAL SURVEY

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Quaternary Geology of Essex County, Southwestern Ontario

By

T.F. Morris

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ESSEX COUNTY QUATERNARY GEOLOGY

ABSTRACT

In Essex County, Quaternary sediments ranging in thickness from 3 m to more than 80 m, overlie marine sedimentary rocks of Silurian and Devonian age. Bedrock outcrops in the study area are restricted to Pelee and several smaller islands in Lake Erie.

The Pleistocene sequence is entirely Late Wisconsinan in age. The oldest unit in the stratigraphic sequence is the Catfish Creek Till (Nissouri Stade). This very compact, stony, sandy silt till lies directly on bedrock and was deposited by ice flowing in a south to southwest direction. It does not outcrop in Essex County and is visible only in quarry sections and drill core. Fine-grained glaciolacustrine sediments (Erie Interstade) generally separate the Catfish Creek Till from the overlying Tavistock Till (Port Bruce Stade). Tavistock Till is a clast-poor clayey silt till that was also deposited by southward flowing ice. It is mantled by a thin (<1 m) unit of glaciolacustrine clayey silt but can be readily observed in numerous natural and man-made exposures. On Pelee Island, there is a hybrid Tavistock-Port Stanley till, deposited as ice flow shifted to the west, late in the Port Bruce Stade.

As the main ice margin receded to the north at the end of the Port Bruce Stade, it left a series of low relief recessional moraines and associated proglacial subaquatic fans. Subsequent glaciolacustrine sedimentation covered most of the area with a veneer of fine-grained sediment. East of Leamington there are parabolic and transverse sand dunes that probably formed after post glacial lake levels fell. Recent deposits include modern alluvial sand and silt, observed along most rivers and creeks, and organic accumulations, observed in bogs and marshes in shoreline areas.

Radiocarbon dates for organic materials found in a shallow water deposit of Glacial Lake Arkona (Mackinaw Interstade) are 13 150 ± 100 years BP (WE-01-89) and 13 225 ± 200 years BP (BGS 1404). A musk-ox metacarpal bone from a Lake Arkona bar was dated at 13 410 ± 100 years BP (TO-1803) and organic material from a Glacial Lake Warren bar yielded an age of 10 000 ± 200 years BP (BGS 1311).

Potential sources of aggregate in the area are limited to eskers and subaquatic fans buried beneath fine-grained glaciolacustrine deposits and Tavistock Till. Environmental concerns in the study area include: 1) bedrock collapse; 2) groundwater; 3) fractured and stratified clay plain; 4) possible hydrocarbon seeps; 5) shoreline erosion and; 6) flood hazards.

Quaternary Geology of

Essex County, Southwestern Ontario

By

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Manuscript approved for publication by C. Baker, Section Chief, Sedimentary and Environmental Geoscience Section, Ontario Geological Survey, February 21, 1994.

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INTRODUCTION

Location and Access

Essex is the southern-most county in Ontario (Figure 1). The study area includes most of the county except for a small area along the eastern boundary and encompasses parts of 6 National Topographic Series 1: 50 000 map areas: 40J/6, 40J/3, 40J/2, 40J/7, 40G/15 and 40G/10. These maps represent an area of approximately 1800 km. The principle communities are Windsor, Amherstburg, Essex, Belle River, Kingsville and Leamington.

Highways 401, 3 and 2 provide major road access within the study area and are supported by a close network of county and township roads. Railway freight service is via the Canadian National, Canadian Pacific, Con Rail and the Chesapeake and Ohio Rail. Via Rail provides passenger rail service. Major air passenger and freight services operate from the Windsor airport.

Present Geological Survey

This geological survey examines the properties, distribution, and relationships of various geological materials in Essex County. Surficial geologic mapping of the area began in the summer of 1988 and was completed in 1989. Field methods involve describing, sampling and comparing materials observed in natural and man-made exposures, soil probing, and sonic drilling. The sonic drillhole logs were supplemented by data from waterwell, petroleum drillhole, and road engineering borehole records. Where possible, information from field notes and maps from previous surficial mapping programs

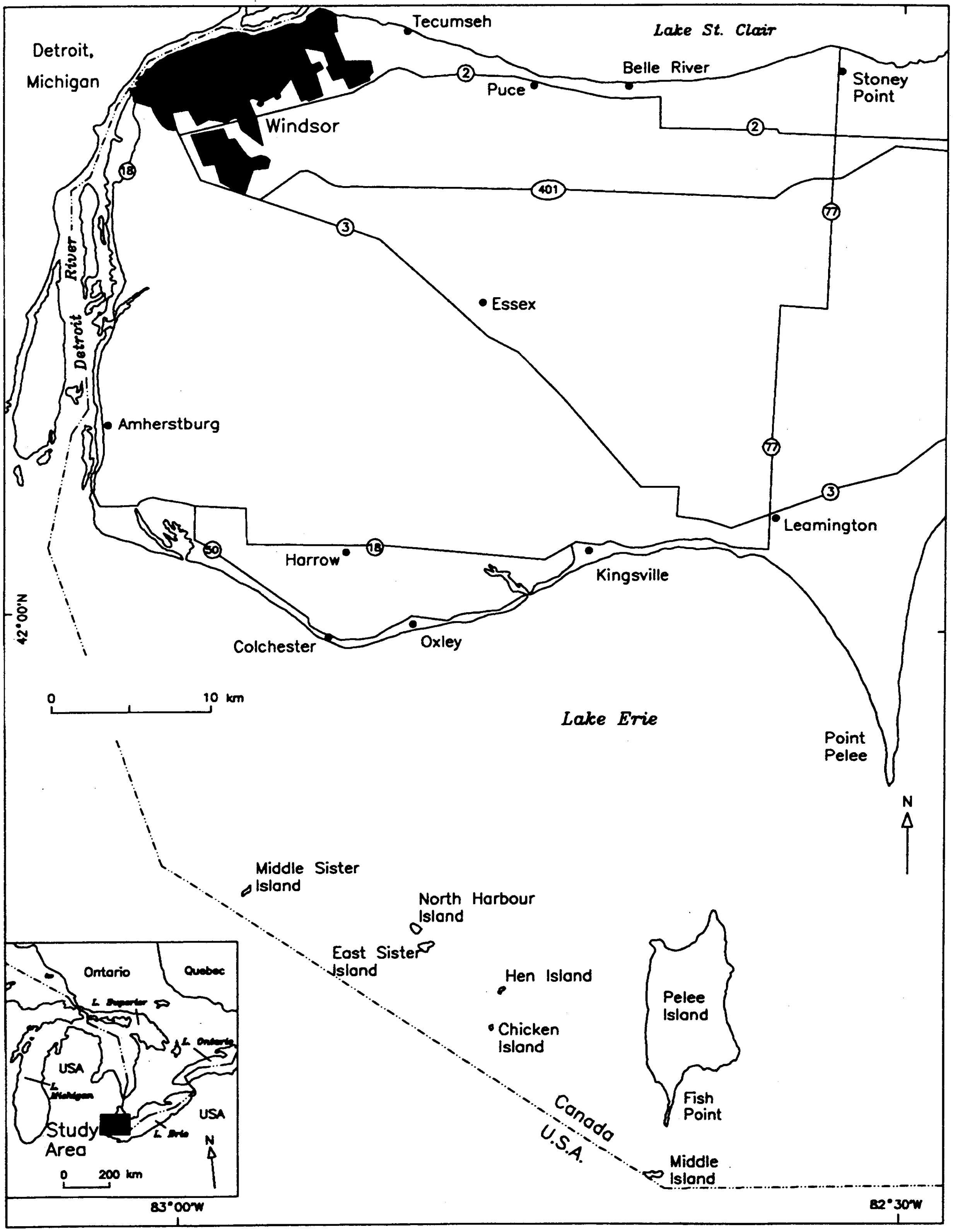

Figure 1. Location of map area.

(Watt 1947; Vagners 1970, 1971) is integrated with data from the present study.

Remote sensing images were used to help identify buried materials and surface landforms and to provide horizontal control. The types of images used include: 1) black and white aerial photographs (1: 10 000 and 1: 50 000); 2) false coloured infrared images (1: 15 000); 3) uncontrolled infrared images (1: 50 000); 4) a Landsat image (MSS5 bands 3,4,5); and 5) radar imagery (1: 15 840 and 1: 500 000).

Acknowledgements

E. Scarsbo (1988) and G. Cousineau (1989) provided competent field and mapping assistance. S. Moore and T. Warner assisted with data processing and drafting.

The Ontario Centre for Remote Sensing provided infrared and Landsat imagery and the Canada Centre for Remote Sensing supplied radar imagery. Consumers Oil and Gas provided 1: 50 000 scale infrared images. Waterwell records came from the Ontario Ministry of the Environment. The Petroleum Resources Laboratory, Ontario Ministry of Natural Resources, supplied oil and gas drillhole records and the Ontario Ministry of Transportation provided road engineering information.

J.H. McAndrews (University of Toronto) carried out pollen and macrofossil analysis. K.L. Seymour (Royal Ontario Museum) and C.S. Churcher (University of Toronto) identified the muskox bone. B. Koop and P. Kennette Jr. provided access to their aggregate operations and J. Armstrong and F. Pietrangelo allowed access to rock quarries. Many private landowners permitted access to their properties.

The writer wishes to thank a number of people at both federal and provincial government ministries for their co-operation. These include V.H. Singhroy, formerly of the Ontario Centre for Remote Sensing; Steve Szoke and J. Petrozziello of the Ontario Ministry of Transportation; J.P. Coakly of Environment Canada; and T.R. Carter of the Petroleum Resources Laboratory, Ontario Ministry of Natural Resources. P.J. Barnett, R.I. Kelly, C.L. Baker, A.F. Bajc and B.H. Feenstra of the Ontario Geological Survey provided lively discussion and constructive criticism on topics relevant to this study.

The writer extends his warmest thanks to each of the above for their contribution to this project.

Previous Work

The Paleozoic bedrock of the region has been mapped by Caley (1945), Caley and Sanford (1952), Sanford and Brady (1956), Sanford (1959, 1961, 1968) and Telford and Russell (1982). Paleozoic stratigraphy is discussed by Caley (1945, 1947), Sanford and Brady (1956), Uyeno et al. (1982) and Carter (1989). Uyeno et al. (1982) summarized the Paleozoic paleontology of the area and Birchard and Risk (1990) discuss aspects of the paleontology. Economic aspects of the Paleozoic geology are summarized by Derry, Michener, Booth and Wahl and the Ontario Geological Survey (1989), Prud'homme

(1989), and Carter (1989). Russell (1993) investigated sinkhole development in the region.

Caley (1945) and Caley and Sanford (1952) compiled bedrock topography maps for Essex County and Gagne (1981) constructed a regional bedrock topography map. Several drift thickness maps have been prepared for Essex County (Boutette 1979; Caley and Sanford 1952; and Vagners et al. 1973a, 1973b).

The surficial geology of Essex County was first investigated by Taylor (1913) and Leverett and Taylor (1915). The most recent and comprehensive report on the surficial geology of Essex County is by Chapman and Putnam (1984). Other work on aspects of Quaternary geology in Essex County include: 1) regional lake level studies (Hough 1963; Eschman and Karrow 1985; Calkin and Feenstra 1985); 2) glacial chronology studies (Vagners 1972a, 1972b; Dworkin et al. 1985; Arroyas 1988; Brown 1989); 3) process studies (Byrne and Trenhaile 1977; Trenhaile and Dumala 1978); 4) geologic hazard assessment (Boyd 1981; Quigley and Zeeman 1980); 5) materials studies (Soderman et al. 1961; Boutette 1979; Lakhan 1975; Galinski 1983); 6) groundwater investigations (Desaulniers et al. 1981; Sklash et al. 1987); and 7) a soil survey (Ontario Agricultural College 1989).

Physiography and Drainage

Essex County consists of 3 physiographic regions: 1) St. Clair Plains; 2) Erie Spits; and 3) Pelee Island (Figure 2; Chapman and Putnam 1984). The Essex Clay Plain, a subregion of the St. Clair Clay Plains, dominates most of the County. This subregion is generally flat with a low gradient rising north from Lake St. Clair. The flatness of the clay plain is broken by 2 high knolls, northwest of Leamington and surrounding Harrow and Colchester, which rise 41 m and 12 m respectively above the plain. Three till ridges capped with beach sand trend southeast through the town of Essex, northeast of Harrow and northwest of Colchester. The largest ridge, which passes through the town of Essex, is 6 m high.

There are 2 types of shoreline around the mainland of Essex County: 1) low lying areas along the south shore of Lake St. Clair, from the mouth of the Detroit River mouth to Colchester and from Oxley to Kingsville; and 2) bluffs up to 20 m high (Boyd 1981) from Colchester to Oxley and Kingsville to Leamington. These bluffs are cut by river channels in several places.

The Erie Spits Region includes Point Pelee and Fish Point on Pelee Island. The west shore of Point Pelee consists of a series of sand beaches aligned southeastward with sand dunes inland from the modern beach. The east shore has a single beach that converges with the western shore to form a sand point. Fish Point was not included in Chapman and Putnam's (1984) Erie Spits Region but was formed by the same processes.

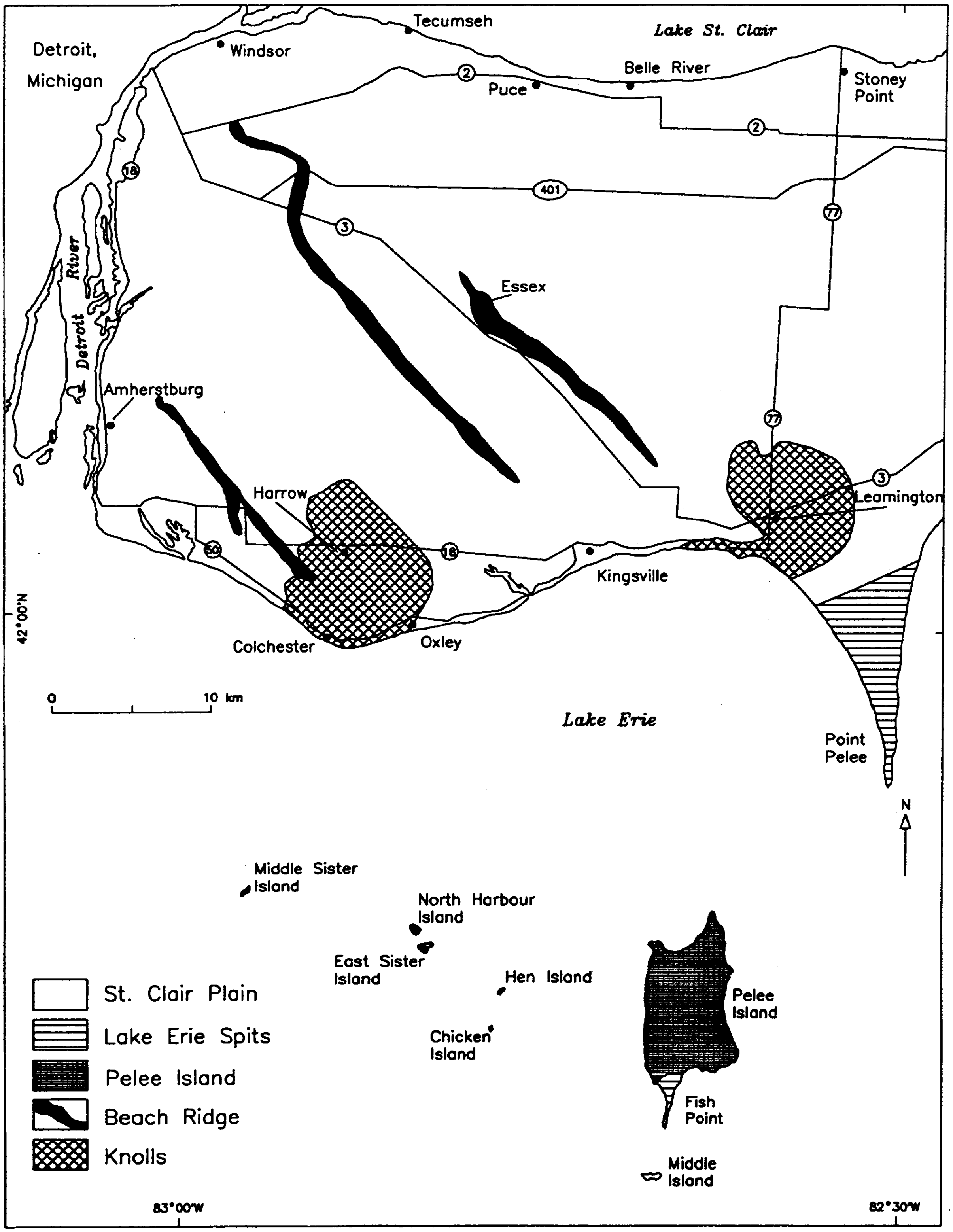

Figure 2. Physiographic regions and features of Essex County (after Chapman and Putnam 1984). The flat topography is broken only by beach ridges and 2 knolls in the Leamington and Harrow areas.

The Pelee Island Region includes Pelee, Middle, Hen, the Chicken, North Harbour, Middle Sister and East Sister islands. Of these, Pelee Island is the largest, extending 6 km in width, 14 km in length and rising 5 m above lake level. The flatness of the landscape is broken where the bedrock is close to surface. Limestone benches are exposed on the northwest and southeast corners of the island. A 1 m high abandoned beach ridge occurs inland along the island's east shore. Middle Island, 0.5 km long by 0.25 km wide, is a flat limestone plain covered by a thin veneer of drift and stands about 11 m above lake level. The other islands are smaller and of similar nature.

A ridge, trending southeast through the town of Essex, defines a drainage divide, north of which water flows into Lake St. Clair. South of the divide streams empty into the Detroit River and Lake Erie. The consistent orientation of rivers and streams implies bedrock control.

BEDROCK GEOLOGY

Rock Types, Stratigraphy, and Distribution

Essex County is underlain by a thick section of Paleozoic sedimentary rocks. These rest unconformably upon a basement complex of Precambrian metamorphic rocks that are probably a southern extension of the Central Gneiss Belt of the Grenville Structural Province (Easton and Carter 1994). The Paleozoic rocks that outcrop or subcrop in the area range in age from Late Silurian to Middle Devonian and include the Upper Silurian Bass Island Formation and the Middle Devonian Detroit River Group, Dundee Formation, and Hamilton Group (Figure 3).

The Bass Island Formation consists of tan and cream coloured microsucrosic dolostone with some oolitic zones (Telford and Russell 1982). The Detroit River Group is made up of the Sylvania, Amherstburg and Lucas formations. The Amherstburg and Lucas formations subcrop in Essex County, but the Sylvania Formation, which is equivalent in age to the Amherstburg Formation, does not. The Amherstburg Formation consists of brown dolostone, oolitic and bioclastic dolostone, and coralgal limestone. The brown dolostone varies from laminated to massive to vuggy. Chert is present locally. Rocks assigned to the Lucas Formation include grey brown, massive coralline bioclastic limestone, light brown stromatolitic calcarenite, and anhydrite. The upper Anderdon Member of the Lucas Formation is composed of a pure, microcrystalline to very finely crystalline vuggy limestone with zones of interbedded rubbly

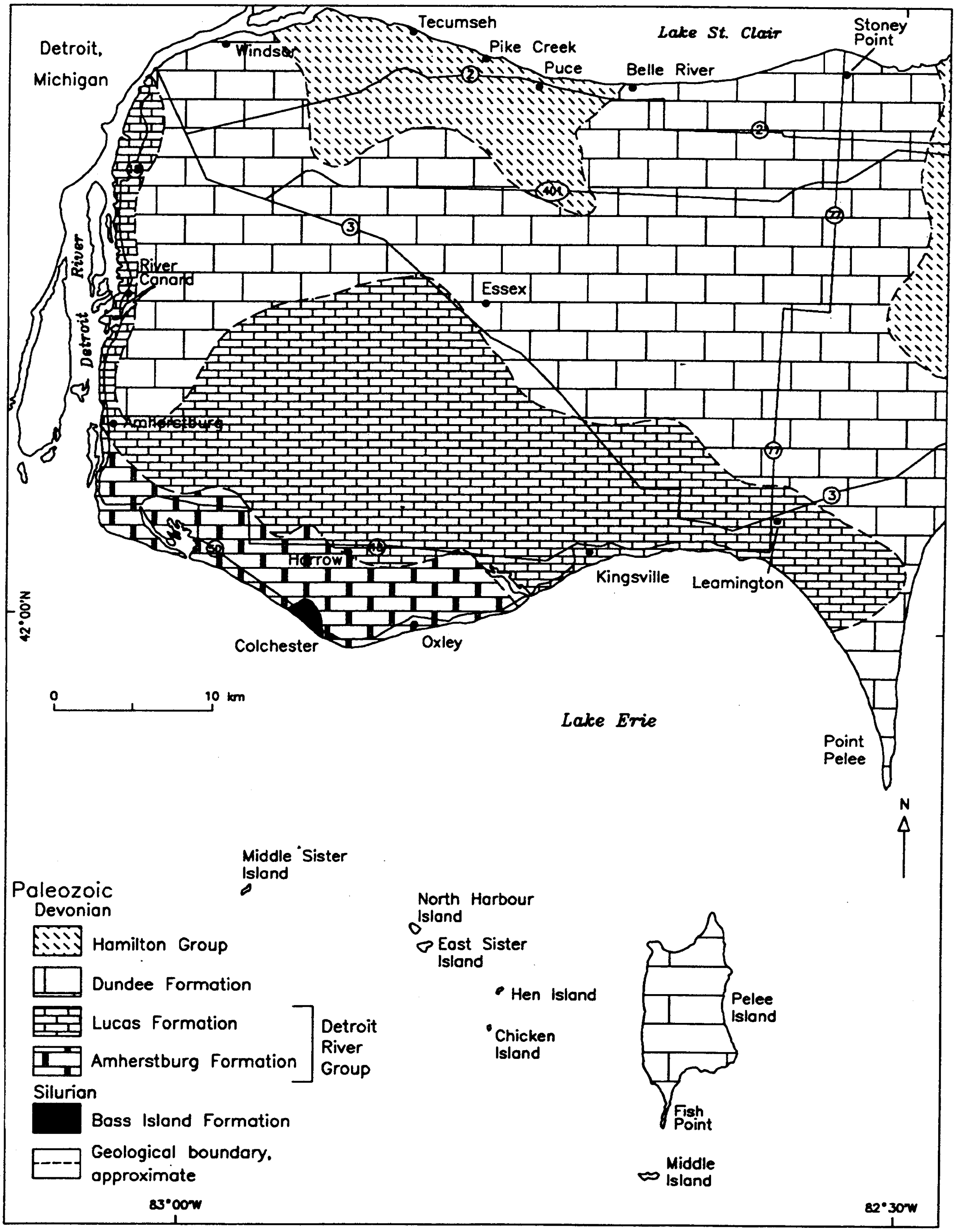

Figure 3. Paleozoic geology of Essex County (after Telford and Russell 1982).

limestone, and mottled and banded limestone (Derry Michener Booth and Wahl and Ontario Geological Survey 1989).

The Dundee Formation consists of brown, cherty crinoidal limestone in the subsurface, but where exposed on Pelee Island it is a massive, brown bituminous bioclastic limestone. A recent study by Birchard and Risk (1990) suggests that the limestone on Pelee Island is equivalent to the Columbus Formation of Ohio, which is statigraphically below the Dundee Formation. The Hamilton Group is composed of grey shale and argillaceous limestone.

There are 4 prominent bedrock fracture orientations: north-northwest, northwest, northeast and east (Figure 4). These orientations correspond closely with the conceptual fracture framework for southwestern Ontario proposed by Sanford et al. (1985).

Bedrock Topography

An updated bedrock topography map (back pocket) has been compiled using data from sonic borehole logs, highway engineering borehole records, petroleum drilling records, and waterwell records. The waterwell records have some inaccuracies in well locations and elevations of materials encountered. The other borehole records serve as control points for the waterwell records to help insure map accuracy.

The bedrock surface slopes gently northeast. Bedrock surface elevation varies from 49 to 55.5 m asl around the Amherstburg area to 42 m asl in the Stoney Point area. North of the Lake Erie

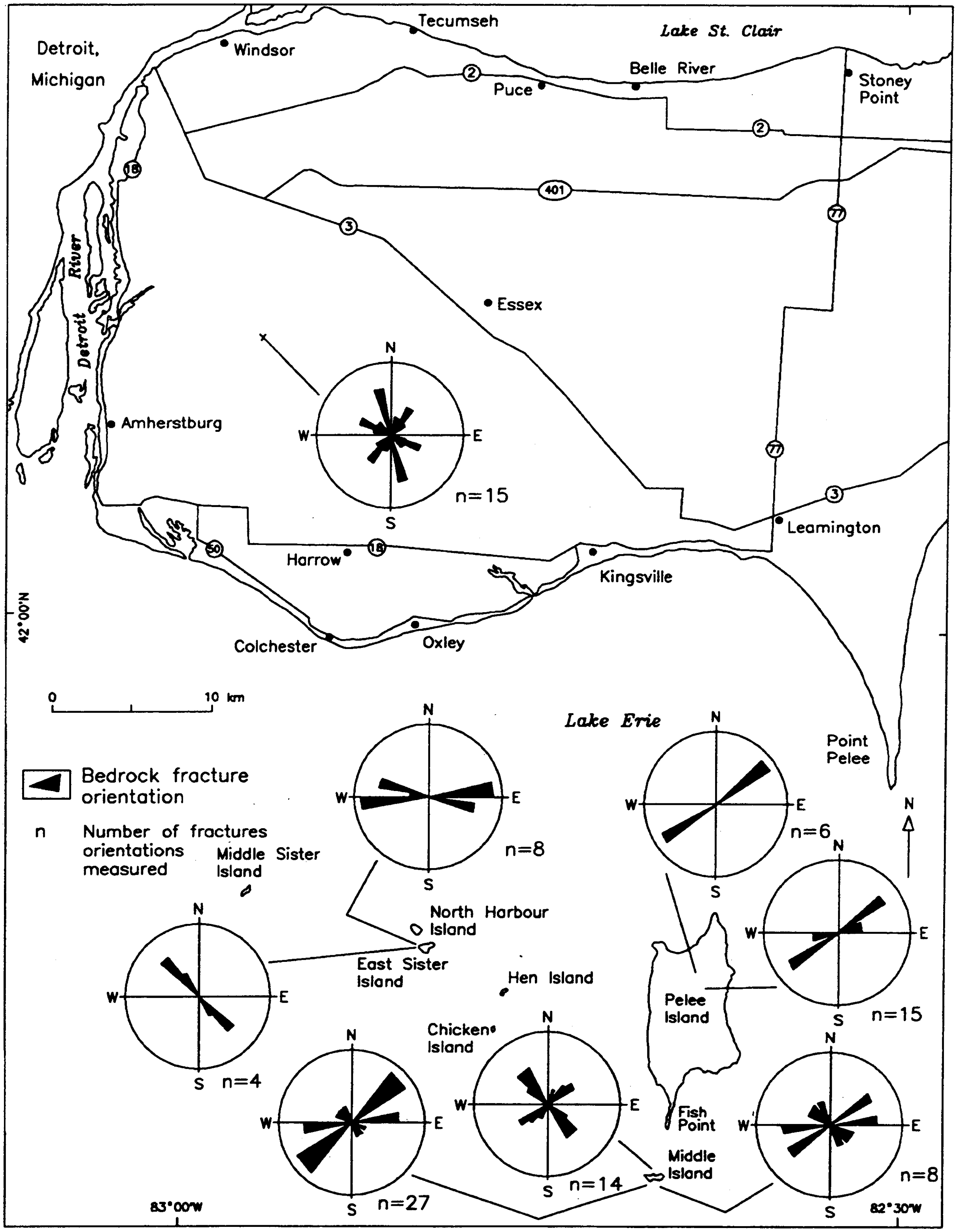

Figure 4. Measured orientation of bedrock fractures. Number of observations is listed adjacent to rose diagram.

shoreline, between Leamington and Amherstburg, there are several points that rise as much as 6 m above the surrounding bedrock surface.

In the southwestern part of the county there are several depressions on the bedrock surface. There may be similar depressions in the northeast but the available data is limited. Most of these depressions are shallow, less than 6 m deep, but 7 depressions extend to depths of 6 to 9 m. Two of these occur north and west of Kingsville, 2 southeast of Leamington, 1 north of Amherstburg and just south of River Canard, 1 southeast of Windsor and another south of Pike Creek.

Economic Geology

Limestone

All 3 active quarries in Essex County produce armour stone and crushed stone products. Chemical stone is extracted from the Anderdon Member of the Lucas Formation at the McGregor Quarry, 10 km northeast of Amherstburg. Building stone is quarried at the Amherstburg Quarry, 2 km east of Amherstburg and the northeast corner of Pelee Island.

Salt

Rock salt is mined near Windsor from salt beds of the Silurian Salina formation and brine is pumped from lower parts of this Formation for vacuum salt production. Brine operations near Amherstburg produce sodium carbonate and by-product calcium chloride (Prud'homme 1989).

Oil and Gas

Oil is extracted from oil pools within Silurian and Ordovician aged rocks (Carter 1989). In 1990 there were 14 producing oil fields yielding 82 500 m^3 of oil (T.Carter, Ministry of Natural Resources, personal communication, 1993). Despite depressed oil and gas prices, on-shore drilling for petroleum has increased over the last 5 years, probably due to encouraging plays in Ordovician reservoirs, proximity to markets and low cost of exploration (Carter 1989). As of 1990, there were no gas producing fields in Essex County.

QUATERNARY GEOLOGY

Introduction

This report follows the Wisconsinan Stage classification of Dreimanis and Karrow (1972) and Karrow (1984). The Quaternary geology and nomenclature for areas adjacent to Essex County are described by Fitzgerald et al. (1979), Fitzgerald and Hradsky (1980), Farrand (1982), Fullerton (1986), Quinn and Goldthwait (1979), Totten (1973), White (1982), and Kelly (1991).

All known Pleistocene sediments in Essex County were deposited during the Late Wisconsinan Substage. The oldest stratigraphic unit is the Catfish Creek Till, a stony, sandy, clayey silt till deposited during the Nissouri Stade (de Vries and Dreimanis 1960). It is overlain by stratified clayey silt deposited in Glacial Lake Leverett during the Erie Interstade (Dreimanis 1958). This glaciolacustrine unit is overlain by the fine-grained Tavistock Till, which was deposited during the Port Bruce Stade (Karrow 1974; Cowan 1975, 1976). Tavistock Till comprises the bulk of the fine-grained sediment in the study area. Thinly-laminated glaciolacustrine clay and silt directly overlie the Tavistock Till.

Following the Port Bruce Stade, sand and gravel were deposited as proglacial subaquatic fans in Glacial Lake Maumee at the beginning of the Mackinaw Interstade. From late in the Port Bruce Stade to the present day, a sequence of proglacial and postglacial lakes have occupied the Lake Erie basin, forming beaches and offshore bars and depositing fine-grained sediments.

Drift Thickness

Drift thickness varies between 0 to 80 m. Areas of thick drift occur: west of Leamington (35 to 60 m); north of Colchester (30 to 40 m); in southeast trending belts (5 to 10 m) in southwestern Essex County; and east trending belts elsewhere. The drift is thick over bedrock depressions southeast of Windsor (60 m) and east of Leamington (50 m), but is quite thin around Amherstburg and southeast of Leamington. A drift thickness map is present in the back pocket of this report.

Glacial Deposits

At least 2 southward ice advances from the Lake Huron basin occurred during the Late Wisconsinan substage. Each deposited a major till unit: the lower Catfish Creek Till; and the Tavistock Till. A later westward flow through the Lake Erie basin formed a Port Stanley - Tavistock hybrid till present on Pelee Island.

Catfish Creek Till

Catfish Creek Till was first called the "lower till" by Dreimanis (1951) and later formally named for the type section locality, Catfish Creek, on the north shore of Lake Erie (de Vries and Dreimanis 1960). It is widespread over the interlake region of southern Ontario (Karrow 1984) and has been recognized in the Tillsonburg (Barnett 1982), Orangeville (Cowan 1976), Brantford (Cowan 1972), Guelph (Karrow 1968), Lucan (Sado 1980), St. Marys (Karrow 1977) and Kent County (R. Kelly, Ontario Geological Survey, personal communication, 1993) areas.

Catfish Creek Till was deposited in southern Ontario during the Nissouri Stade, circa 21 000 years BP (Karrow 1984). Related end moraines and tills were deposited in northern Ohio at this time (Morner and Dreimanis 1973). At Bradtville, the Catfish Creek Drift consists of 3 different units, each of which represents a different ice flow event (Dreimanis 1987). In chronological order (oldest to youngest) these were: 1) ice flow to the southeast from the Lake Huron basin; 2) ice movement out of the Lake Erie basin to the northwest; and 3) a combined southwest flow from both lake basins (Barnett 1985; Dreimanis 1987).

In Essex County, Catfish Creek Till lies directly on bedrock, as observed in sections at the McGregor Quarry and in boreholes of the 1989 drilling program (see Fig. 13, Appendix A). It is a single massive unit, except under the Essex moraine, where a boulder lag separates 2 Catfish Creek Till units (Appendix A, hole E-89-07). Waterwell records and engineering borehole logs indicate a hardpan or gravel layer lying directly over bedrock throughout the county. This hardpan layer is interpreted to be Catfish Creek Till.

The mean grain size values of the till matrix fall in the sandy silt range, but the texture varies greatly (Appendix C, Table 1). The variation in sand content probably is caused by transport distance and incorporation of fine-grained limestone bedrock. Catfish Creek Till is massive and compact and the stone content can be as high as 30%. Colour varies from dark brown (10YR 4/3) to greyish brown (10YR 5/2). The thickness of the unit generally ranges between 0.3 and 3 m, but a 10.0 m thick section was encountered in a sonic borehole through the Essex moraine. Fabric analysis indicates that mean clast orientation within this till is 210°.

Distinctive clasts, derived from Huronian Supergroup sedimentary rocks, were found within the Catfish Creek Till. These include fragments of sandstone and jasper conglomerate from the Lorraine Formation and diamictite derived from the Gowganda, Bruce, and/or Ramsay Lake formations. They indicate a source in the

TABLE 1: Physical and Chemical Characteristics of Till in Essex County

Unit	Number of Samples	Geochemistry Co	Cr	Cu	Ni	Pb*	Zn	Fe*	Carbonates Total	Ratio[1]	Heavy Minerals %Total	%Mags.	Garnets %Total	Ratio[2]	Grain Size %Clay	%Silt	%Sand
Port Stanley/ Tavistock Hybrid Till	2																
Mean		21.0	83.5	33.5	46.0	22.0	110.0	2.5	2.8	0.7	5.0	3.6	9.4	3.6	37.5	48.5	14.0
Std. Dev.		2.0	0.5	0.5	0.0	0.0	5.0	0.0	0.8	0.2	0.6	1.0	0.4	0.2	0.5	1.0	0.5
Tavistock Till	36																
Mean		11.8	63.0	28.6	34.1	11.9	82.8	2.5	26.0	1.0	2.8	8.4	3.5	2.1	27.2	50.3	22.2
Std. Dev.		2.5	11.8	3.5	6.6	4.9	19.1	0.0	6.5	0.4	1.0	2.0	3.6	3.2	10.5	9.7	7.8
Catfish Creek Till	13																
Mean		7.2	43.5	22.8	23.5	5.0	61.4	2.5	51.1	1.6	4.1	8.3	10.0	0.9	16.1	44.5	40.1
Std. Dev.		4.4	16.2	7.8	8.6	0.0	20.1	0.0	17.6	0.8	2.0	2.4	3.2	0.4	5.6	7.0	10.3

* Half of the the value of detection limit was used to calculate mean and standard deviation when values fell below detection limit of 10 ppm for Pb and 5 ppm for Fe

[1] Carbonate ratio as percent calcite to dolomite

[2] Purple to red garnet ratio

Southern Province of the Canadian Shield, with ice movement through the Lake Huron basin. However, fabric and related striae orientation data imply that the Catfish Creek Till in Essex County was deposited by ice from the northeast. This suggests that the till is equivalent to the youngest till in the Catfish Creek Drift sequence at Bradtville (Dreimanis 1987). The distinctive clasts may have been incorporated by ice from older materials and subsequently deposited.

Mean carbonate content (22%) and heavy mineral content (2.5% of the fine sand fraction) are similar to values from elsewhere in southern Ontario (Barnett 1982; Cowan 1972, 1976; Karrow 1968, 1977; Sado 1980). However, the ratio of calcite to dolomite is different, ranging between 0.20 to 1.83. This probably reflects the chemical properties of the carbonate bedrock underlying Essex County. Garnet comprises approximately 4% of the heavy mineral fraction with a purple to red garnet ratio of about 1.6 (Table 1). Trace element concentrations are comparable to levels from other areas. Chromium concentrations tend to decrease to the southwest (Figure 5). The 2 Catfish Creek Till units under the Essex moraine are similar in texture but have different carbonate contents.

Gwynn and Dreimanis (1979) used heavy mineral and garnet contents to differentiate between Huron and Erie lobe tills. Tills derived from the Precambrian Grenville Province (Erie Lobe) have heavy mineral contents greater than 1%, total garnet contents between 14% and 55% of the heavy mineral fraction, and purple to red garnet ratios of 1.0 or less. Tills with Superior and Southern

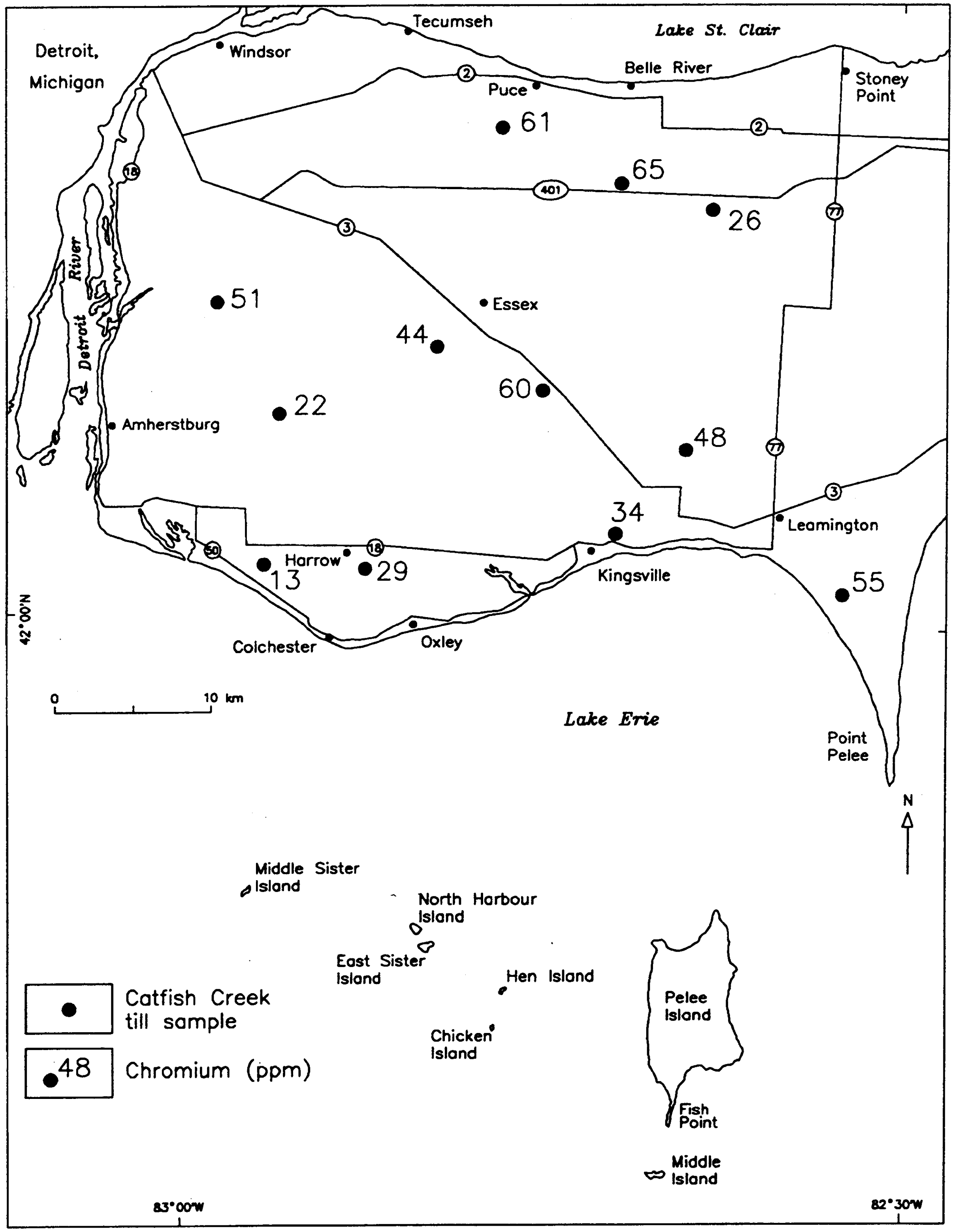

Figure 5. Distribution of chromium (ppm) in Catfish Creek Till. Note general decrease in chromium content (ppm) from north to south.

province source areas (Lake Huron Lobe) have heavy mineral contents of less than 1%, garnet less than 10%, and ratios of purple to red garnets of 1.0 or more.

The heavy mineral content (greater than 1.0%) of the 2 Catfish Creek Till units under the Essex moraine indicates deposition by ice flow from the Grenville Province (Erie Lobe). In contrast, the total garnet content of the heavy mineral fraction (less than 14.0%) and the ratio of purple to red garnet (greater than 1.0) indicates deposition from ice flow from the Superior and Southern provinces (Huron Lobe). Based on the criteria established by Gwynn and Dreimanis (1979) the data do not identify conclusively the origin of material for these 2 till units.

Elsewhere in Essex County mean values for heavy mineral content (4.08%), the ratio of purple to red garnet (0.88) and pebble fabric (210°) indicate provenance from the Grenville Province. This suggests that throughout most of Essex County, the Catfish Creek Till was deposited by Erie Lobe ice, representing the youngest of the 3 Catfish Creek units described by Barnett (1985) and Dreimanis 1987).

Tavistock Till

The Tavistock Till was formally named for the town of Tavistock in the Stratford area (Karrow 1974). It has been recognized in the Woodstock (Cowan 1975), Orangeville (Cowan 1976), St. Marys (Karrow 1977) and Lucan (Sado 1980) areas. Tavistock Till was deposited by ice flowing south and southwest out of the

Georgian Bay and Lake Huron basins during the Port Bruce Stade (Karrow 1984), and is time equivalent to the Erie lobe Port Stanley Till (Cowan 1976).

The Tavistock Till directly overlies Catfish Creek Till throughout Essex County, except in the southwest, where glaciolacustrine silt and clay separate the 2 tills. This upper till is overlain by fine-grained glaciolacustrine deposits, but is close to surface in the northeastern part of the county.

Tavistock Till has a clayey silt to silty clay matrix (Table 1) with a generally low stone content (less than 5 to 10%), although in moraines it can be sandier and stonier. Fresh till is dark grey (10YR4/1), but where oxidized it ranges from brown (10YR5/3) to dark yellowish brown (10YR4/4). The till is very soft when wet but compact when dry. Although typically massive, locally there are flow structures and deformation structures. Thickness varies between 15 to 28 m. Several fabric determinations indicate the mean clast orientation within this till varies between 165° and 215° (Fig. 6). There appears to be 2 dominant clast orientations around 205° and 165°. This would suggest 2 different ice flow directions over Essex County. However, more measurements of clast orientations are required before such a conclusion can be made. The presence of clasts of Huronian rocks also indicate southward ice flow.

South of Harrow, sand and gravel separates Tavistock Till into upper and lower units. The upper unit is a relatively thin sheet. In Lake Erie shorebluff sections, this upper unit is massive to the

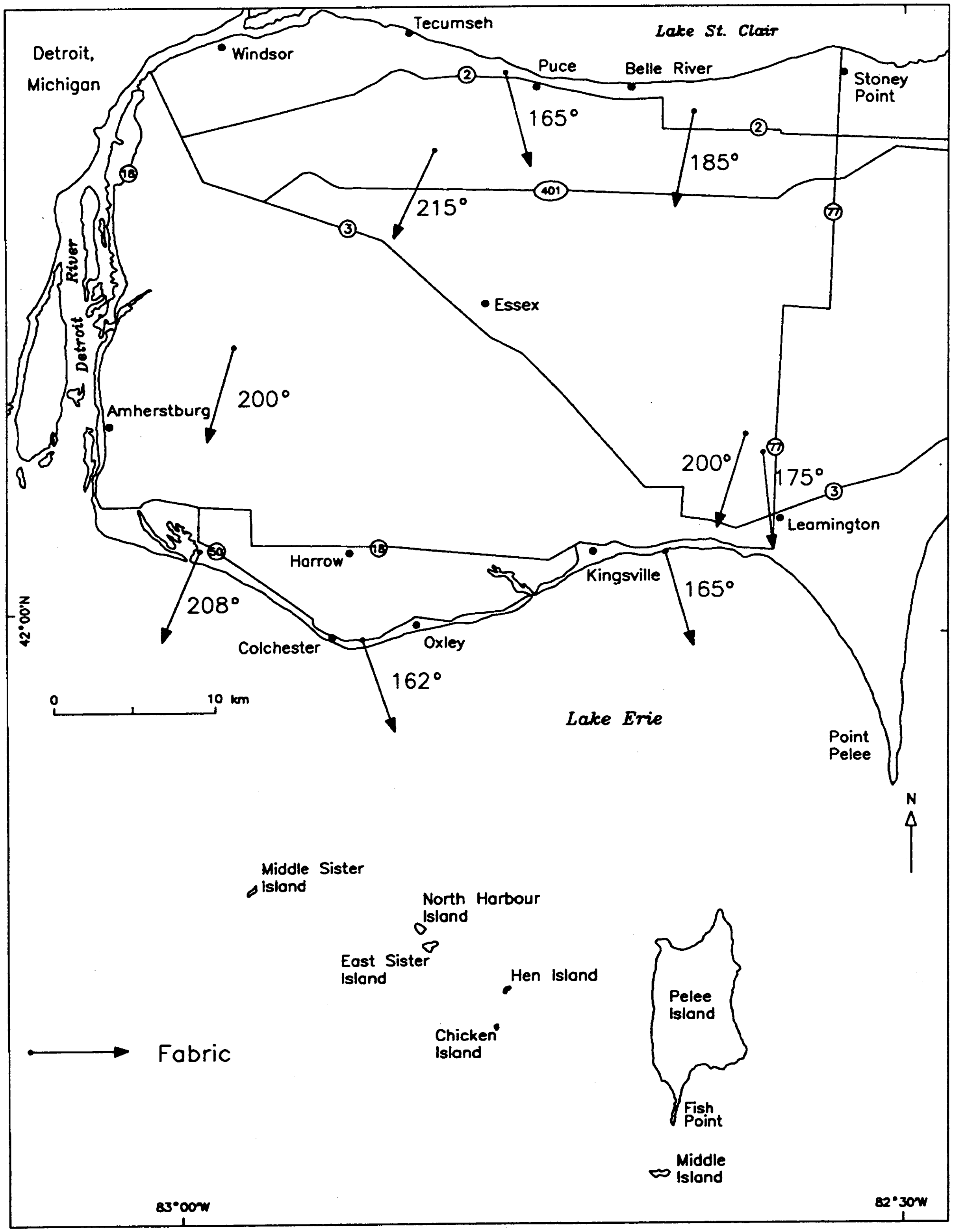

Figure 6. Summary of representative mean clast orientations determined by clast fabrics in Tavistock Till.

west but grades into a laminated diamicton with flow structures to the east (see Figure 12). The margin of the till sheet is marked by a subtle south trending ridge. This ridge can be traced north from Lake Erie to a point south of Harrow.

Mean total carbonate content is approximately 26% (Table 1), which is low relative to the same till elsewhere in southern Ontario, except in the Guelph area (Cowan 1976; Karrow 1968, 1977; Sado 1980). In both the Guelph area and Essex County, the glacier overrode shale bedrock immediately up-ice effectively lowering the carbonate content of its basal debris load by dilution. The calcite to dolomite ratio is close to 1. Heavy mineral content is close to 3% with magnetics making up about 8% of that fraction, similar to values reported elsewhere (Cowan 1976; Karrow 1968, 1977; Sado 1980). The garnet content increases northward but remains less than 14.0%. The ratio of purple to red garnet is generally greater than 1.0% across the study area. The garnet data imply that ice flow was from the north (Gwynn and Dreimanis 1979).

Port Stanley - Tavistock Hybrid Till

The Port Stanley Till is a fine-grained, almost stone-free till, first described in the Port Stanley area by de Vries and Dreimanis (1960). It was deposited during the Port Bruce Stade by ice flowing west through the Lake Erie basin. Large quantities of glaciolacustrine silt and clay were incorporated into this till (Karrow 1984). Cowan (1976) considers this till to be contemporaneous with the Tavistock Till. In the eastern Lake Erie basin, a fluctuating ice margin deposited 3 major Port Stanley Till sheets and several minor till layers interbedded with varved glaciolacustrine sediments of Lake Maumee (Dreimanis 1971).

On Pelee Island, there is a dark grey (10YR4/1) clayey silt till underlying glaciolacustrine silty clay. This compact till is generally massive, although flow structures were observed locally. A limited number of waterwell records indicate that thickness may exceed 53 m in the northeast-central part of the island. Clast orientation measurements did not reveal a preferred direction. No Huronian clasts were noted in this till.

Low total carbonate content (3%), determined from a near surface sample, likely reflects surface weathering and leaching of carbonate (Barnett, Ontario Geological Survey, personal communication, 1990). The relative magnetic mineral concentration of the sample is lower than that of the Catfish and Tavistock tills of Essex County (Table 1) and the Port Stanley Till elsewhere in southern Ontario. The purple to red garnet ratio is higher than for the Tavistock Till on the mainland (Table 1).

Neither laboratory analysis nor physical properties clearly define the till on Pelee Island as either Tavistock or Port Stanley. The last westward flow of ice through the basin was a combined Huron-Erie flow (Fullerton 1986) and it is possible that the till on Pelee Island is a hybrid of these.

Recessional Moraines

The Essex moraine and the Kingsville boulder belt of Taylor (1913) are recognized in this report as part of a series of recessional moraines (Figure 7; Surficial Geology Map, Map Unit 2A). The Kingsville boulder belt of Taylor (1913) has been extended west and northwest and re-named the Kingsville moraine. These moraines were initially identified on remote sensing imagery as lighter tones (Photo 1), which are due to superior drainage. They have relatively stony surfaces and are slightly sandier than adjacent glaciolacustrine sediments and Tavistock Till (Appendix C). The moraines are slightly elevated above the surrounding clay plain and correspond well with areas of thicker drift on the drift thickness map.

Vagners (1972a, 1972b) mapped some of these moraines as beach ridges due to the presence of a sand cover. However, the bulk of material which comprises the ridges is till, not sand (Table 2). The elevation of the ridge above the clay plain, therefore, is only partly due to the presence of a sand cover.

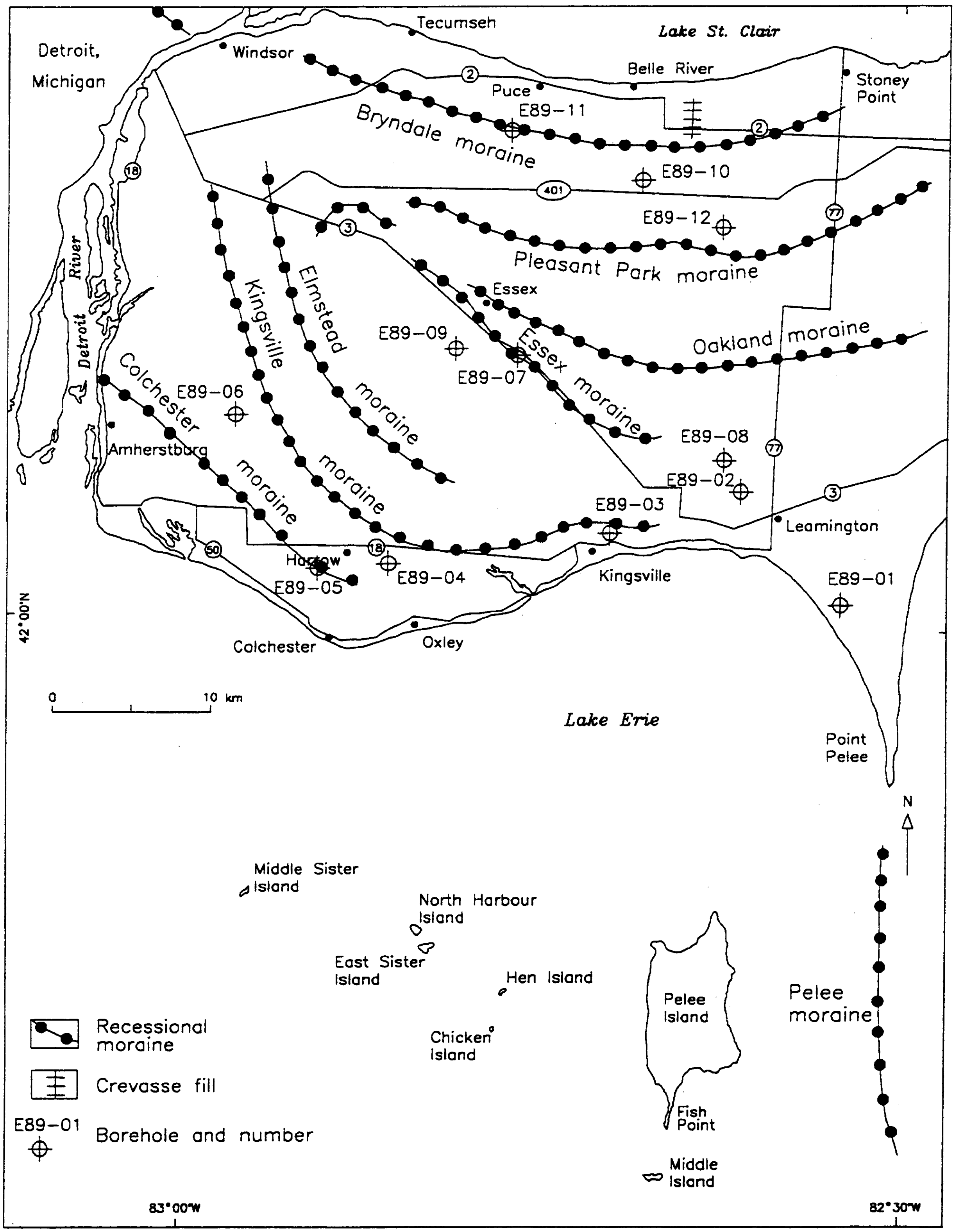

Figure 7. Distribution of recessional moraine.

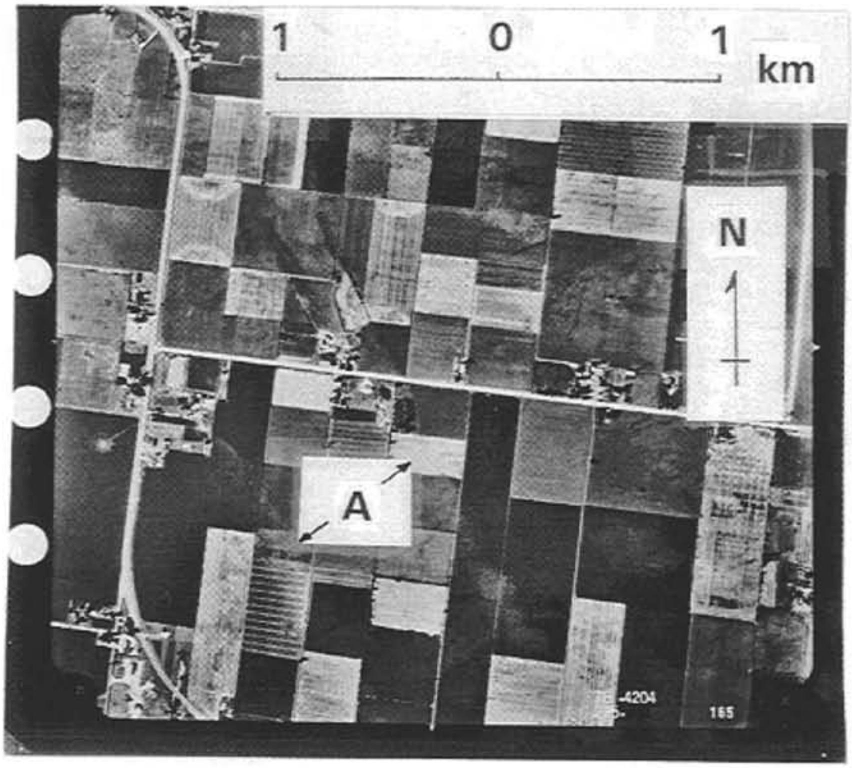

Photo 1. Partially buried recessional moraine. Recessional moraine's (A) higher topography (relative to the surrounding glaciolacustrine plain) enhances drainage off it's surface. The enhanced drainage causes a lighter tone on the 1:10 000 scale black and white aerial photograph. Ontario Ministry of Natural Resources, photo number 78-4204-225-165.

TABLE 2:

SUMMARY OF SAND THICKNESS OVER RECESSIONAL MORAINE

Moraine	Thickness of Sand Cover (m)	Elevation above Clay Plain (m)
Byrndale	0.5	2.8
Essex	1.2	1.6
Kingsville	0.5- 1.0	3.0

During the spring of 1989, sonic boreholes were drilled to bedrock through the crests of 4 moraines in Essex County (Appendix A, holes E-89-03, 05, 07, 11) with 2 additional holes proximal to moraines (Appendix A, holes E-89-09, 12). The Tavistock Till encountered in the moraines is more variable in texture than Tavistock Till found elsewhere. This is exemplified by the cyclical sequence of coarser and finer-grained units of Tavistock Till found in hole E-89-05. This suggests deposition as debris flows off the ice margin where some sorting of material may have occurred. With distance away from the ice margin, sorting of material is better developed, as observed in holes E-89-09 and E-89-12. Till samples from holes drilled in the clay plain (Appendix A, E-89-01 and E-89-06) have more uniform textures.

Glacier ice may have been pinned on bedrock highs, allowing the deposition of some of the moraines and associated proglacial subaquatic fans (see Glaciofluvial sub-chapter). A sand and gravel bench on the southwestern side of the Essex moraine and a thin sand drape (15 cm) over silt and Tavistock Till on the northeastern side of the ridge are probably products of glaciolacustrine modification of a subaquatic fan. There may have been ice at this moraine position during the later stages of the Port Bruce Stade as well as the Nissouri Stade. This is suggested by the anomalously thick layer of Catfish Creek Till underlying the Tavistock Till.

East of Belle River, there is a south trending ridge capped by 1 to 3 m of sand (Figure 7). Drilling indicates that the ridge consists of stratified materials (Sklash, University of Windsor, personal communication, 1990); it is probably a crevasse fill.

Bedrock Erosion Features

Features resulting from ice flow over bedrock include plucked bedrock surfaces and striae. Plucked bedrock surfaces consist of rock benches formed by compressive ice flow over a bedrock outcrop. These are present in a quarry west of McGregor. Striae were measured in the Amherstburg and McGregor quarries and on bedrock outcrops on Pelee, East Sister, Hen and Middle islands.

There are 9 bedrock plucked bedrock surfaces on the limestone bedrock at the south end of the McGregor Quarry (Photo 2). Each plucked bedrock surface consists of a ramp, crest and face. The ramps exhibit a shallow dip (3°) to the northeast and the face dips steeply (~ 80°) to the southwest. The crest of these features are aligned sub-perpendicular to ice flow as indicated by superimposed striae aligned 220° and 225°. Smaller, less pronounced plucking of the bedrock surface is visible on the northeast side of some fractures aligned sub-perpendicular to the striae. This plucking indicates southwesterly ice flow. Some of these fractures are

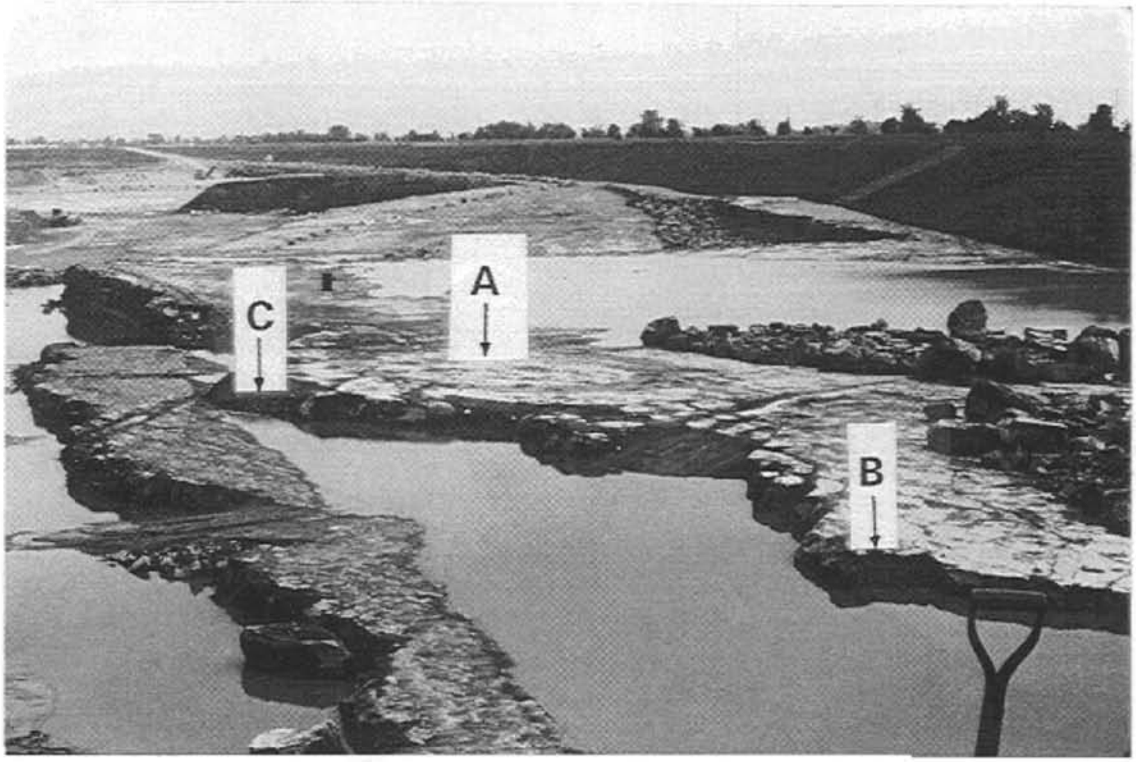

Photo 2. Glacially plucked bedrock surface, McGregor Quarry, Essex County. Each plucked bedrock surface consists of a ramp (A), crest (B) and face (C).

filled with till.

There is neither vertical nor horizontal displacement of bedding in the bedrock within and between the plucked bedrock surface. This implies that these plucked surfaces were not formed by tectonic movement. The striae orientation on the bedrock surface (220°) is the same as the mean pebble fabric of the overlying Catfish Creek Till (220°), which suggests that both the striae and the plucked surfaces at the McGregor Quarry were formed during the Nissouri Stade by compressive ice flow over the site.

Vagners (1972a, 1972b) reported 140° striae cross-cutting 220° striations at the Amherstburg Quarry, but only the 220° set was observed during this mapping project. Small-scale plucking at this quarry of the bedrock surface on the northeast sides of 140° striking fractures also indicates southwesterly ice flow. On Pelee, Hen, East Sister and Middle islands, sets of 270° striae cross-cut older 180° striations.

"P" forms, aligned at about 270°, were found on Pelee, East Sister and Middle islands where the bedrock was freshly exposed (Photo 3). They have a variety of different shapes, including open and closed spindles, furrows, comma form, sichelwannen, flute and rock drumlin. These shapes are the same as those described by Kor et al. (1991) and Sharp and Shaw (1989), who conclude that they are formed by the flow of debris charged meltwater confined beneath glacier ice. The forms may contain striae that trend roughly parallel to the trend of the "P" forms themselves. These striations are younger than the "P" forms and indicate that locally

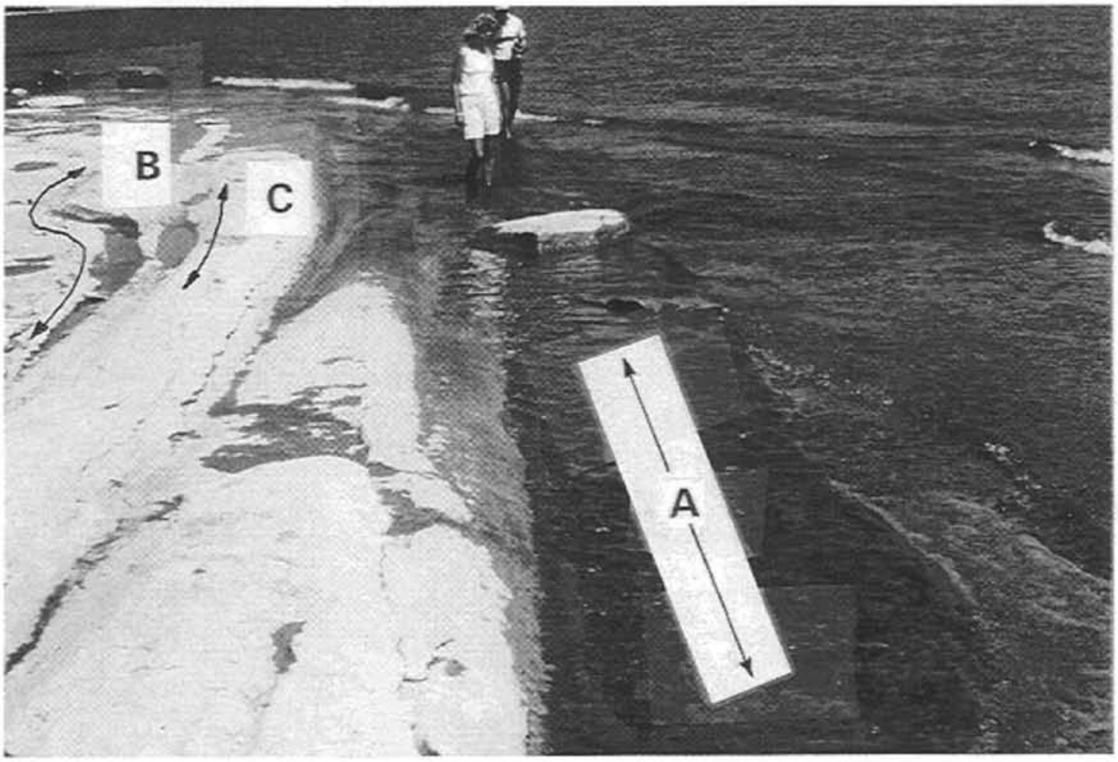

Photo 3. "P" forms at South Bay, Pelee Island. These features formed by confined flow of sediment rich glacial meltwater beneath glacial ice. "P" form shapes observed on this photograph include flutes (A), closed spindle (B) and a furrow (C).

the glacier re-contacted the bedrock surface. Ages of the striae and "P" forms are unknown for Pelee, East Sister and Middle islands.

Glaciofluvial Deposits

Proglacial Subaquatic Fans

Proglacial subaquatic fans are distributed along the north shore of Lake Erie from west of Colchester to Leamington (Figure 8). The interpretation of these deposits is based on sedimentology and their spatial relationships with moraines. Local topography is higher at most fan locations. There is sand at the surface of some fans, but others, exposed in Lake Erie bluff sections (see Figure 12), are capped by glaciolacustrine silts and clays. Some fans are overlain by Tavistock Till. Hence, the fans were likely deposited within Glacial Lake Maumee from an unstable, but northward retreating, ice margin.

A sand distribution map (see Figure 15) and remote sensing information aided identification of 7 proglacial subaquatic fans (Figure 8). Southeasterly paleocurrent directions, the presence of Huronian jasper conglomerate and diamictite clasts, and the northerly orientation of fan apices all indicate that the fan sediments were deposited from Huron lobe ice. Sands are stratigraphically associated with Tavistock Till.

Sedimentological structures and features associated with these fans are similar to those described for proglacial subaquatic fans

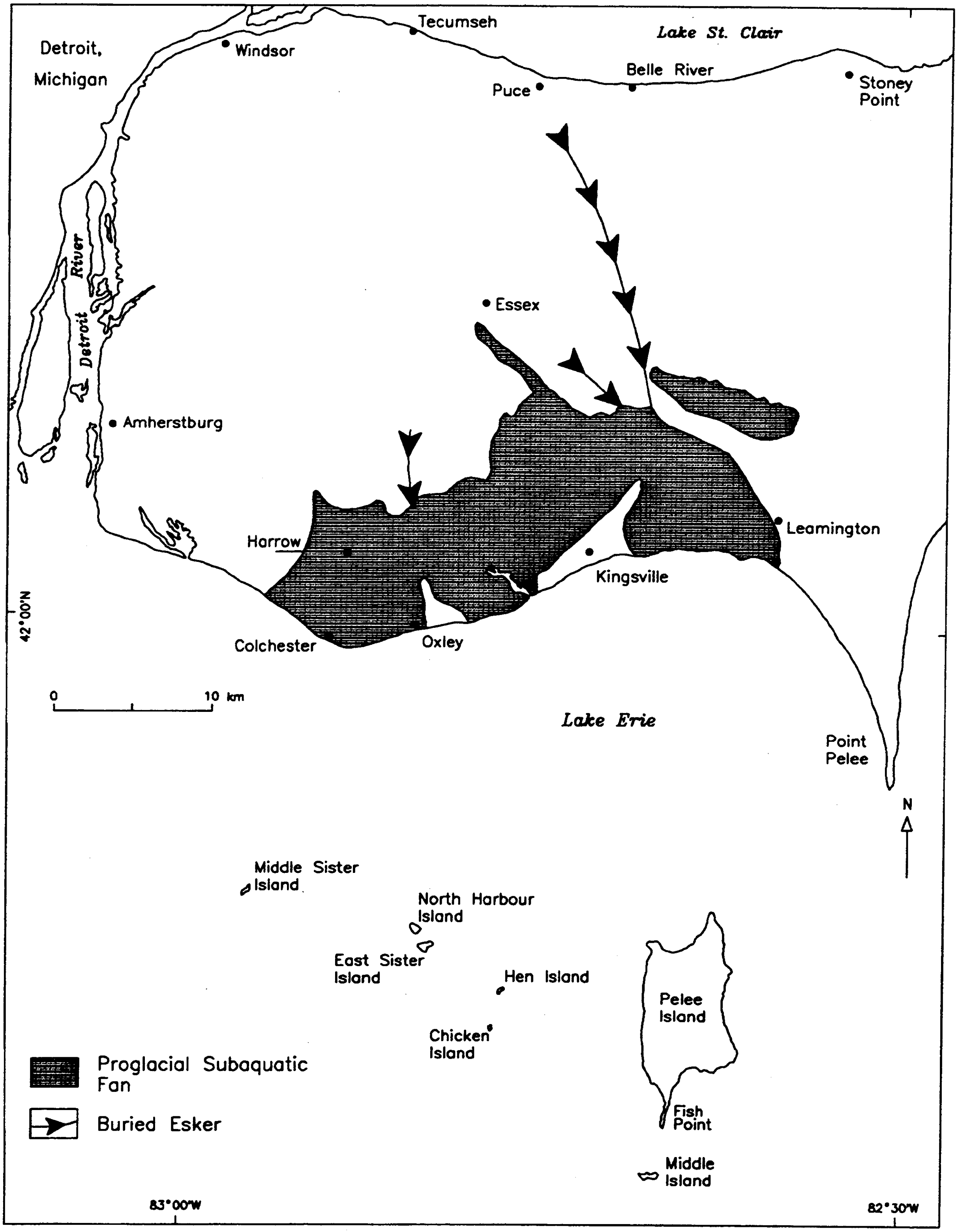

Figure 8. Distribution of proglacial subaquatic fans and buried eskers.

elsewhere (Ashley et al. 1985; Postma et al. 1983; Rust and Romanelli 1975; Rust 1977). Commonly, massive sands are found in exposures proximal to recessional moraines, usually at the base of stratigraphic sections, and may contain rounded diamicton clasts. The massive sand is sometimes very compact and may contain ball and pillow structures. Where this occurs, the massive sand is commonly overlain by Tavistock Till. Ashley et al. (1985) state that massive sand is common where water, exiting from a confined channel at the base of an ice sheet, enters a standing body of water as an underflow.

At one site close to a moraine, planar sand beds are off-set and till has been injected upwards into the massive sand (see description for section 9, Figure 12, in the Stratigraphy section).

Trough cross-beds and planar beds are usually found overlying massive sand beds or down-flow from recessional moraines. Cross bedding, trough orientation, and the dip of the planar beds all indicate southeasterly paleoflows (Figure 9). Like the massive sand, these beds may contain rounded diamict clasts and flame water escape structures. Off-set beds in some sections indicate faulting after deposition.

Channel scours are rare, but, where present, these features commonly cut through planar and trough cross-bedded strata. Most are small (1 to 2 m wide by 1 to 2 m deep) and contain fills of massive sand. One large channel scour (6 m deep by 4 m wide) contains steeply dipping planar beds with a strong eastward paleocurrent (see Figure 14, Photo 4).

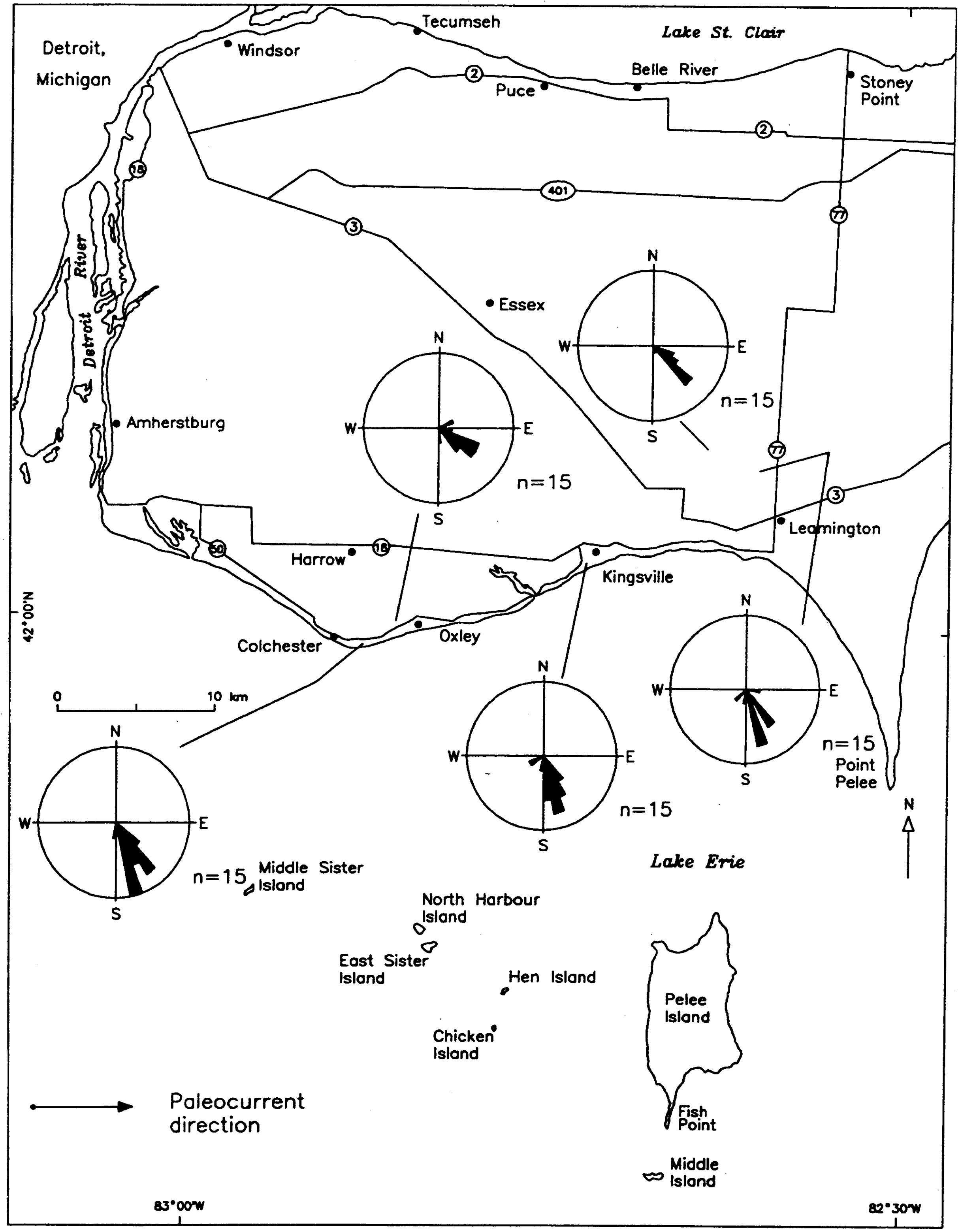

Figure 9. Summary of representative mean paleocurrent directions measured from structures associated with proglacial subaquatic fans.

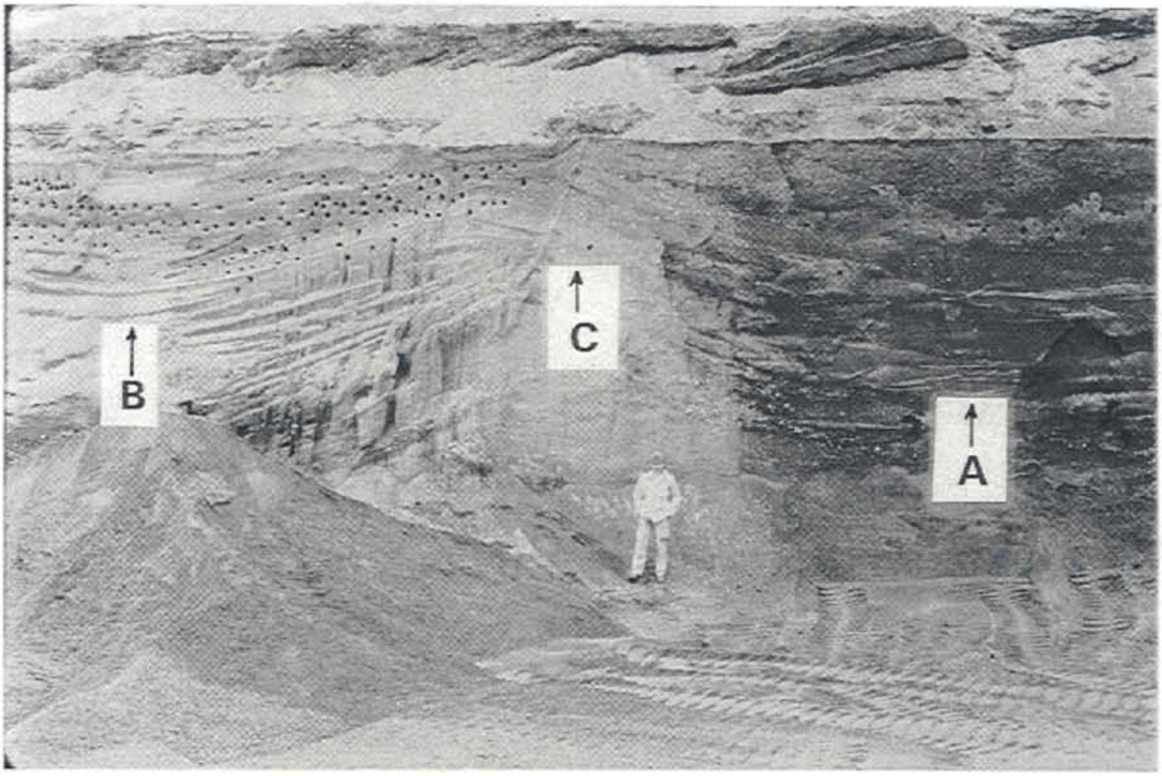

Photo 4. Channel scour within proglacial subaquatic sediments, west wall of the Erie Sand and Gravel pit near Leamington. Sand structure indicates deposition of sand in a proglacial subaquatic environment. Features in this photograph include: (A) trough cross beds; (B) gently dipping planar beds and; (C) margin of a channel fill.

Eskers

Vagners (1972a, 1972b) identified 4 eskers in Essex County: 2 west of Harrow and 2 east of Harrow. The 2 m high ridges west of Harrow are located on a proglacial subaquatic fan at 192 m asl, the well documented Glacial Lake Grassmere water plane level. Both morphology and location imply that they are beach ridges, not eskers. The 2 ridges east of Harrow are 10 to 20 m wide and 1.75 km long and are composed of sand and large boulders. They lead directly into the apex of a subaquatic fan.

During the present study, 2 additional eskers were found on surface, one south of Albuna and the other north of Goldsmith (Quaternary geology map, back pocket). The first is a sharp-crested ridge that trends southwards and is splayed at the southern end. It is 2.5 m high and 4 m wide where exposed at the surface and is flanked by sandy glaciolacustrine clay. The massive sand core is capped by easterly dipping planar beds of sand. The other esker has been greatly modified by glaciolacustrine processes and human activities. This ridge is 1 m high by 2 m wide and is splayed at the southern end.

In addition, 3 buried eskers were identified in Essex County (Figure 8). The largest, first noted on remote sensing imagery as a lighter tone, stretches southeast from Belle River to Albuna. Locally, there is some relief associated with this feature. A borehole placed close to the centre of the esker encountered buried sand (Appendix A; E-89-10) but no sand was found in holes drilled east and west of this feature. An independent drilling programme also encountered buried sand related to the esker (M. Sklash, University of Windsor, personal communication, 1990). A peculiar distribution of isotopically young water in Essex County is aligned identically to the trend of this esker (Chekiri et al. 1993; Sklash 1990; Sklash et al. 1987).

Two other buried eskers were found using the sand distribution map (see Figure 15). The first is a short esker extending south from Barretville into the apex of a subaquatic fan. The second trends southeast from Cottam and also feeds into the apex of a proglacial subaquatic fan.

Glaciolacustrine Sediments

Silts and Clays

There are 2 stratigraphic units of fine-grained glaciolacustrine sediments in Essex County. The older unit is exposed at the McGregor Quarry and was encountered in 3 sonic drill holes (Appendix A; E-89-01, 05, 12). Stratigraphically, it lies between the Catfish Creek and Tavistock tills. The elevation (159 m asl) and stratigraphic relationships of this unit suggest deposition into Glacial Lake Leverett during the Erie Interstade (Dreimanis 1958). In a section at the McGregor Quarry, this older unit drapes the surface of the Catfish Creek Till. In the same section, the lower part of the Tavistock Till contains rip-up clasts of this older glaciolacustrine unit.

Sediments comprising this unit at the McGregor Quarry are predominantly silt and clay with wavy laminated upper and lower beds separated by horizontally laminated material. The wavy laminations vary between 1 to 5 mm thick and contain abundant red clay clasts. The transition to uniform (2 mm) horizontal laminations is gradational. Overall thickness of the unit ranges between 0.4 to 1.5 m. The colour is dark brown (7.5YR 3/2), clast content is less than 1%, and the mean carbonate content is 29%. Table 3 summarizes laboratory analyses for this unit.

Younger glaciolacustrine deposits (map unit 3) overlie Tavistock Till and form the surface cover for most of Essex County. This unit is less than 1 m thick in the northeast and thickens westward to at least 6 m. The upper weathered zone ranges from 0.5 to 3.0 m in thickness. Typically, the glaciolacustrine material is composed mainly of rhythmically laminated silt and clay (Table 3) but there is also a sandy silt phase. Laminations are generally 1 to 5 mm thick and red clay clasts are abundant. Where measured, the beds typically dip gently toward 190° Above the contact with the Tavistock Till, bedding orientation is random and the dip is steeper. Flow structures, such as flow cones, are present but are relatively rare. The transition to the weathered horizon is diffuse. There are some beds of *in situ* unoxidized silt, clay, and red clay clasts within the weathered zone. The sandy facies (map unit 3A) is poorly exposed but appears to have the same structural characteristics as the finer-grained underlying sediments. This sandier phase is probably associated with buried subaquatic fans.

Total carbonate content of the unweathered silt-clay fraction

TABLE 3: Physical and Chemical Characteristics of Glaciolacustrine Deposits in Essex County

Unit	Number of Samples	Geochemistry (ppm) Co	Cr	Cu	Ni	Pb*	Zn	Fe*	Carbonates Total	Ratio[1]	Heavy Minerals %Total	%Mags.	Garnets %Total	Ratio[2]	Grain Size %Clay	%Silt	%Sand
Upper, Weathered Glacio-lacustrine	48.0																
Mean		13.0	77.0	30.8	40.3	19.0	113.7	2.5	10.6	0.8	2.2	5.9	4.4	0.8	37.0	37.3	25.7
Std. Dev.		3.1	13.9	8.0	10.1	13.5	34.1	0.0	10.4	0.5	1.4	3.3	3.9	0.9	13.9	11.9	18.1
Upper, silty sand, glacio-lacustrine	6.0																
Mean		11.0	59.0	29.5	28.5	17.5	92.8	2.5	19.4	1.0	3.9	7.0	7.2	0.5	15.8	40.7	43.5
Std. Dev.		2.5	11.9	5.4	4.0	7.8	26.4	0.0	13.0	0.3	0.9	3.2	3.6	0.3	7.6	15.2	17.0
Upper, glacio-lacustrine	28.0																
Mean		10.9	63.9	28.3	32.5	12.0	83.3	2.5	21.0	0.9	2.3	8.3	4.1	1.6	37.2	40.9	17.6
Std. Dev.		3.1	17.0	6.0	8.7	3.2	21.5	0.0	6.7	0.5	1.4	3.2	4.0	2.2	16.1	15.3	13.0
Lower, glacio-lacustrine	4.0																
Mean		11.2	59.8	26.5	31.5	11.8	70.2	2.5	29.6	1.5	4.0	10.1	9.0	1.4	35.0	52.6	12.4
Std. Dev.		1.3	2.6	2.7	1.7	1.5	7.2	0.0	1.4	1.4	1.2	1.1	3.3	1.0	6.0	2.8	7.0

* Half the value of detection limit was used to calculate mean and standard deviation when values fell below detection limit of 10 ppm for Pb and 5 ppm for Fe.

[1] Carbonate ratio as percent calcite to dolomite.

[2] Purple to red garnet ratio.

for the lower glaciolacustrine unit averages 29% (Table 3). The garnet content (all less than or equal to 9%) and purple to red garnet ratio (greater than 1) imply that the Precambrian shield component of these sediments was derived mainly from the Superior and Southern provinces. The general increase in heavy mineral content to the south may indicate the influence of material supplied from Lake Erie ice. The pronounced weathering of the upper part of this glaciolacustrine unit is reflected in: 1) the low total carbonate; 2) elevated trace element values (- 230 mesh fraction; determined by comparing the mean of each element and confirmed by a T-Test); 3) presence of clays such as smectite and vermiculite; and 4) the partial or complete destruction of sedimentary structures. It is likely that iceberg keel drag probably also destroyed structure in the upper part of the glaciolacustrine unit. The undulating thickness of the weathered zone may be partly due to varying depth of keel drag.

Soderman et al. (1961) argue that Essex County surface material is till. They base their argument on the varying degrees of overconsolidation of the surface unit, lower values of liquidity index, sensitivities of less than 3, lack of structure and grain size distribution. The present study has found that the fine-grained surface unit has distinctly different properties than the Tavistock Till. The structural properties (diffuse contact with underlying, unaltered glaciolacustrine material, abundance of red clay clasts and the occasional *in situ* beds of unaltered material) are more consistent with its interpretation as a glaciolacustrine deposit than a till. Most of the characteristics of the weathered zone can be explained by pedogenic processes.

Shoreline Deposits and Features

Wave-related processes formed beach ridges, offshore bars, and spits in proglacial and postglacial lakes and also created distinct wave-cut notches on the surface of the proglacial subaquatic fans (map unit 4). Surface elevations of these features were determined from 1: 25 000 scale NTS map sheets with a 25′ (7.6 m) contour interval. The chronology of lakes in the Lake Erie basin is well documented and the reader is referred to Calkin and Feenstra (1985) for a comprehensive summary of the evolution of the basin. Table 4 provides a brief summary of the elevations of Late Wisconsinan lakes and related features found during the present survey.

Northwest of Leamington at the Bondi Pit (UTM 363600m.E 456070m.N.), the altitude of the upper surface of a bar deposit (217 m) approximates the Arkona I level (216 m). This bar, developed on a subaquatic fan, lies to the east of a Glacial Lake Whittlesey wave-cut bench (226 m) and west of a Glacial Lake Warren wave-cut bench (209 m). The materials making up this Arkona I deposit include massive sand and gravel which grade laterally southward to steeply dipping foreset beds. The dip of these beds decreases southward. The whole sequence is capped by sand with multi-directional ripple cross-laminations that grades eastward to easterly dipping planar beds (see Figure 14 and related site description in the Stratigraphy section).

Table 4: Summary of glacial lake history for the Lake Erie basin.

LAKE STAGE	CHRONOLOGY years BP	ELEV. m.	FEATURES IN ESSEX COUNTY	ELEV. m.
Lundy	12 460- 12 400	189	Discontinuous beach ridges	189
Grassmere	12 510- 12 460	195	Beaches, Wave-cut benches	192-198
Warren III	12 620- 12 510	204	Beach ridges	204
Wayne	12 710- 12 620	201	Beach ridges	201
Warren II	12 750- 12 710	206		
Warren I	12 840- 12 750	209	Wave-cut benches, beaches	208-209
Whittlesey	13 010- 12 840	226	Offshore bar	226
Arkona III	13 660- 13 590	212		
Arkona II	13 740- 13 660	213		
Arkona I	13 790 13 740	216	Offshore bar	216

A bovid metacarpal bone (Photo 5) was discovered at the contact between the subaquatic fan and bar deposits (209 m altitude). The bone collagen was radiocarbon dated at 13 410 ± 100 years BP (TO-1803). It was identified as cf. Euceratherium sp. (Morris *et al.* 1994), a shrub-ox that inhabited lower hills in a forest-tundra type environment. It is the first fossil of its kind to be found in Ontario.

On the east side of the Erie Sand and Gravel pit, organic

Photo 5. Left metacarpal of a muskox bone, cf. Euceratherium sp. collected from the Erie Sand and Gravel pit. This bone was recovered by a backhoe operator from a bar which formed in Glacial lake Arkona. The bone has a radiocarbon age of 13 410 ± 100 BP (TO 1830).

material was found at a similar contact and altitude (209 m; see Figure 14 and related site description in the Stratigraphy section; Photo 6). Plant macrofossils from these organic layers were radiocarbon dated at 13 225 ± 200 years BP (BGS 1404) and 13 150 ± 100 years BP (WE-01-89). Pollen, microfossil, and plant macrofossil assemblages (Figures 10, 11) indicate a forest-tundra type environment with a mean July temperature of 14°C (Morris *et al.* 1994).

Northwest of Leamington (UTM 362700m.E 455920m.N), there is a Glacial Lake Whittlesey bar at 226 m asl, about 10 m higher than the Glacial Lake Arkona beaches. A storm beach is superimposed on the bar at 229 m asl. Beach sands overlying the Lake Arkona bar are probably related to Lake Whittlesey. These sands are laminated with some ripple cross lamination, probably indicative of a beach middle shoreface.

Sand exposed in a section (UTM 365900m.E 456110m.N) within a Glacial Lake Warren bar displays both planar beds and cross-bedding. A west trending channel cuts through these sand structures. Extending eastward from this bar is a narrow fan composed of massive sand with coarse gravel that includes diamicton clasts. This fan is likely a spit formed by eastward current along the north side of the Glacial Lake Warren bar. South of this site (UTM 366500m.E 456040m.N) on the same bar, shell and wood macrofossils were found 1 m below the ground surface. Radiocarbon dating of the wood yielded a minimum date of 10 000 ± 200 years BP (BGS 1311) for the bar.

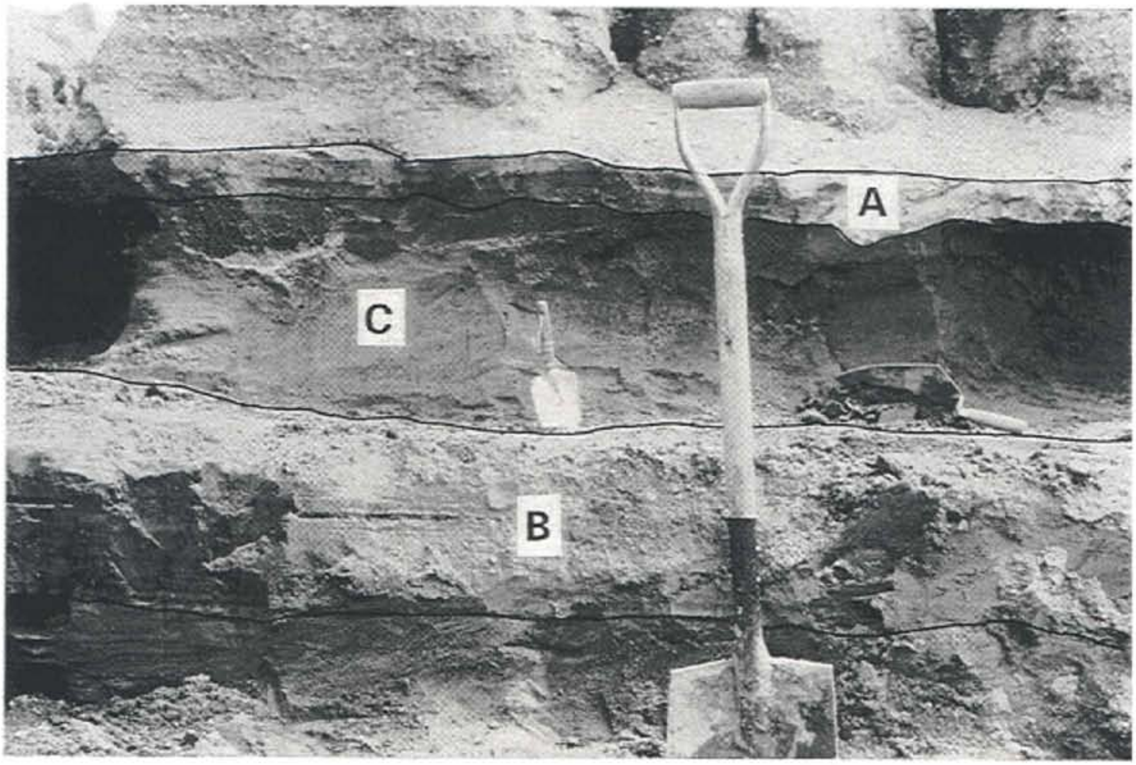

Photo 6. Organic deposit, Erie sand and Gravel pit. Thinly laminated silts and clays with organic mats (A, B). These beds were deposited within a protected embayment of a bar which formed within Glacial Lake Arkona. A breach in the bar, possibly during a storm event, caused avulsion of sand (C) into the embayment. The organic material has radiocarbon ages of 13 225 ± 200 (BGS 1404; from B) and 13 150 ± 100 BP (WE 0189; from A).

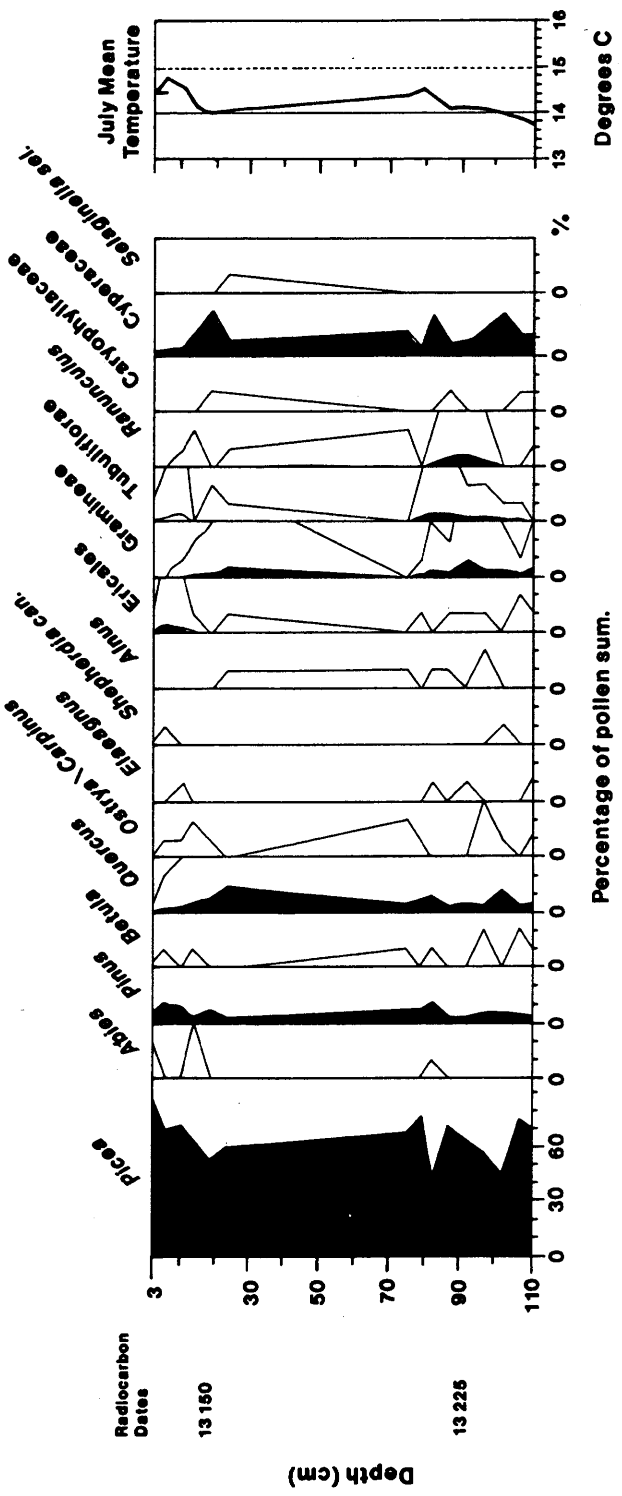

Figure 10. Summary pollen diagram from organic beds, Erie Sand and Gravel pit.

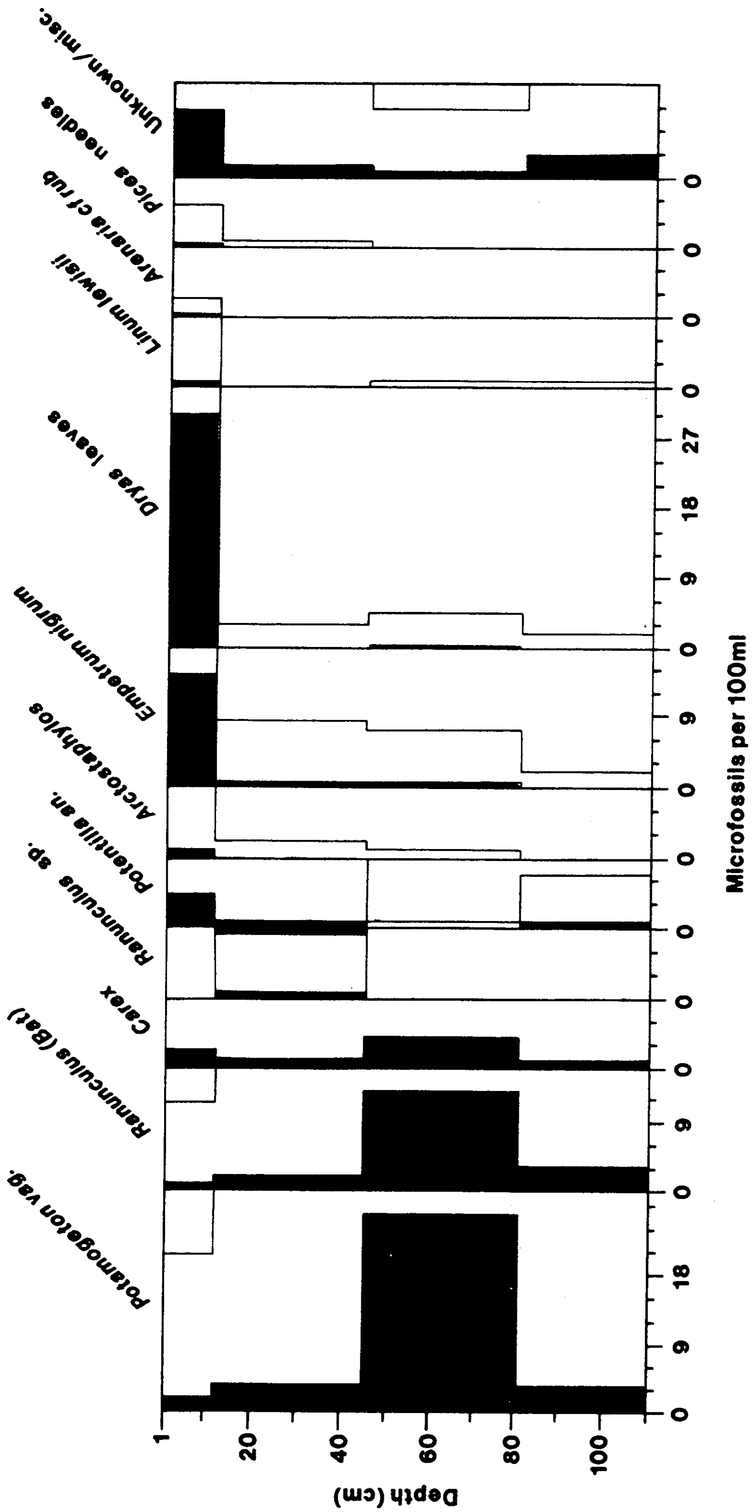

Figure 11. Summary macrofossil assemblage from organic beds, Erie Sand and Gravel pit.

A pit exposure in a large area of sand around Albuna (UTM 362500m.E 456620m.N) displays planar beds and ripple cross laminations, indicative of middle shoreface sedimentation. The elevation of this beach deposit is between 192 m asl and 198 m asl. It is probably the upper part of a proglacial subaquatic fan reworked by wave action in glacial Lake Grassmere. On the Essex Moraine, there is a gravel bar (UTM 348600 m.E. 457170 m.N.) at 198 m asl and a sand and gravel bench on the southwest side of the moraine at 195 m asl. There is no obvious source for the beach material and this large quantity of sand and gravel could not have been washed out of the moraine.

Sand Drapes

Sand drapes are thin sand layers (less than 1 m thick) overlying glaciolacustrine silt and clay. Three distinct types of drapes have been identified: 1) thin layers (less than 15 cm; map unit 3A); 2) thicker drapes of less than 1 m associated with beach ridges and erosional channels that expose the underlying silts (map unit 3C); and 3) clayey silt deposits interbedded with layers of sand and sandy silt (map unit 3B). Thin sand drapes (map unit 3B) northeast of the Essex Moraine and southwest of the Colchester Moraine, probably formed during storm events in Glacial Lake Grassmere. Sand derived from exposed subaquatic fans forms thin and discontinuous deposits (less than 1 m thick; map unit 3C) over glaciolacustrine silts and clays northwest and west of Leamington and in Windsor. A small basin west of Harrow contains interbedded clayey silt and sand (map unit 3A).

Iceberg Keel Marks

Keel marks are formed by iceberg drag on the bottoms of proglacial lakes, in water up to 225 m deep (Todd et al. 1988). Similar drag marks are also made by winter lake ice during spring breakup (Grass 1984). Iceberg keel marks are common throughout the study area and are most clearly visible on 1: 10 000 scale black and white aerial photographs (Photo 7). They appear as shallow surface depressions in fields. Some are more than 4 km long but rarely exceed 20 m in width. The classic shapes are described by Lewis et al. (1985) and Woodsworth-Lynas et al. (1985) and consist of curves, switchbacks, pirouettes, straight segments and skips. Iceberg keel marks can be paired and can also cross-cut each other.

Postglacial Deposits and Features

Lake Rouge

South of Windsor, deposits of sand and sandy silt occupy a shallow basin bounded by the Bryndale, Elmstead, and Colchester moraines (map unit 5). Abandoned fluvial channels, which cut through the Bryndale Moraine, terminate at the head of a fan-shaped sand deposit in the northern part of the basin. Another abandoned channel cuts through the Colchester Moraine north of Malden Centre. This channel exhibits a gradient of 3 m over 1 km and terminates at a thin (1 m thick) fan-shaped sand body. Distal to the channels

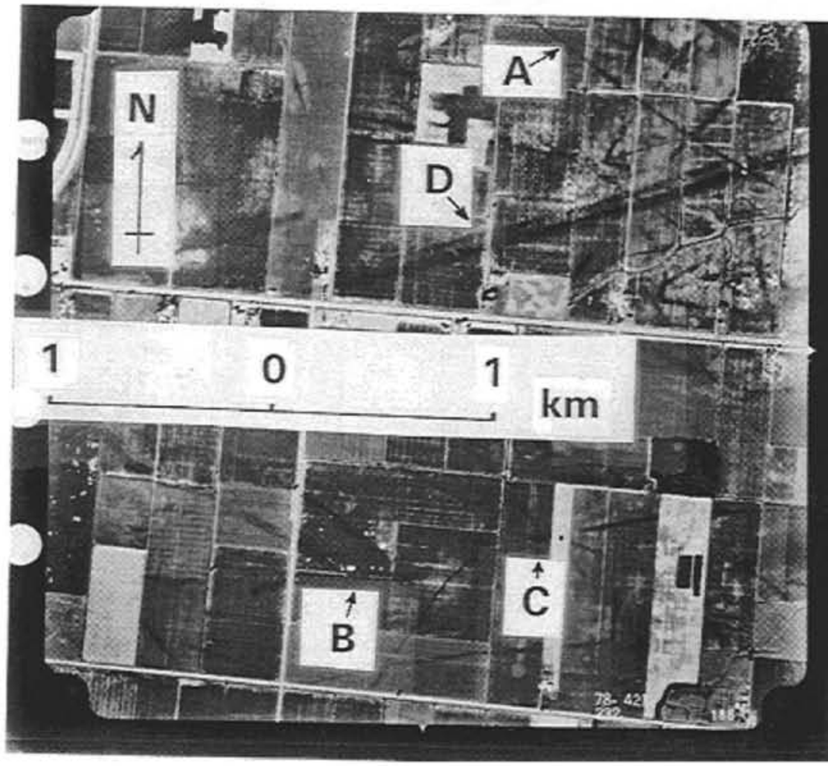

Photo 7. Iceberg keel marks north of Leamington. These features were formed as icebergs within glacial lakes dragged their keels over the former lake bottom. These features can be as long as 4 km and as wide as 20 m. This 1:10 000 scale black and white aerial photograph illustrates some iceberg keel shapes: (A) curved line; (B) switch-backs; (C) cross-cuts; and (D) paired keels. Ontario Ministry of Natural Resources, photo number 78-4212-232-186.

the material becomes sandy silt (map unit 5a). Vagners (1972a, 1972b) postulated that the sands and silts were deposited in a short-lived lake (Lake Rouge) that formed part of a discharge route from Early Lake Algonquin (Lake Huron basin) and Early Lake St. Clair to Early Lake Erie.

Early Lake Erie

Other lacustrine features in the area include several beaches and a wave-cut notch at 180 m asl, an elevation that does not correlate with any of the proglacial lakes discussed above (map unit 5). These features are located east of Leamington. They may be related to transgression in the Lake Erie Basin, circa 1 900 years BP as proposed by Barnett (1985) in the Port Rowan area, near the eastern end of the basin. This rise in lake level is marked by a series of deltas, at 180 m asl, about 5 m above present lake level.

Eolian Deposits and Features

Four areas east of Leamington host eolian deposits with parabolic, transverse or modified transverse dunes. The dunes consist of fine sand and are usually less than 1 m high (map unit 6). The time of formation is unknown. In the Simcoe area, Barnett (1978) postulated that dunes formed as glacial lakes regressed. However, in the Tillsonburg area, Barnett (1982) found evidence that dunes formed as a result of land clearing. In Essex County modern eolian processes occur in fields left fallow where soil moisture is low. Local farmers had observed and had heard of dune migration subsequent to cultivation. This suggests that 2 phases of eolian erosion and deposition may have occurred: 1) dune formation associated with recession of glacial lakes; and 2) modern eolian activity associated with cultivation and reactivation of older dunes.

Modern Shoreline Deposits

Shoreline features associated with modern Lake St. Clair, elevation 175.3 m asl, include a sand beach with beach ridges (map unit 7). Along the modern Lake Erie shoreline, elevation 174.6 m asl, the major sedimentary features are a sand beach and 2 spits: Point Pelee and Fish Point on Pelee Island.

Modern Bog and Marsh Deposits

Modern organic deposits (map unit 8) are found in bogs and marshes in shoreline areas of Essex County. Along the Detroit River, Lake Erie and Lake St. Clair shorelines, flooding of river and creek mouths during periods of high water has created swamps. Storm beach material and debris have ponded water forming a bog on East Sister Island. There are marshes at Point Pelee and at Fish Point on Pelee Island where beaches have enclosed large bodies of still water. The thickness of these bog and swamp deposits is unknown.

Modern Alluvial Deposits and Features

Modern alluvial deposits occur along most river and creek beds in the area (map unit 9). In most regions, alluvium consists of gravel and fine-grained material derived from the Tavistock Till and glaciolacustrine deposits. Near the north shore of Lake Erie, the alluvium is much sandier due to the availability of sand eroded from proglacial subaquatic fans.

Cultural Features

Cultural features (map unit 10) are found throughout Essex County and include quarries, landfills, mine waste, aggregate pits and sewage lagoons.

Stratigraphy

Composite stratigraphic sections and fence diagrams have been compiled using information obtained from exposures in Lake Erie shore bluffs, aggregate operations and quarries, Ministry of the Environment water well records, sonic drill core logs (this study) and road engineering borehole records. These composite sections illustrate the stratigraphic relationships between sediments and aid in the interpretation of depositional environments and processes. Detailed descriptions of sections discussed here are summarized in Appendix B.

Leamington to Kingsville

Bluff sections between Leamington and Kingsville (Figure 12, stations 8 to 10) are very close to the Kingsville recessional moraine. Exposure is limited by erosion control programs. The 2 best exposures exhibit different sediment assemblages. The Kingsville section (Figure 12, station 8) exposes Tavistock Till capped by glaciolacustrine clayey silt and beach sand that was probably derived from subaquatic fans.

One of the Gosfield South Township sections (Figure 12, station 9) contains 3 units of Tavistock Till interbedded with sand, indicating a fluctuating ice margin. The uppermost till unit is somewhat sandier than the lower units, probably reflecting incorporation of the underlying sands. The lower sand unit consists of beds of massive sand, rippled sand, clayey sand with abundant clay clasts and clay stringers. A column of till from the lowest unit has been injected up through this sand bed. The faulted planar beds of the upper sand unit have dips ranging from 0 to 90°. A sharp, wavy contact separates these faulted sand beds from overlying massive beds of coarse sand.

Oxley to Colchester

At stations 1 to 7 (Figure 12), the sections consist of fine-grained till and flow tills related to the ice advance which deposited Tavistock Tills. Farther east, sand overlies fine-grained glaciolacustrine sediments and till. This sand unit thickens eastward. It is thought that this complex assemblage of

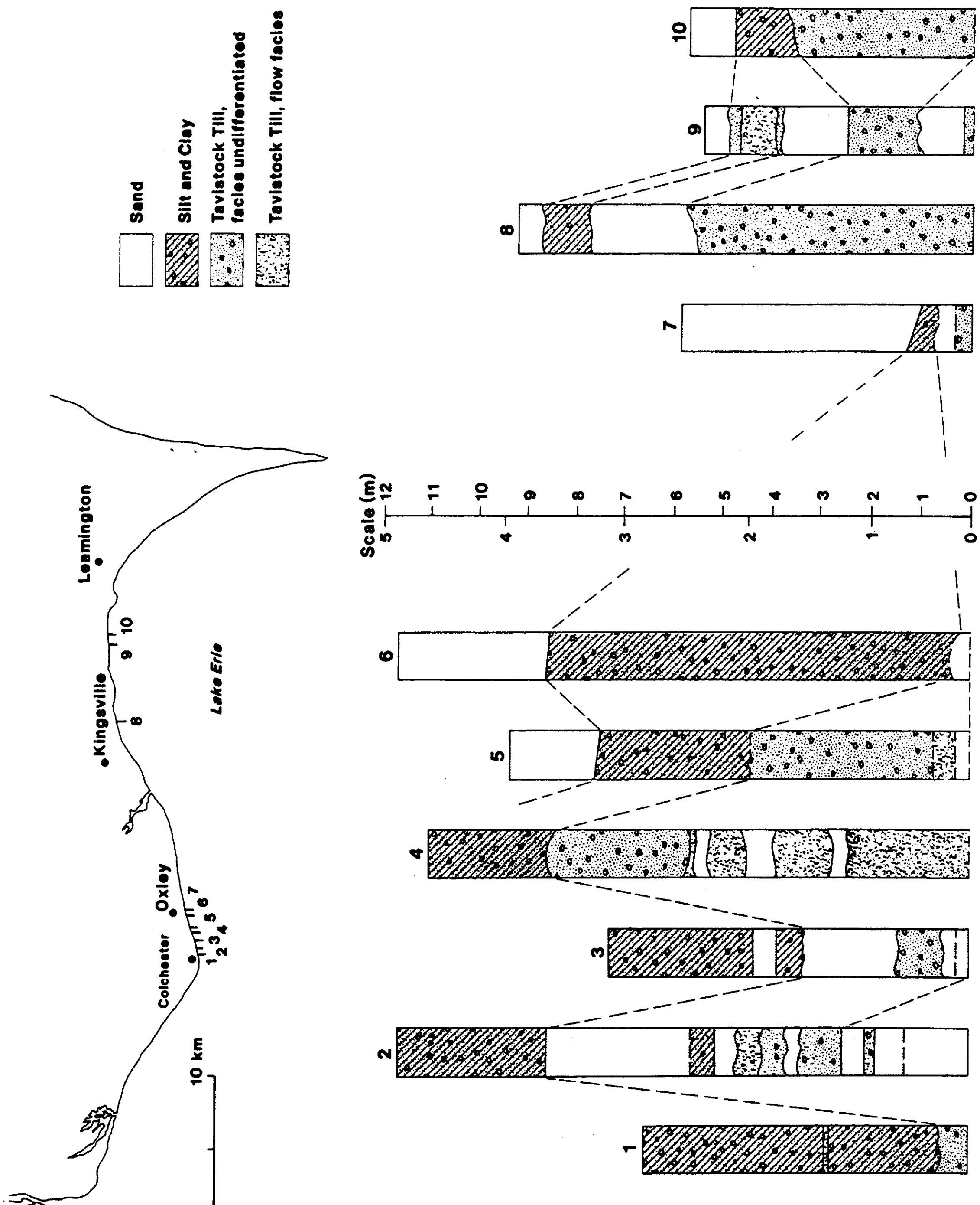

Figure 12. Representative Lake Erie bluff sections logged between Colchester and Leamington. Sections, listed by number, are described in the Stratigraphy section of the report. Bottom of each section represents lake level.

sand and associated clay was deposited near a northward retreating ice margin. The upper sand unit was probably deposited in a proglacial subaquatic fan and later modified by glaciolacustrine processes.

McGregor Quarry

In the McGregor Quarry (Figure 13), Catfish Creek Till rests directly on bedrock and is separated from the overlying Tavistock Till by rhythmically laminated clay and silt. The period of deposition of these sediments exposed in the quarry walls extended from the Nissouri stade to the end of the Port Bruce Stade.

Erie Sand and Gravel Pit

There are 3 excellent exposures in the Erie Sand and Gravel pit; the west, east and north exposures (Figure 14). The south wall of the gravel pit is badly slumped. For a detailed description of the sections the reader is referred to Appendix B.

The lower materials and associated structures observed in all 3 exposures indicate that materials were deposited in a proglacial subaquatic environment. Lower units in the lower exposure consist of massive sand indicating open channel turbulent flow; common where glacier meltwater at the base of an ice sheet enters a standing body of water (Ashley et al. 1985). In addition, the clayey silt clasts and stringers within sand, plus the till lying directly over massive sand in the western exposure indicates proximity to glacier ice. Trough-cross and planar

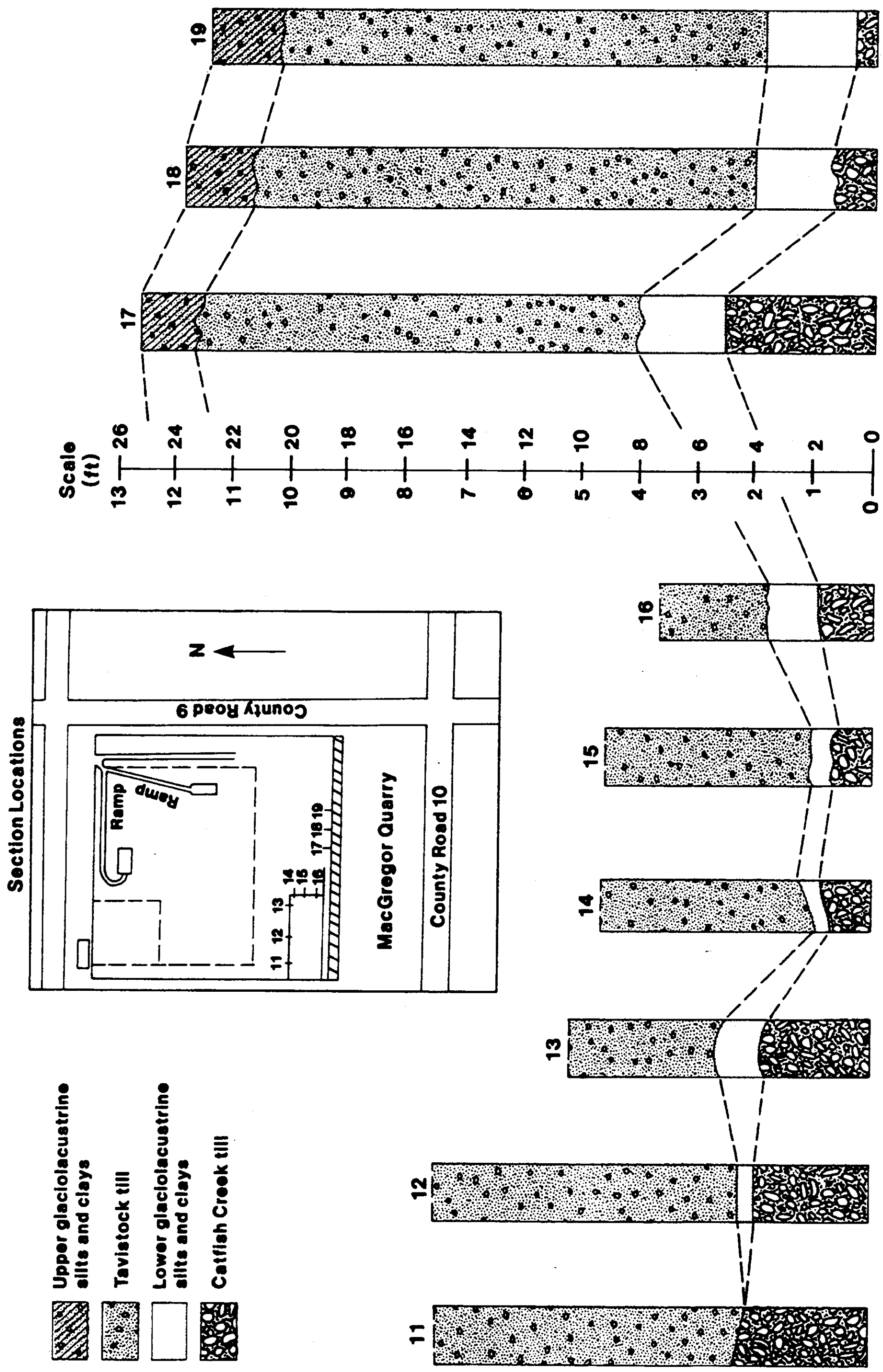

Figure 13. Representative sections logged within the McGregor Quarry. Sections, listed by number, are described in the Stratigraphy section of the report. Bottom of each section rests on the Quarry floor.

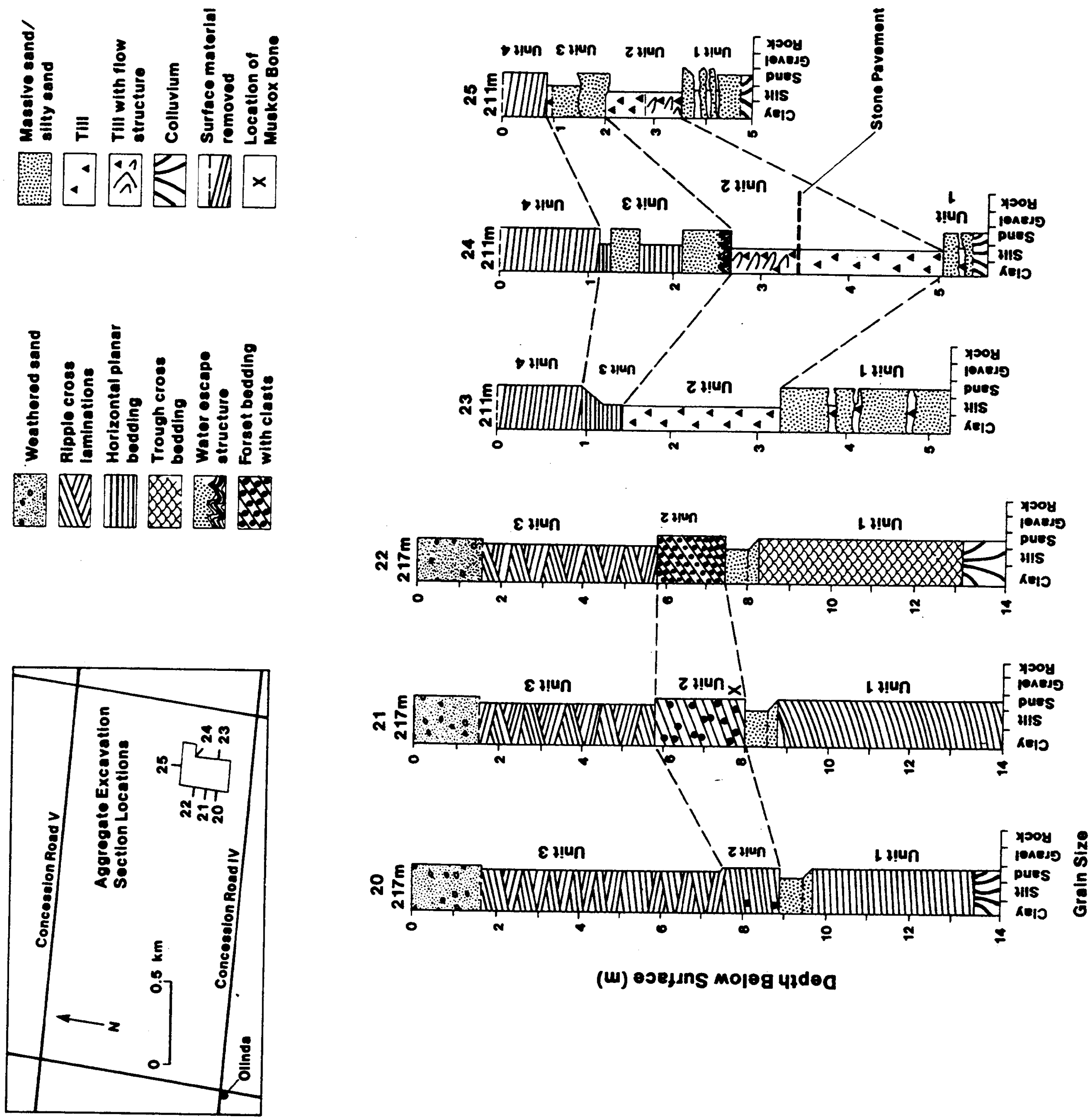

Figure 14. Representative sections from the Erie Sand and Gravel pit. Sections, listed by number, are described in the Stratigraphy section of the report.

bedding and the channel scour, observed in the western exposure, are structures associated with proglacial subaquatic fans (Ashley et al. 1985; Rust 1977; Rust and Romanelli 1975; Postma et al. 1983).

Following deposition of the lower units lake water regressed. The regression is recorded by the cf. Euceratherium sp. bone recovered at the contact between the fan surface and overlying materials, and the pollen and plant fossil assemblages recovered from the still water deposits of the eastern section. Transgression is marked by the burial of the organics by near-shore deposits in the eastern section and the formation of a bar over the cf. Euceratherium sp. bone in the western section.

Sand Distribution Map

The sand distribution map (Figure 15) was constructed using waterwell records, Ministry of Transportation borehole logs, and data from sonic drilling. As previously mentioned, concern has been raised regarding the reliability of waterwell records. Useful information can be obtained if data is treated carefully and if there are other information sources to help verify well logs. Drill logs from the 1989 drilling programme and Ministry of Transportation boreholes provide useful, reliable data and serve as controls on the waterwell records. It can be safely assumed that waterwell drillers can recognize and describe the differences

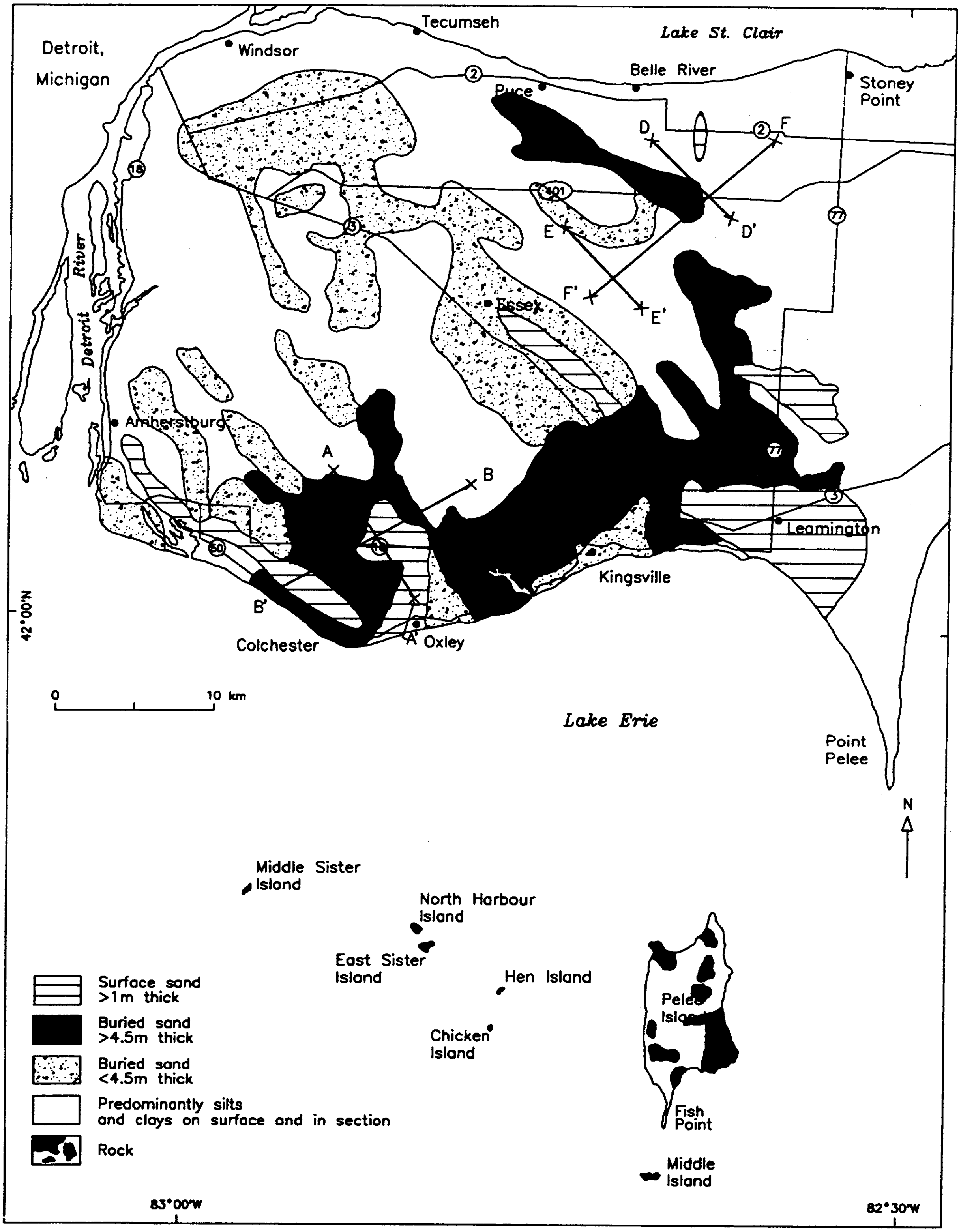

Figure 15. Sand distribution map for Essex County. Note the large body of buried sand along the north shore of Lake Erie. Data was compiled from subsurface data which includes; waterwell logs, private drilling logs and drilling logs from this project.

between clay and sand. In a given area, groups of well records that describe similar sequences can be used to recognize anomalous logs.

Figure 15 clearly illustrates a large body of buried sand that extends from west of Colchester and Harrow to Leamington. Thinner layers (less than 4.5 m) of buried sand trend southeast in belts across southwestern Essex County. There are areas of surface sand greater than 1 m thick, south and east of Harrow and around the Leamington area.

The first of 2 fence diagrams constructed from the map transects a proglacial subaquatic fan in the Harrow area (Figure 16). Tavistock Till overlies Catfish Creek Till and both tills are cut by a large body of sand. This sand pinches out to the north and thickens southward where it is exposed at surface. Glaciolacustrine silts and clays overlie all other sediments.

The second fence diagram is drawn through a buried esker and a till plain (Figure 17). The oldest material, Catfish Creek Till, is overlain by Tavistock Till. To the northwest, minor layers of sand or sandier clay are associated within a recessional moraine. The buried esker is represented by a substantial thickness of sand directly overlying bedrock.

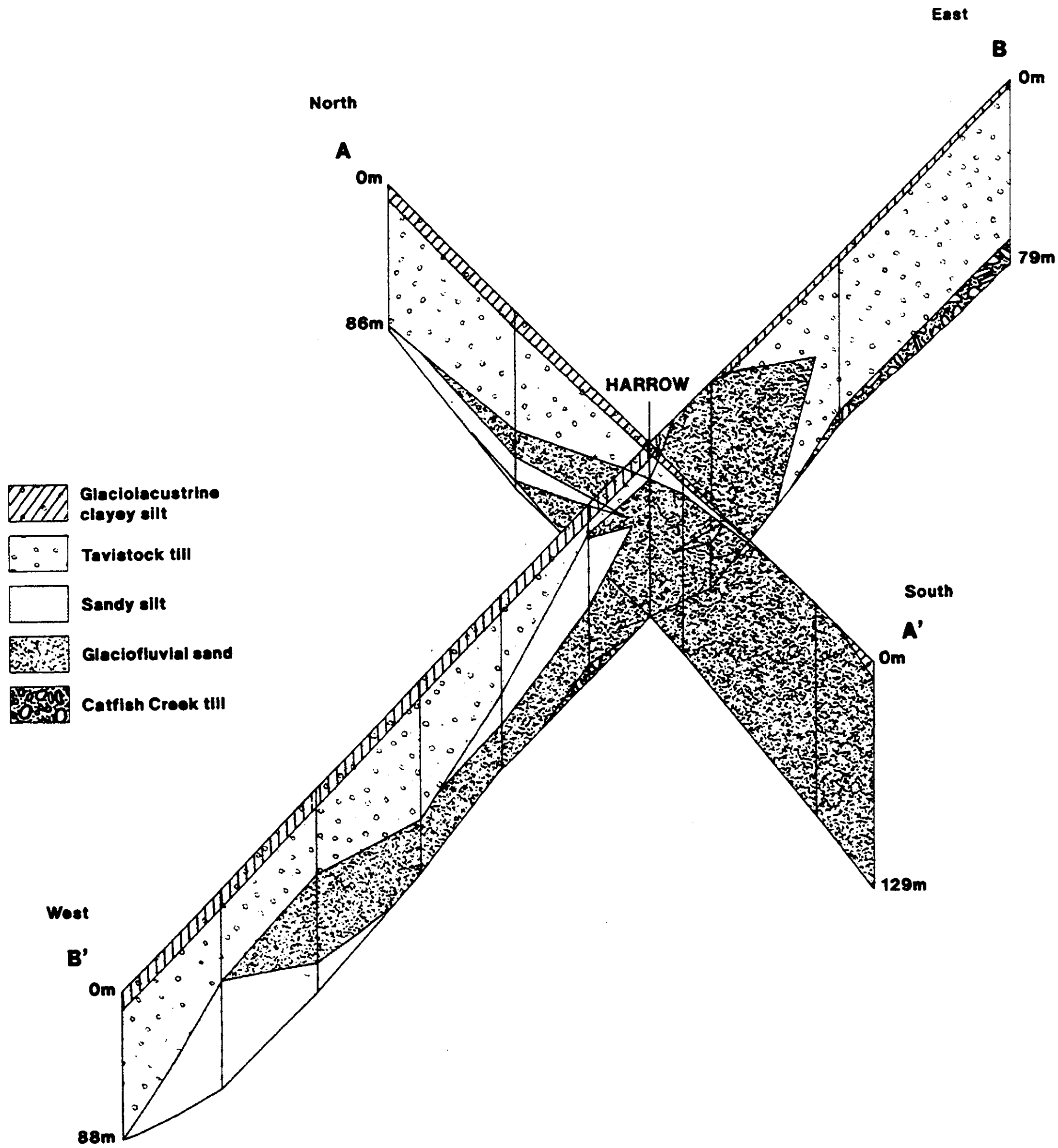

Figure 16. Fence diagram through a partially buried proglacial subaquatic fan at Harrow. Catfish Creek Till lies on top of the bedrock.

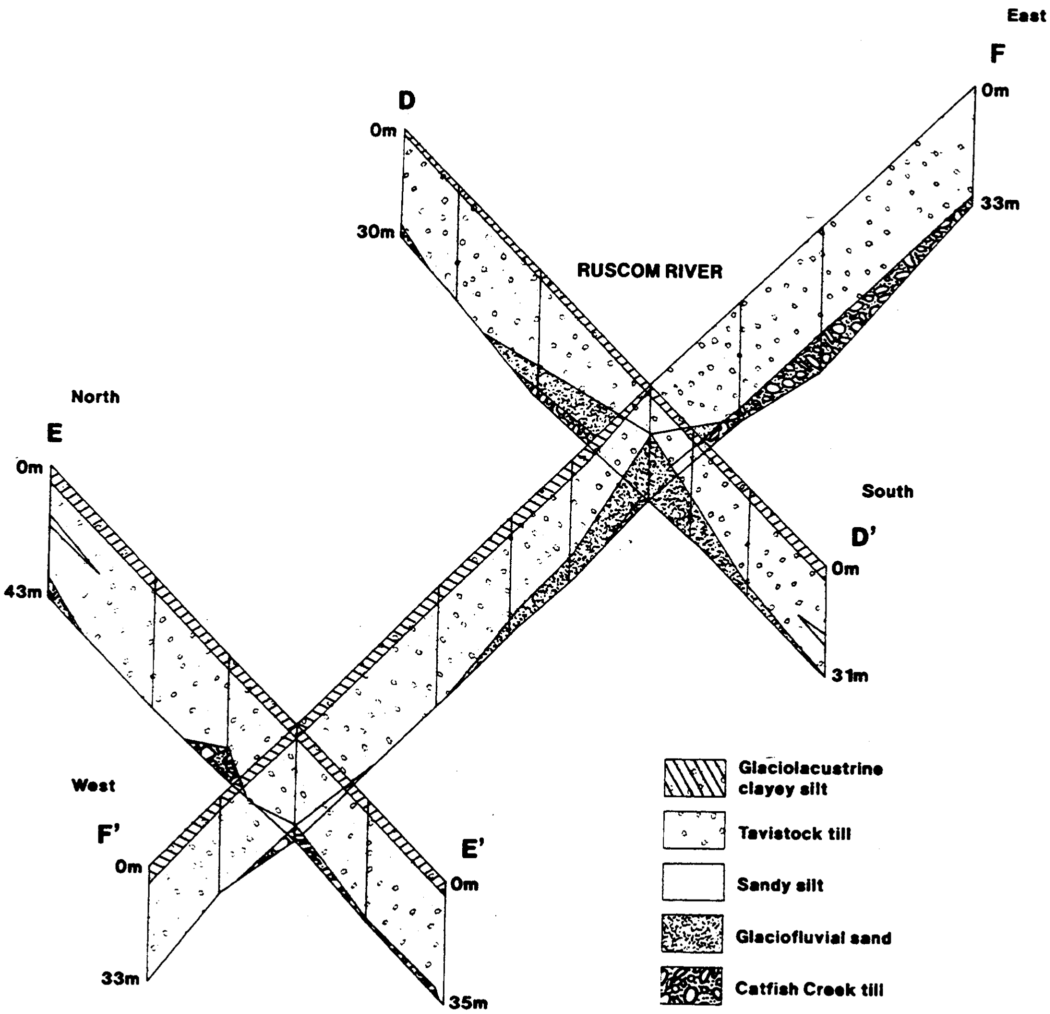

Figure 17. Fence diagram through northern Essex County. This fence diagram partially intersects a buried esker.

Glacial History

The earliest recorded ice advance in Essex County occurred during the Nissouri Stade (23 000 years BP; Figure 18) and reached as far south as northern Ohio (Morner and Dreimanis 1973). This advance deposited the Catfish Creek Till and locally striated, fractured and eroded the bedrock surface.

The 3 units in the Catfish Creek Drift at Bradtville (Dreimanis 1987) represent different ice flow events with the youngest unit deposited by ice flow from the northeast. In Essex County, indicators such as heavy mineral and garnet content, ratio of purple to red garnets, till fabric and related striae indicates that southwesterly flowing ice deposited the Catfish Creek Till. The Catfish Creek Till in the study area is considered to be equivalent to the youngest unit at Bradtville.

A series of ice-marginal lakes formed as the ice retreated northward at the end of the Nissouri Stade (Dreimanis 1969, Morner and Dreimanis 1973). At the height of the Erie Interstade (15 500 years BP) Glacial Lake Leverett occupied the Lake Erie basin. The laminated glaciolacustrine clayey silt that rests on top of Catfish Creek Till in southwestern Essex County was deposited at this time.

At the beginning of the Port Bruce Stade, ice advanced south from the Lake Huron basin and coalesced with ice from the Lake Erie basin. Initially, the stronger Huron basin flow deflected ice in the Lake Erie basin southwards and deposited till sheets and moraines in northern Ohio (Totten 1973; White 1982; Dreimanis and Goldthwait 1973 and Goldthwait et al. 1965). During this stade,

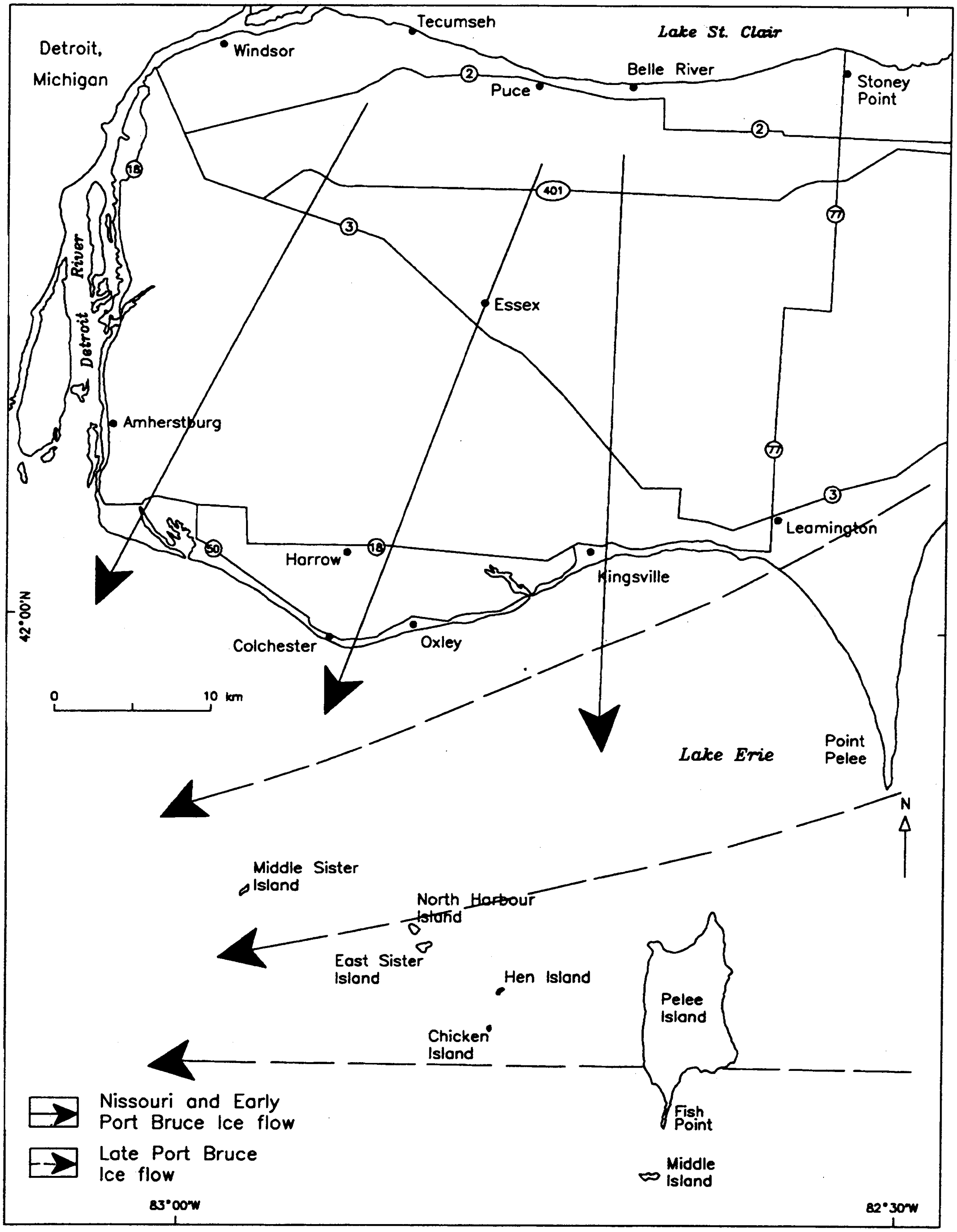

Figure 18. Generalized ice flow over Essex County during the Nissouri and Port Bruce Stadials.

the Tavistock Till was deposited (Figure 18) by southward flowing ice, as indicated by the physical and chemical properties of the till including pebble fabric. The fine-grained matrix of this till reflects incorporation of clay and silt derived from the underlying deposits of Glacial Lake Leverett. Erosion of large quantities of glaciolaciolacustrine sediments during the Port Bruce Stade may explain their absence in some of the drillholes of the 1989 sonic drilling program.

During the later stages of the Port Bruce Stade, ice flow from the Lake Huron basin waned and ice flow from the Lake Erie basin increased. This resulted in a westward shift of ice movement in the western Lake Erie basin (Fullerton 1986; Figure 18). The "P" forms on Pelee, East Sister and Middle islands possibly formed during this time. On Pelee Island, this shift in flow direction may have caused mixing of sediments derived from Lake Huron basin ice, with materials carried by ice from the Lake Erie basin. This may explain the physical and chemical properties of the hybrid Port Stanley- Tavistock till found on the island.

During the initial phase of the Mackinaw Interstade, ice must have retreated from the western end of the Lake Erie basin to at least the Pelee Moraine (Calkin and Feenstra 1985) to allow for the deposition of proglacial subaquatic fans (Figure 19) in Glacial Lake Maumee. The ice sheet was likely quite unstable due to the presence of abutting glacial lakes. This may have caused the ice sheet to surge repeatedly. Surging and calving of the ice sheet produced icebergs, evidence for which is preserved in the form of

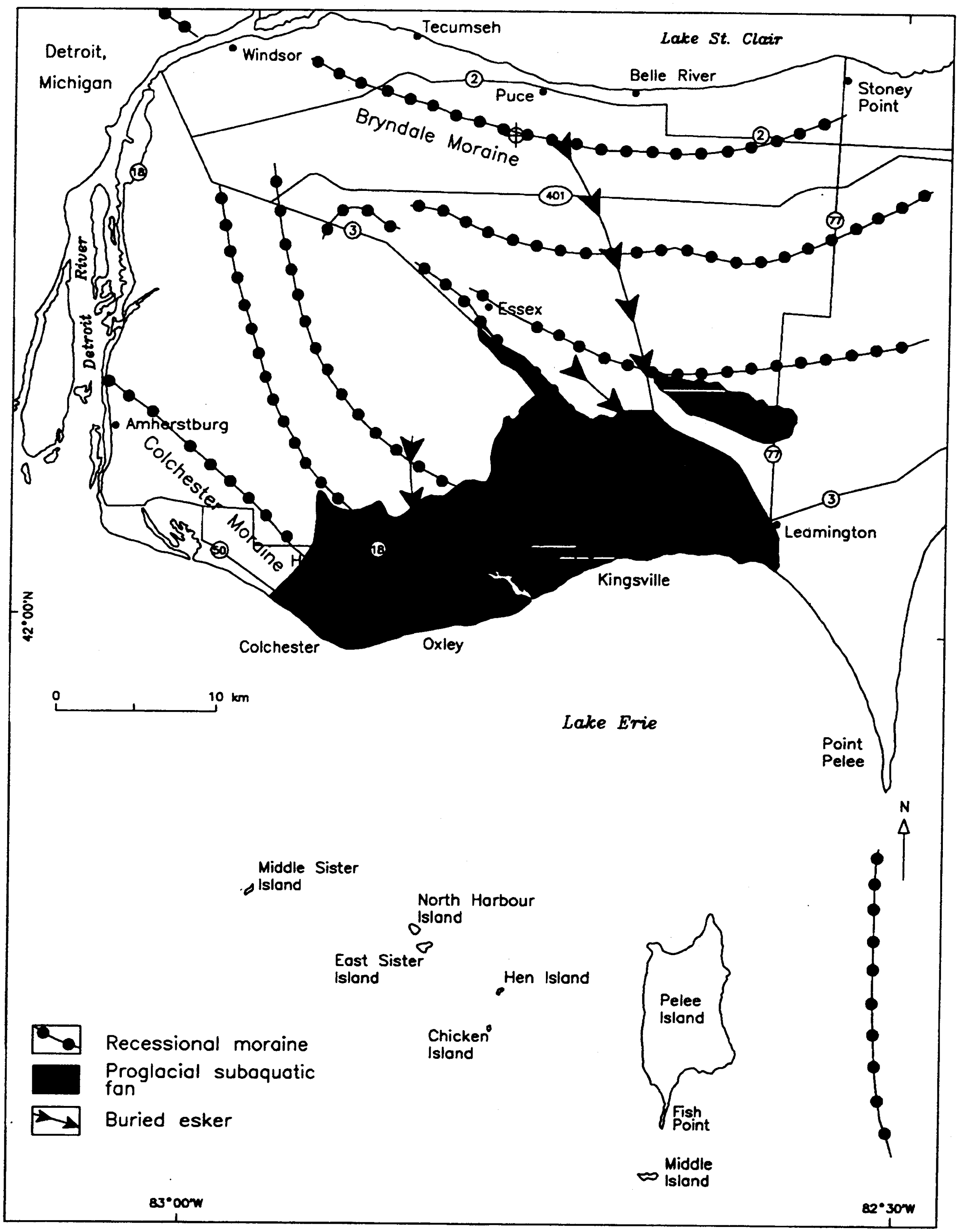

Figure 19. Glacial landforms deposited in Essex County during the retreat of ice at the end of the Port Bruce Stade.

iceberg keel marks. Oscillations of the ice margin may explain why there are interbeds of Tavistock Till within the fan deposits and why most fans are buried or partially buried by Tavistock Till.

Either during surge events, or as the ice sheet stabilized temporarily as it retreated north from the area, several recessional moraines were deposited. Although these ridges have a subtle surface expression they have had significant impact on the Quaternary and cultural history of the area. The Bryndale moraine, for example, controlled the flow of water from the southern outlet of Lake Algonquin (Huron Basin) to Early Lake Erie (Erie Basin).

Similarly a ridge of till extends northwest from the Colchester moraine through Amherstburg and into the Detroit River. This ridge was dredged throughout the late 1800's to allow shipping through the Detroit River (S. Alder, Environment Canada, personal communication, 1989). This moraine also controlled the southern outlet of Lake Rouge and is cut by an impressive channel north of Malden Centre.

Glacial Lake Arkona covered most of Essex County during the early and later stages of the Mackinaw Interstade (Figure 20). A bar northwest of Leamington probably formed in this lake early in this interstade.

During the Port Huron stade advancing ice northwest and east of Essex County caused lake waters to rise to Glacial Lake Whittlesey levels (Figure 20) as outlets were blocked. Sand was reworked from the fan surface west of the Glacial Lake Arkona bar and adjacent deposits by current within Glacial lake Whittlesey.

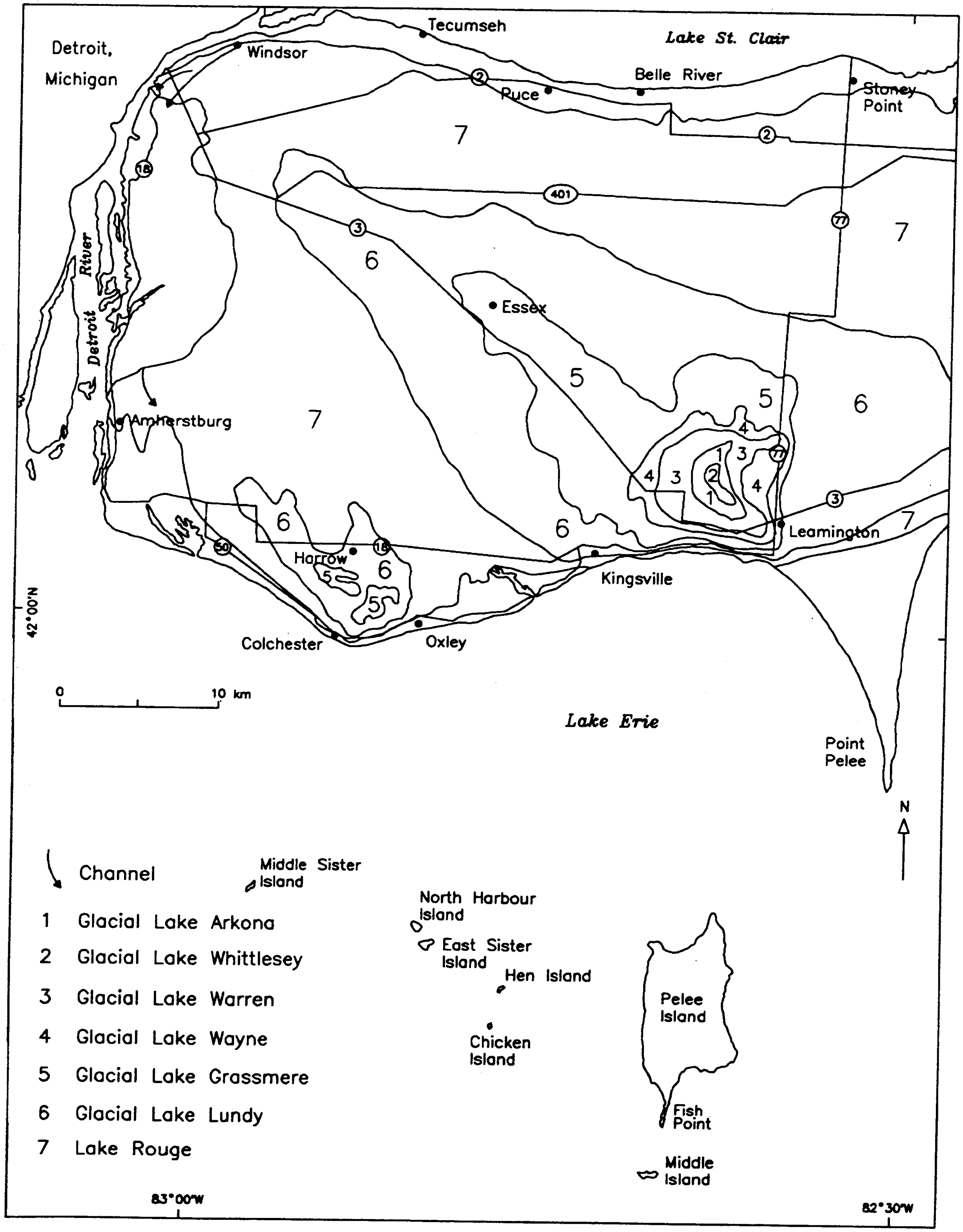

Figure 20. Paleogeography of glacial and post-glacial lake levels in Essex County.

This reworked sand covered not only the bar and adjacent deposits but also deposited a thin layer of sand over the glaciolacustrine silts and clays north and east of Leamington.

As ice retreated north during the Two Creeks Interstade water level dropped, marking the inception of the Lake Warren stage. The highest Lake Warren phase is marked by a wave-cut bench and well developed spit on the south and north sides of the Glacial lake Arkona bar. Both the mid-water phase of Glacial Lake Warren and Glacial Lake Wayne are marked by beach ridges.

Glacial Lake Grassmere (Figure 20) formed during the Greatlakean Stade. The surfaces of subaquatic fans southwest of the Essex moraine, at Albuna and south of Harrow were modified by lacustrine processes in this lake. Sand was transported eastward over the Tavistock Till sheet to form a fan east of Oxley, and 2 beach ridges were formed east of Harrow. During the latter part of the Greatlakean Stade, lake waters fell to Glacial Lake Lundy levels (Figure 20). This lake left beach ridges at 187 m asl.

Following this series of glacial lakes, Early Lake Algonquin in the Lake Huron basin drained southward to Early Lake Erie through Early Lake St. Clair and Lake Rouge. Water discharged from Early Lake St. Clair breached the Bryndale moraine (Figure 19) and deposited a thin fan of sand at the north end of Lake Rouge (Figure 20). Lake Rouge drained into Early Lake Erie via channels cut through the Colchester moraine.

A wave-cut notch and beach ridges east and south of Leamington record water level in the Lake Erie basin at 170 m asl, about 5 m above the present day level. This is thought to represent the late transgression marked by the Port Rowan deltas in the eastern part of the Lake Erie basin (Barnett 1985).

APPLIED QUATERNARY GEOLOGY

Agricultural Soils

Soils in Essex County began forming as early as ~14 500 years BP, on the island exposed after the regression of Glacial Lake Whittlesey (Figure 20). The many different soil types in Essex County are presently being reclassified and remapped (Ontario Agricultural College 1989). Sandy soils are found on or around subaquatic fans, such as along the north shore of Lake Erie and south of Windsor, where cash crops, such as tomatoes, cucumber, and lettuce, are grown. Clay soils host crops of soya bean, corn, and wheat.

Economic Geology

Aggregate

The active sand and gravel operations in the area are in Glacial Lake Whittlesey and Warren beaches and a Glacial Lake Maumee proglacial subaquatic fan. Much of the aggregate produced in Essex County is material suitable for Granular Base Course B and C (Ontario Geological Survey 1989).

Extraction within proglacial subaquatic fans is limited to 1 site. Here aggregate is composed of fine-grained sand and gravel (Appendix C, Ontario Geological Survey 1989) of generally uniform grain size and structure. Silt and clay lenses within the sands are present. The sand is used as backfill or is mixed with coarser material for asphalt. The aggregate potential of other fan deposits may be limited by material quality and thick cappings of till and glaciolacustrine sediments. Drilling of specific sites is necessary to assess deposit quality and overburden thickness.

The 24 licensed aggregate operations within proglacial beach deposits extract material with gravel content ranging from less than 10% to 40% (Ontario Geological Survey 1989). Silt and clay lenses within beach sands are not a problem but the sand does require blending to produce high-specification fine aggregate products (Ontario Geological Survey 1989).

Clay

Three commercial clay pit and plant operations in Essex County produced drainage tile, roofing tile and brick. These include B. Broadwell and Son (northwest of Kingsville), Central Tile and Brick Corporation Ltd. (Belle River) and Comber Tile Yard Ltd. (Comber). These plants are no longer in operation due to poor clay quality and use of alternate materials (eg. plastic drainage tile). Clay is used to line a local landfill site northwest of Leamington (A. Koop, Erie Sand and Gravel, personal communication, 1990).

Environmental Geology

Bedrock Collapse

Fractures penetrating the Devonian limestones may channel water into salt beds in the Silurian Salina Formation, causing preferential solution weathering. Sinkholes have developed on the ground surface by collapse of the underlying bedrock caused by salt solution mining. The depressions on the bedrock surface identified during this study (see Bedrock Topography section; Bedrock Topography Map, back pocket) may be related to dissolution of underlying Salina beds or to other processes, such as karst development. Sinkhole development can occur rapidly (Russell 1993) and, whether caused by natural or man-made processes, it poses a serious environmental hazard.

Groundwater

Groundwater distribution and recharge areas in Essex County are poorly understood, although groundwater is important for household and farm use. Buried and surface sand bodies illustrated in Figure 15 are potential groundwater and recharge areas. Potable groundwater will likely be found in these sand bodies.

Clay Plain

The northern Essex clay plain has been regarded as suitable for containment of hazardous waste materials, based on the thickness and "diffusion-dominated hydrogeological regime" of the clay (Desaulniers et al. 1981). Recently, concern has been expressed that the clay may not be a suitable medium because of sand layers and possible fractures.

Fence diagrams suggest that most of these sand layers, as shown on the sand distribution map (see Figure 15), are probably discontinuous. However, extensive drilling, and perhaps seismic work, are needed to evaluate candidate landfill and hazardous material disposal sites.

Fractures have been identified in the clay overburden (this study, Keller et al. 1986) and Sklash (1990) expressed concern about vertical fractures through the clay, over and adjacent to the buried esker northwest of Leamington. These fractures are potential conduits for contamination to reach the underlying aquifer.

Potential Hydrocarbon Seepage Features

Fractures in the clay cover also may allow hydrocarbon seepage. On 1: 10 000 scale black and white aerial photographs, suspected hydrocarbon seepage features appear as individual circular to ellipsoid shapes, with white haloes surrounding black centres (Photo 8). The centres range in diameter from 6 to 20 m. The halos are 2 m to 20 m in width.

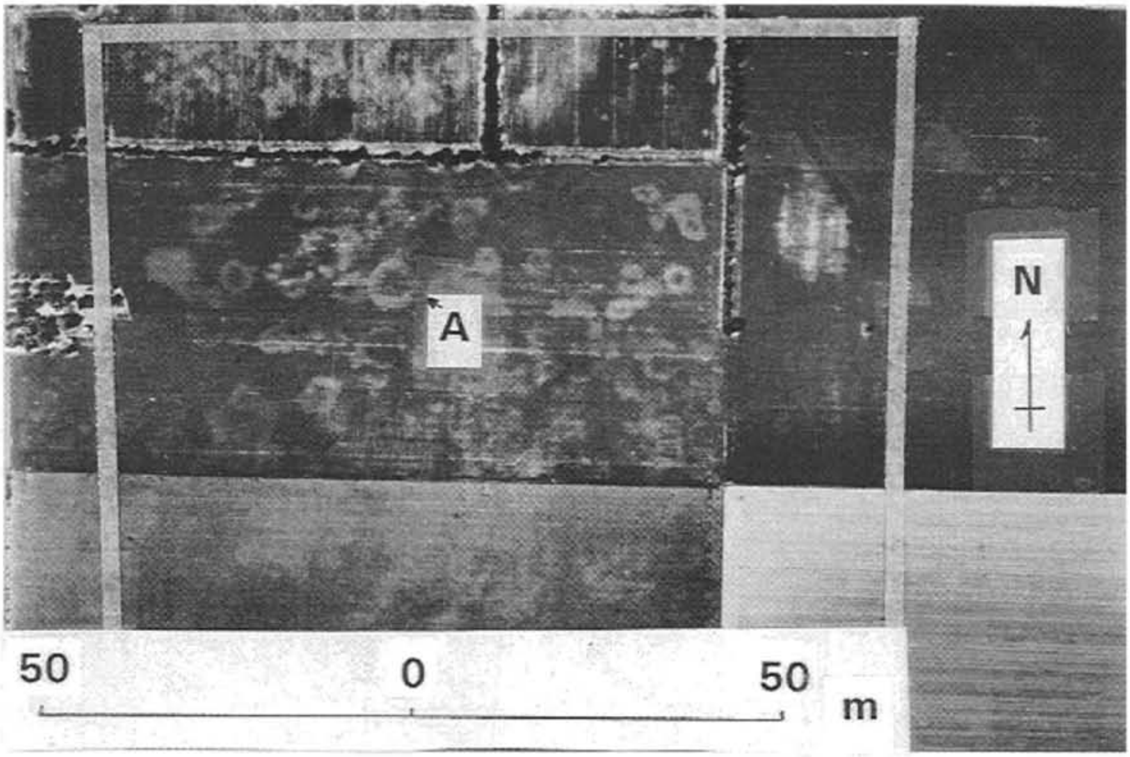

Photo 8. Field of potential hydrocarbon seeps, circular features (A).

Groups of these potential seepage features form irregularly-shaped clusters or elongated northerly or westerly oriented fields (Figure 21). The north-trending fields are mainly in northeastern Essex County, northeast of the proposed location of the mid-continental rift. The block-shaped and west trending fields predominate to the southwest of the proposed location of the mid-continental rift (Figure 21). These features are found only on clay plain, not in areas of coarser textured soils.

Crop growth is poor on these features. In fallow fields, Scottish thistle commonly grows where these features exist. These surface features were observed on both high, dry ground and low, moist ground. The physical characteristics of the soils associated with these potential hydrocarbon seepage features do not appear to be unique. On the bedrock floor of the General Chemical Quarry east of Amherstburg, there are 2 similarly shaped features (Photo 9). These similar features observed on the bedrock surface are similar in size to the circular features visible on aerial photographs and in fields due south of the quarry. The physical properties of the rock in quarry floor are relatively uniform (Photo 9).

There is a weak spatial association between these surface features, producing oil and gas fields, and aeromagnetic trends in the Precambrian basement. In addition, there is an interesting relationship between these variables and conceptual fracture framework in Paleozoic bedrock proposed by Sanford et al. (1985).

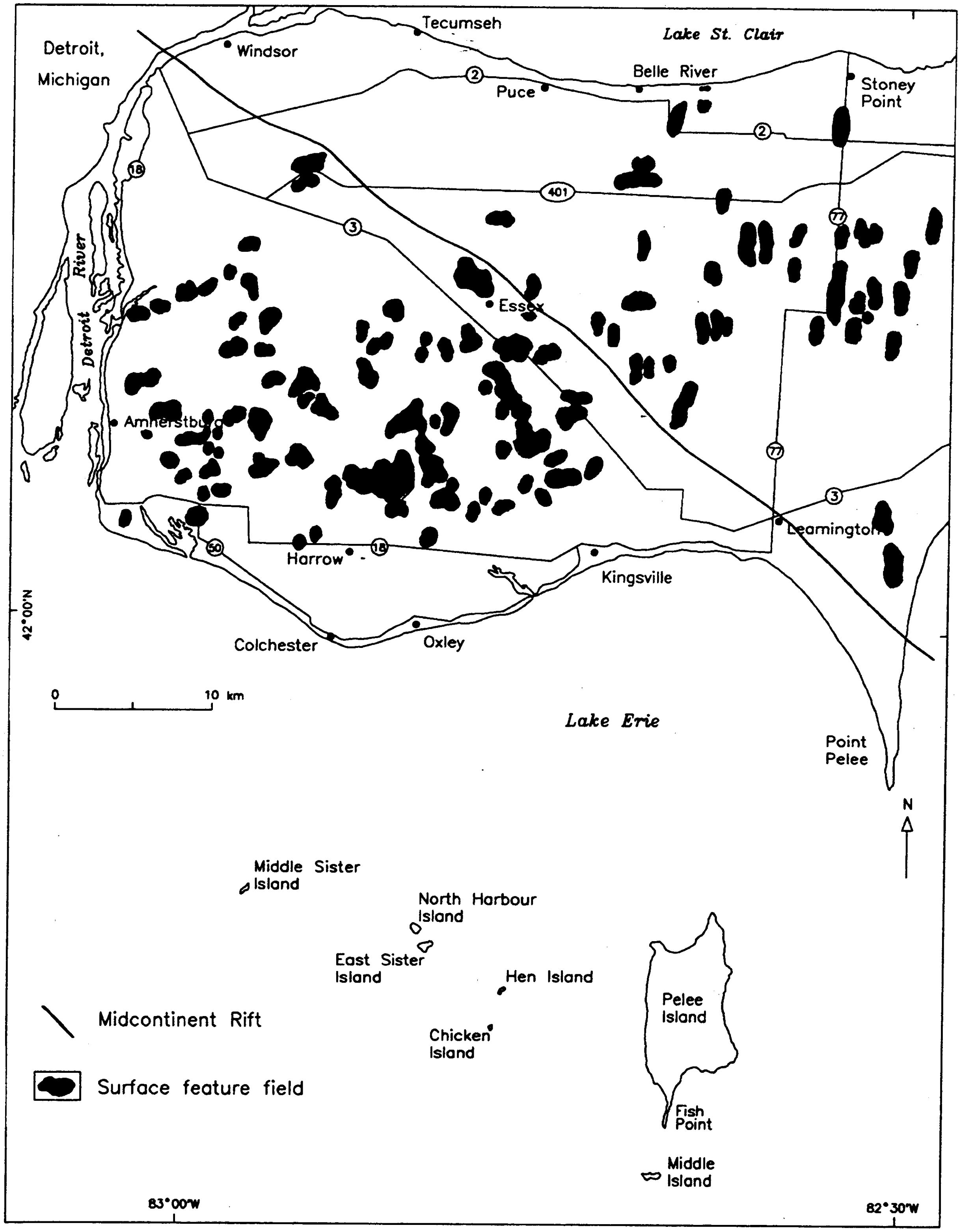

Figure 21. Distribution of fields of potential hydrocarbon seepage features in relation to proposed midcontinent rift. Fields tend to be aligned north- south over the proposed midcontinent rift (northeast part of County) while more west- east or circular fields occur to the southwest of the midcontinent rift (southwest Essex County).

Photo 9. Circular features observed on the McGregor Quarry limestone bedrock surface. These features have a similar appearance to those of the potential hydrocarbon seepage features observed on the overburden surface.

All features show a relationship with the possible extension of the Midcontinent Rift into Essex County (Easton and Carter 1994; Figure 21).

Shoreline Erosion

Material type, stratigraphy and structure make shore bluffs susceptible to erosion, particularly where sand underlies a clay cap. The erosion potential of these areas has been previously recognized (Boyd 1981) and construction of residential or commercial structures near bluffs has in the past lead to loss of property.

Flood Hazard

Several areas adjacent to the Detroit River and Lake Erie are susceptible to flooding during high water stages. Excessive rain can produce major flood damage inland from the north shore of Lake Erie. During the summer of 1989, excessive run-off resulted in clogged culverts, which eventually led to washed out bridges and roads and to major flood damage to residential properties.

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APPENDICES

Explanation of Sampling Numbers and Abbreviations

Drilling sample number: E89-01-01
: Essex / year of drilling, 1989/ borehole number (in sequence from 1-12)/ sample number.

Sample number: SWEL 001
: National topographic Series map sheet (1:25 000 scale)/ sample number.

Explanation of 1:25 000 scale National Topographic Series map sheet abbreviations:

SWEL:	Leamington	SWEAM:	Amherstburg
SWEC:	Comber	SWEHA:	Harrow
SWESP:	Stony Point	SWEMA:	Maidstone
SWEBR:	Belle River	SWERS:	Riverside
SWEW:	Woodslee	SWEPC:	Pike Creek
SWEK:	Kingsville	SWECH:	Colchester
SWEE:	Essex	SWEPI:	Pelee Island
SWECC:	Cedar Creek	SWEWI:	Windsor
SWERC:	River Canard	SWE:	Does not refer to a specific map sheet

Other Abbreviations

-:	Clay mineral absent	nb:	heavy minerals not analyzed for garnets
X:	Clay mineral present	Ni:	nickel
%:	percent	No.:	number
(Con't):	continued	Non. Mag.:	non magnetic
Ca:	calcite	NTS:	National Topographic Map Series
Co:	cobalt	Pb:	lead
Cl:	clay	ppm.:	parts per million
Cr:	chromium	Si:	silt
Cu:	copper	Ss:	sand
Dol:	dolomite	U.T.M.:	Universal Transmercator (grid system)
Fe:	iron	Vermic.:	vermiculite
Gos.:	Gosfield (Township name)	Zn:	zinc
m:	metres		
Mag.:	magnetic		

Note: 1) Carbonate ratio refers to % calcium to % dolomite
2) Garnet ratio refers to % purple to % red garnets

APPENDIX A

Summary of sonic borehole logs.

SONIC BOREHOLE NUMBER: E89-01
LOCATION: NTS, 1:25000 Topographic Map 40J/2a, U.T.M. 371000m.E. 4652200m.N.
SITE DESCRIPTION: SOUTHEASTERN GLACIOLACUSTRINE PLAIN
BOREHOLE SURFACE ELEVATION: 176.8 m

Depth (m)	Description
0.00-2.93	Brown silty clay; badly weathered to 2.9 m; root casts to 2.4 m; microlaminations; red clay and grey silt balls; few to common, rounded to subangular limestone and shale, some striated; lower contact sharp; *Weathered glaciolacustrine.*
2.93-3.38	Grey brown silty clay; inclusions of red clay bands, 3 cm thick within grey clay; few rounded limestone clasts in red bands; grey silty clay is softer than upper weathered material and contains rounded to subangular striated limestone clasts and very few red clay balls, some silt balls; *Glaciolacustrine.*
3.38-18.40	Reddish brown silty clay; stratified layers of red and grey silty clay, soft; stratified layers grade into red clay over 0.1 m; grey clay bands have rare subrounded limestone clasts; red clay bands have red clay balls, few subrounded to angular limestone clasts, striated, rare shale; red clay becomes very soft towards bottom of unit; *Tavistock Till.*
18.40-19.45	Reddish brown silty clay; stratified layers of red and dark brown grey sandy silty clay (see comments on lower clay); contacts between 2 clays are sharp; *Glaciolacustrine.*
19.45-21.10	Dark brown-grey sandy silt clay; massive, but falls apart in layers; common to abundant rounded to angular limestones, granites, shales; limestones striated; *Catfish Creek Till.*
21.10-21.20	BEDROCK, limestone; *Detroit River Group; Lucas Formation.*

SONIC BOREHOLE NUMBER: E89-02
LOCATION: NTS, 1:25000 Topographic Map 40J/2b, U.T.M. 363500m.E. 4660700m.N.
SITE DESCRIPTION: PROGLACIAL SUBAQUATIC FAN
BOREHOLE SURFACE ELEVATION: 217.9 m.

Depth (m)	Description
0.00-3.50	Orange brown sand, fining down unit; massive, loose; sub rounded to subangular gneiss, schist (green), some striated; lower contact diffuse; *Glaciolacustrine.*
3.50-4.20	Brown clayey silt; massive; few granite, gneiss, rare limestone clasts; clasts concentrated at base of unit; *Glaciolacustrine.*
4.20-6.50	Reddish brown-brown medium-coarse sand; massive, loose; few flat to subrounded granite, shale, rare limestone. *Glaciofluvial.*
6.50-7.58	Brown clayey silt-course sand; laminated, clay balls, compact; lower contact compact; *Glacio-fluvial.*
7.58-9.30	Brown medium to coarse sand; massive with clay balls; flat to subrounded shale, limestone, dolomite, red granite; lower contact sharp; *Glacio-fluvial.*
9.30-10.08	Brown clayey silt with clayey sand layers; compact; lower contact sharp; *Glaciofluvial.*
10.08-12.79	Brown coarse sand; rare clay balls; massive, with a 75 cm layer of brown clay at 11.52 m, sand is loose; lower contact sharp; *Glaciofluvial.*
12.79-17.00	Brown silty sand, becomes a brown medium sand at 13.73 m; some lamination (0.01 cm layers), massive over lower 3.5 m of unit; clasts pea sized, mainly shale, some limestone, granite; lower contact sharp *Glaciofluvial.*
17.00-20.80	Brown-dark grey silty sand; massive, becoming laminated with depth, slightly sticky when wet; few limestone, dolomite, shale and rare granite; balls of dark grey sandy clay; lower contact sharp; *Glaciofluvial.*

20.80-21.60	Greyish brown clayey silt; massive, slightly sticky when wet; abundant limestone clasts, striated; lower contact sharp; *Glaciolacustrine.*
21.60-24.70	Grey sand; fines down core to grey sandy silt; massive-to poorly laminated, clay balls, loose; lower contact sharp. *Glaciolacustrine.*
24.70-33.32	Grey fine sand fining down unit to sandy silt; massive at top, laminated at base of unit with red clay balls, ripples at 26.92 m, 33.0 m; lower contact diffuse. *Glaciolacustrine.*
33.32-40.82	Grey coarse sand; laminations 1 to 2 cm thick; lower contact sharp; *Glaciolacustrine.*
40.82-45.60	Brown sandy silt; clay and sand bands; few subangular to subrounded limestones, rare shale; *Glaciolacustrine.*
45.60-50.89	Grey fine sand, 26 cm layer of brown clayey silt at 48.84 m, 22 cm grey sandy silt layer at 46.02 m, few clay balls, loose; very rare-few angular to sub-angular limestone, shale clasts, some limestones striated; lower contact diffuse; *Glaciolacustrine.*
50.89-52.40	Brown clay; massive with 1, 24 cm thick layer of grey fine sand at 51.36 m, sticky when wet; lower contact diffuse; *Glaciolacustrine.*
52.40-53.30	Brown coarse sand; massive; *Glaciofluvial.*
53.30-53.40	BEDROCK, limestone; *Detroit River Group; Lucas Formation.*

SONIC BOREHOLE NUMBER: E89-03
LOCATION: NTS 1:25000 Topographic Map, 40J/2b, U.T.M. 357800m.E. 4655600m.N.
SITE DESCRIPTION: KINGSVILLE MORAINE
BOREHOLE SURFACE ELEVATION: 192.0 m

Depth (m)	Description
0.00-0.69	Grey fine sand; massive, loose; subrounded pink quartz; lower contact sharp; *Glaciolacustrine.*
0.69 0.89	Orange brown clayey silt; massive; weathered schist and granite; lower contact diffuse; *Weathered glaciolacustrine.*

0.89-1.77	Brown fine medium sand; lower contact diffuse; *Glaciofluvial.*
1.77-1.90	Dark grey coarse sand; massive; lower contact sharp; *Glaciofluvial.*
1.90-4.10	Brown clayey silt; laminated silts and clays, interbeds of red clay and red clay balls; common rounded to subangular limestone and few subrounded to subangular granites; surface of second red bed from bottom has a stone pavement; lower contact sharp; *Glaciolacustrine.*
4.10-7.21	Grey clayey silt; massive, sticky when wet, very compact; abundant, subangular to angular limestones, striated, rare subrounded granites; lower contact sharp; *Tavistock Till.*
7.21-7.60	Brown silty clay; red silty clay laminations, upper part of unit is compact becoming very soft with depth, sticky when wet; rare angular limestone clasts; lower contact sharp; *Glaciolacustrine.*
7.60-12.28	See above description of 4.10 to 7.21 m; lower contact sharp; *Tavistock Till.*
12.28-13.68	Brown clayey silt; increased sand concentration with depth; laminated, compact, sticky when wet; rare limestone, shale, quartz; lower contact sharp; *Lower glaciolacustrine.*
13.68-17.50	Brown sandy silt; massive, slightly sticky when wet; few red clay balls; *Glaciolacustrine.*
17.50-18.10	See above description of 4.10 to 7.21 m; *Tavistock Till.*
18.10-18.40	Brown cobbly silty sand; massive, slightly sticky when wet; abundant, striated, bullet shaped limestone clasts; *Catfish Creek Till.*
18.40-18.80	BEDROCK, limestone; *Detroit River Group; Lucas Formation.*

SONIC BOREHOLE NUMBER: E89-04
LOCATION: NTS 1:25000 Topographic Map. 40J/2d, U.T.M. 342700m.E. 4654500m.N.
SITE DESCRIPTION: PROGLACIAL SUBAQUEOUS FAN
BOREHOLE SURFACE ELEVATION: 192.0 m

Depth (m)	Description
0.00-3.30	Red medium to fine sand; laminated at 1.6 m, 2 to 4 mm layers; lower contact diffuse; field surface littered with shield clasts, mainly granites and gneiss; *Glaciolacustrine.*
3.30-3.39	Brown sandy clay; some flow structure; lower contact sharp; *Tavistock Till.*
3.39-18.84	Dark brown coarse sand; laminated, loose; lower contact sharp; *Glaciofluvial.*
18.84-26.80	Pale brown to light grey sand; upper part of unit contains beds of fine sand, middle part of unit contains brown clay lenses, lower part of unit contains beds of fine sand, loose; lower contact sharp; *Glaciolacustrine.*
26.80-27.60	Brown fine silty sand; laminated at upper part of unit, water escape structure at middle and lower part of unit; lower contact sharp; *Glaciolacustrine.*
27.60-28.19	Brown sandy silt; massive, sticky when wet, lower part of unit is marked by interbeds of sand; lower contact sharp; *Glaciolacustrine.*
28.19-34.00	Dark brown black coarse sand; massive, loose; rare subrounded limestone, dolomite, red granite, limestone striated; lower contact sharp, marked by a layer of limestone clasts; *Glaciofluvial.*
34.00-37.10	Pale brown grey sandy silt; massive, except for one sandy cobbly layer; common subangular to angular limestone clasts, some striated, rare subrounded dolomite, unit becomes more cobbly with depth; *Catfish Creek Till.*
37.10-37.80	BEDROCK, limestone; *Detroit River Group; Lucas Formation.*

SONIC BOREHOLE NUMBER: E89-05
LOCATION: NTS 1:25000 Topographic Map 40J/2d, U.T.M. 337700m.E. 4654400m.N.
SITE DESCRIPTION: COLCHESTER MORAINE
BOREHOLE SURFACE ELEVATION: 192.0 m

Depth (m)	Description
0.00-3.35	Orange brown clayey silt; massive with micro-laminations towards base of unit, sticky when wet; rare, subrounded shale, very rare subrounded greenstone, few, subrounded striated limestone clasts; lower contact diffuse; *Weathered Glacio-glaciolacustrine.*
3.35-5.16	Orange brown clayey silt; some coarse laminations, material badly disturbed by drilling; abundant limestone clasts, subangular and striated; red clay bands in lower 40 cm; lower contact sharp; *Weathered glaciolacustrine.*
5.16-32.65	Grey stony clayey silt; layers of stonier material, compact, slightly sticky when wet; rare red clay clasts; common subrounded to angular limestone clasts, dolomite, rare granite and gneiss; lower contact sharp; slightly stonier in the intervals 8.40 to 9.35 m, 14.27 to 14.65 m, 17.60 to 24.25 m and 26.53 to 26.67 m; *Tavistock Till.*
32.65-32.94	Pale brown silty sand; massive, sticky when wet; very rare subrounded, striated limestone clast; lower contact sharp; *Glaciofluvial.*
32.94-33.10	Brown sand; massive, slightly sticky when wet; rare subrounded limestone clasts; lower contact sharp; *Glaciofluvial.*
33.10-33.90	Brown clayey silt; finely laminated; very compact, dry; rare limestone clast, subrounded and striated, rare red shale; lower contact sharp; *Glaciolacustrine.*
33.90-35.40	Grey sandy silt; massive; abundant angular to subangular, striated, limestone clasts, rare dolostone; hydrocarbon smell; *Catfish Creek Till.*
35.40-35.90	BEDROCK, limestone; *Detroit River Group; Lucas Formation.*

SONIC BOREHOLE NUMBER: E89-06
LOCATION: NTS 1:25000 Topographic Map 40J/2d, U.T.M. 337500m.E. 4663800m.N.
SITE DESCRIPTION: WESTERN GLACIOLACUSTRINE PLAIN
BOREHOLE SURFACE ELEVATION: 182.9 m

Depth (m)	Description
0.00-2.30	Reddish brown (mottled) silty clay; massive, compact; rare subrounded limestone clasts; lower contact sharp; *Weathered glaciolacustrine.*
2.30-4.21	Reddish brown clayey silt; microlaminations and flows marked by red and black silty clay beds, sticky when wet; red and black clay clasts; rare subrounded limestone, granite, shale and weathered sandstone clasts; lower contact diffuse. *Glaciolacustrine.*
4.21-18.74	Grey clayey silt; massive, sticky when wet, very compact; few, subangular to angular limestones, striated, few, subrounded granites, rare black shale clasts; lower contact sharp; *Tavistock Till.* 5.71- 7.24 Stonier layer. 14.63- 15.33 Stonier layer, lower contact with underlying layer marked by a large, subrounded, striated, limestone clast (4 cm diameter). 15.33- 18.30 Very rare angular jasper conglomerate, limestone clasts; lower contact diffuse. 18.30- 18.74 Stonier layer, sand concentration increases with depth.
18.74-23.00	Brown, cobbly silty sand; massive, compact; abundant angular limestone and dolostone, angular to subrounded shale and granite clasts; shale clasts almost bullet shaped; lower contact sharp; *Catfish Creek Till.* 19.93- 19.96 Grey gravel; massive, loose; rounded to angular, striated, limestones (striated), dolostones, shales and granites; lower contact sharp. *Glaciofluvial.*
23.00-23.30	BEDROCK, limestone. *Detroit River Group; Lucas Formation.*

SONIC BOREHOLE NUMBER: E89-07
LOCATION: NTS 1:25000 Topographic Map 40J/2f, U.T.M. 353900m.E 4667200m.N.
SITE DESCRIPTION: ESSEX MORAINE
BOREHOLE SURFACE ELEVATION: 198.1 m

Depth (m)	Description
0.00-0.80	Red cobbly sand; massive, loose; abundant Precambrian shield clasts, limestone and shale clasts, limestones striated; lower contact sharp. *Glaciolacustrine*.
0.80-1.16	Grey coarse sand; massive, becomes cobbly towards contact with lower unit, loose; subrounded limestone, jasper conglomerate, gneiss, schist, shale and dolostone clasts, limestones striated; lower contact marked by a pebble layer. *Glaciolacustrine*.
1.16-1.21	Reddish brown silty clay; microlaminae, compact; red clay balls; lower contact sharp. *Glaciolacustrine*.
1.21-30.16	Grey-red silty clay to clayey silt, microlaminae which become thicker towards base of unit, then massive at 4.16 m, compact; 1 to 2 cm diameter subrounded to angular limestone clasts, striated, angular, very rare subrounded granite and dolomite; lower contact sharp, becomes softer with depth. *Glaciolacustrine*.
30.93-31.25	Red silty clay; flow structure, compact, becoming softer with depth; red clay clasts; few subrounded to flat limestone clasts; lower contact sharp. *Glaciolacustrine*.
31.25-31.70	Grey silty sand; massive, except at 31.50 m red flow structure, loose; few subrounded to angular limestone clasts, some striated; lower contact sharp; *Tavistock Till*.
31.70-33.19	Grey clayey silt, becomes sandier down unit; massive, stiff, rare red clay clasts; few limestone clasts; *Tavistock Till*.
33.19-33.65	Brown silty sand; massive, except for a 6 cm layer of coarse sand compact; common subrounded limestone clasts; lower contact sharp, marked by a 21 cm layer of coarse sand. *Tavistock Till*.
33.65-37.10	Brown stony silty sand; massive, slightly sticky when wet, compact; abundant subrounded to angular, striated, limestone clasts; lower contact diffuse. *Tavistock Till*.

37.10- 39.50	Brownish grey clayey silt; massive except for microlaminations at top; stiff; common subrounded to angular limestone clasts, rare granite, chert, some striated limestone clasts; lower contact sharp. *Tavistock Till.*
37.10- 39.50	Brownish grey clayey silt; massive except for microlaminations at top; stiff; common subrounded to angular limestone clasts, rare granite, chert, some limestones striated; lower contact sharp. *Tavistock Till.*
39.50- 48.50	Brown silty sand; massive, very compact; abundant subrounded to angular, striated limestone, tillite, quartz, shale and granite clasts; hydrocarbon odour. *Catfish Creek Till.* 40.00- 41.60 Boulder layer consisting of 3 large boulders (2 limestone, 1 greenstone) with layers of brown sandy clay between each. *Glaciofluvial.*
48.20- 48.50	BEDROCK, limestone. *Dundee Formation.*

SONIC BOREHOLE NUMBER: E89-08
LOCATION: NTS 1:25000 Topographic Map 40J/2b, U.T.M. 361900m.E. 4663400m.N.
SITE DESCRIPTION: APEX, PROGLACIAL SUBAQUATIC FAN
BOREHOLE SURFACE ELEVATION: 198.1 m

Depth (m)	Description
0.00- 1.80	Reddish brown silty clay; weathered microlaminae, some flow structure; red clay clasts; few angular limestone clasts, some striated, very rare subrounded granite; lower contact sharp. *Weathered Glaciolacustrine.*
1.80- 2.40	Grey clayey silt; massive, sticky when wet; rare angular limestone clasts; lower contact marked by a 1 cm pebble layer of subrounded limestone clasts. *Tavistock Till.*
2.40- 3.10	Brownish grey stony silty sand; very faint laminations, compact, slightly sticky when wet; abundant subrounded to rounded limestone clasts, rare granite; lower contact sharp. *Tavistock Till.*
3.10- 8.47	Brown silty sand; weakly laminated, stiff, water escape structure towards lower part of unit; lower contact marked by a 2 cm thick clay layer. *Glaciofluvial.* 4.74- 4.94 Massive

8.47- 18.95	Brown sand-course sand; laminated, loose; lower contact sharp, marked by a clay drape. *Glaciofluvial*. 17.40- 17.66 Water escape structure marked by increased clay concentration; lower contact sharp.
18.85- 23.00	Brown clayey silt; flows depicted by bands of sand and clay; lower contact sharp. *Tavistock Till*.
23.00- 32.55	Brown sand, unit fines down core; laminated, loose; lower contact sharp. *Glaciofluvial*.
32.55- 34.30	Brown fine sand; massive; lower contact sharp, marked by a washed stony layer. *Glaciofluvial*.
34.30- 35.44	Dark brown stony sandy silt; massive, very compact; abundant angular to subrounded limestone clasts, rare shale and dolomite; lower contact sharp. *Tavistock Till*.
35.44- 37.10	Pale brown stony silty sand; massive, compact; abundant, subrounded to angular limestone clasts, rare granite, shale. *Catfish Creek Till*.
37.10- 37.80	BEDROCK, limestone. *Dundee Formation*.

SONIC BOREHOLE NUMBER: E89-09
LOCATION: NTS 1:25000 Topographic Map 40J/2f, U.T.M. 343800m.E 4668400m.N.
SITE DESCRIPTION: WESTERN GLACIOLACUSTRINE PLAIN
BOREHOLE SURFACE ELEVATION: 193.6 m

Depth (m)	Description
0.00- 1.44	Reddish brown silty clay; microlaminations, becoming coarser down core, compact; common subrounded to angular limestone clasts, rare red sandstone, dolomite, granite; lower contact diffuse. *Weathered Glaciolacustrine*.
1.44- 4.18	Brown silty clay; laminated, sticky when wet; common subrounded limestones, granite, sandstone, dolostone; unit becomes greyer, softer, fewer stones towards contact, laminations become more random and high angled with depth; lower contact diffuse. *Glaciolacustrine*.
4.18- 9.83	Grey silty clay; massive, except at 4.48 m where microlaminations observed, stiff, sticky when wet; very rare red clay clast; few subrounded limestone, dolostone, granite and shale clasts; lower contact sharp; *Tavistock Till*.

9.83-14.89	Brownish grey sand; massive, loose; at 10.31 m, a 2 to 4 cm band of brown clay; 2 grey clay clasts at base of unit; very rare angular limestone clasts within clay; all contacts sharp. *Glaciofluvial.*
14.89-16.17	Pinkish brown clayey silt; massive, very soft; rare limestone clasts; pinkish colour caused by stretching of red lenses and clay balls by drill; lower contact diffuse. *Glaciolacustrine.*
16.17-25.27	Grey silty clay, material stonier at 24.60 m; massive, stiff, sticky when wet; very rare, red clay clast; few, subrounded limestone, dolostone, granite and shale clasts; lower contact sharp. *Tavistock Till.*
25.27-28.43	Brown silty sand; massive, except for a layer of sand at 27.90 m, slightly sticky when wet, soft; lower contact sharp. *Glaciofluvial.*
28.43-28.62	Pale brown sandy silt; massive, 1, 5 cm ball of medium sand within middle of unit; lower contact diffuse. *Tavistock Till.*
28.62-30.26	Pale brown silty sand, coarsens with depth; upper unit massive, unit has planar beds folded up likely by drilling, slightly sticky; lower contact sharp. *Glaciofluvial.*
30.26-33.20	Dark brown stony sandy silt; massive, except for a 80 cm layer of clayish sand, compact, slightly sticky; common to abundant subrounded to subangular, striated limestone, sandstone, gneiss, dolostone, shale clasts, lower contact sharp. *Tavistock Till.*
33.20-33.57	Brown clayey silt; laminated, sticky, very compact; few subrounded to angular limestone, 1 striated, rare granite; lower contact sharp. *Lower Glaciolacustrine.*
33.57-35.60	Brown silty sand; massive, compact; common subrounded limestones, more abundant with depth; lower contact diffuse. *Catfish Creek Till.*

	35.11- 35.20	Dark brown coarse sand; massive; very rare limestone clasts; lower contact sharp.

35.60- 36.20	BEDROCK, limestone. *Detroit River Group; Lucas Formation*

SONIC BOREHOLE NUMBER: E89-10
LOCATION: NTS 1:25000 Topographic Map 40J/2g, U.T.M. 358100m.E. 4677200m.N.
SITE DESCRIPTION: BURIED ESKER
BOREHOLE SURFACE ELEVATION: 185.9 m

Depth (m)	Description
0.00- 4.08	Brown silty clay; massive, laminations in lower part of unit; few angular to subrounded limestone clasts, striated, rare shale and granite; lower contact diffuse. *Weathered Glaciolacustrine.*
4.08- 6.03	Brown clayey silt; laminated, compact; common subrounded to angular limestone clasts, some striated, common shale and granite; lower contact marked by 2 subrounded, striated limestone clasts. *Glaciolacustrine.*
6.03- 7.98	Brownish grey clayey silt; massive, sticky when wet, stiff; few subrounded to subangular limestone, shale, dolomite and granite clasts; lower contact sharp. *Tavistock Till.*
7.98- 9.17	Brown clayey silt; laminated, compact; common subrounded to angular limestone clasts, some striated, common shale and granite; lower contact marked by 2 subrounded, striated limestone clasts. *Glaciolacustrine.*
9.17- 17.64	Brownish grey clayey silt; massive, sticky when wet, stiff; few subrounded to subangular limestone, shale, dolomite and granite clasts; lower contact sharp. *Tavistock Till.*
	11.82- 13.21 Pale brown sandy silt; massive, soft, slightly 13.21 sticky when wet; rare, subrounded limestone clasts; lower contact sharp.
	13.21- 16.08 Dark brown sandy silt; massive, compact, slightly sticky when wet; rare, subrounded, limestone clasts; lower contact diffuse.
17.64- 17.94	Brown fine sand; massive, loose; lower contact sharp. *Glaciofluvial.*

17.94-21.77	Pale brown silty clay; massive with vertically stretched red layers, very soft; red clay clasts; rare, subrounded limestone clasts; lower contact diffuse. *Glaciolacustrine.*
21.77-22.56	Brown silty sand; planar bedded, slightly sticky when wet; lower contact sharp. *Glaciofluvial.*
22.56-23.35	Brown sandy clay; massive, sticky. *Glaciofluvial.*
23.35-23.47	Brown fine sand; massive, loose; lower contact sharp. *Glaciofluvial.*
23.47-30.30	Black brown coarse sand; massive, loose; lower contact sharp. *Glaciofluvial.*
30.30-32.40	Dark stony silty sand, massive, very compact, slightly sticky when wet; abundant subrounded to angular limestone, sandstone, dolostone, chert, granite, shale clasts, some striated. *Catfish Creek Till.*
32.40-32.90	BEDROCK, limestone. *Dundee Formation.*

SONIC BOREHOLE NUMBER: E89-11
LOCATION: NTS 1:25000 Topographic Map 40J/7c, U.T.M. 351300m.E. 4681400m.N.
SITE DESCRIPTION: BYRNEDALE MORAINE
BOREHOLE SURFACE ELEVATION: 181 m

Depth (m)	Description
0.00-0.34	ROAD GRAVEL.
0.34-0.82	Black to brown sand; massive, loose; rare subangular granites; lower contact sharp; *Lacustrine.*
0.82-4.25	Brown clayey silt, upper part massive, below weathering zone laminations which become more steeply and randomly orientated with depth, compact; few subrounded limestone, shale, weathered sandstone clasts; lower contact sharp; *Glaciolacustrine.*
4.25-44.20	Grey silty clay, becomes sandier with depth; massive, common red clay clasts at 15.80 m, sticky when wet, stiff, becomes soft with depth; rare subrounded to subangular limestone, green and pink granite clasts; limestone clasts are striated; lower contact sharp. *Tavistock Till.*

	20.80- 20.90,	Brown clayey silt; massive, sticky when wet, soft; very rare limestone clast; lower contact diffuse. Other such layers observed at 31.00- 31.50, 31.60- 31.70 and 31.90- 40.70.
	28.80- 30.40	Clay becomes very red; rare red clay clasts; large subangular, striated limestone clast; lower contact sharp.
	30.40- 30.60	Pale brown clayey silt; massive, slightly sticky to sticky when wet, stiff; very rare limestone clast; lower contact sharp.
	40.70- 41.50	Brown stony silty sand; massive, slightly sticky when wet, compact; abundant subrounded to angular limestone, few dolostone, granite; lower contact sharp.
	41.50- 41.60	Black coarse sand, some pebbles; massive, loose; very rare clay ball; few subrounded limestone clasts; lower contact sharp.
	41.60- 44.20	Brown stony silty sand; massive, slightly sticky when wet, compact; abundant subrounded to angular limestone, few dolostone, granite; lower contact sharp.

44.20- 48.10 Brown sandy clay; massive, compact, slightly sticky; abundant subrounded to angular granite, sandstone, limestone, dolostone clasts. *Catfish Creek Till.*

48.10- 49.30 BEDROCK, limestone. *Dundee Formation.*

SONIC BOREHOLE NUMBER: E89-12
LOCATION: NTS 1:25000 Topographic Map 40J/2g, U.T.M. 363500m.E. 4675900m.N.
SITE DESCRIPTION: NORTHERN GLACIOLACUSTRINE PLAIN
BOREHOLE SURFACE ELEVATION: 184.4 m

Depth (m)	Description
0.00- 1.80	Silt and very fine sand; indistinct horizontal planes; rare subangular to subrounded limestone, quartz and igneous clasts; lower contact diffuse. *Weathered Glaciolacustrine.*
1.80- 3.02	Brown stony sandy silt; laminated, compact; common subangular to rounded limestone, igneous and rare black shale. *Glaciolacustrine.*
3.02- 5.93	Grey sandy silt, becomes brown clayey silt with depth; indistinct laminations, massive below 4.36 m; rare to common subangular to subrounded mafic volcanic and limestone clasts; lower contact sharp. *Tavistock Till.*

5.93-15.60	Pinkish silty clay; reddish mud pellets common, especially in lower 40 cm; rare subrounded limestone clasts. *Glaciolacustrine.*
15.60-17.52	Greyish clayey silt; massive; rare reddish mud clast; rare limestone and shale clast. *Tavistock Till.*
17.52-18.48	Pinkish silty clay; massive; rare subrounded limestone. *Glaciolacustrine.*
18.48-23.46	Greyish clayey silt becoming a sandy silt over lower 2.02 m.; 1, 30 cm layer of sandier material at 21.14 m; rare subrounded limestone; lower contact sharp. *Tavistock Till.*
23.46-25.90	Grey gravelly sand which fines to silty sand at 23.90 m; common subangular to subrounded limestone clasts; rare shale, igneous, and dolostone clasts; lower contact sharp. *Glaciofluvial.*
25.90-26.05	Grey stony silty sand; shale, igneous and limestone clasts; lower contact sharp. *Glaciofluvial.*
26.05-26.16	Greyish clayey silt; massive; rare clay clast; rare clast; lower contact sharp. *Tavistock Till.*
26.16-26.53	Grey stony silty sand; massive; common subangular to rounded shale and limestone clasts; lower contact sharp. *Glaciofluvial.*
26.53-28.11	Grey silty clay; massive; rare red clay clast. *Glaciolacustrine.*
28.11-28.18	Dark grey silty sand; shale and limestone clasts. *Glaciofluvial.*
28.18-32.00	Grey silty clay; massive; rare reddish clay clast; rare limestone and shale clast; lower contact sharp. *Glaciolacustrine.*
32.00-32.55	Brownish pink silty clay; common red and green clay clasts; rare subrounded to rounded limestone, shale and rare igneous clasts; lower contact sharp. *Glaciolacustrine.*
32.55-32.90	Stony clayey silt. *Catfish Creek Till.*
32.90-33.40	BEDROCK, limestone. *Dundee Formation.*

APPENDIX B

Description of Measured Sections

All descriptions are from the top of the section and thicknesses are given in metres. Interpretations appear in italics

Colchester to Oxley Sections (*see* Fig. 12).

Station 1 UTM 340600m.E. 4649300m.N.

0.00- 2.50	Pale brown to red silty clay; laminated, compact; vertical 1 m fractures; common red clay clasts, increased concentration towards lower contact; common limestone, granite and shale clasts; rare striated limestone clasts; lower contact sharp. *Glaciolacustrine.* 1.53- 1.58 Red silty clay; massive, compact; flow structure oriented 190°; lower contact sharp.
2.50- 2.72	Grey silty clay; massive, compact; common limestone clasts. *Tavistock Till.*

Station 2 UTM 340700m.E. 4649300m.N.

0.00- 1.25	Pale brown silty clay; laminated, compact; limestone, granite and shale clasts concentrated in bedding planes; lower contact sharp. *Glaciolacustrine.*
1.15- 2.40	Pale brown fine sand; layers, 1 to 4 cm thick, of wavy laminated sand; lower contact wavy. *Glaciofluvial.*
2.40- 2.58	Dark brown clay; massive at top, becomes laminated towards base; rare limestone clasts; lower contact diffuse. *Tavistock Till.*
2.58- 2.82	Dark brown silty sand; few clay lenses, one with common red clay clasts; lower contact wavy. *Glaciofluvial.*
2.82- 3.40	Reddish brown silty clay, becoming more clay rich over the lower 20 cm; massive, compact; abundant shale, limestone, dolostone and granite; lower contact wavy. *Tavistock Till.*
3.40- 3.52	Brown fine sand; massive, loose; lower contact wavy. *Glaciofluvial.*
3.52- 3.94	Brown clay as described 2.40 to 2.58 m; lower contact sharp. *Tavistock Till.*

3.94- 4.17 Brown fine sand as described 3.40 to 3.52 m; lower contact sharp. *Glaciofluvial.*

4.17- 4.26 Brown clay as described 2.40 to 2.58 m; lower contact wavy. *Tavistock Till.*

4.26- 4.42 Brown fine sand, cross-bedded; lower contact wavy, with coarser planar bedded sand. *Glaciofluvial.*

Station 3 UTM 340800m.E. 4649300m.N.

0.00- 1.20 Pale brown silty clay; laminated, compact; limestone, granite and shale clasts concentrated within bedding planes; lower contact wavy. *Glaciolacustrine.*

1.20- 1.40 Orange brown sand; massive with beds of clay, 1 to 2 cm thick; rare clay clasts; lower contact sharp. *Glaciofluvial.*

1.40- 1.66 Pale brown silty clay as described 0.00 to 1.20 m; lower contact wavy. *Glaciolacustrine.*

1.66- 2.46 Orange brown sand as described 1.20 to 1.40 m; lower contact wavy. *Glaciofluvial.*

2.46- 2.80 Reddish brown silty clay; massive, compact; abundant shale, limestone, dolostone and granite; lower contact wavy. *Tavistock Till.*

2.80- 2.94 Brown silty sand; massive, soft. *Glaciolacustrine.*

Station 4 UTM 340900m.E 4649300m.N.

0.00- 1.00 Pale brown silty clay; laminated, compact; limestone, granite and shale concentrated within bedding planes; lower contact wavy. *Glaciolacustrine.*

1.00- 2.34 Orange brown sand; massive with 1 clay band 1 to 2 cm thick; rare red clay clast; lower contact sharp. *Glaciofluvial.*

2.34- 4.10 Brown silty sand; massive with beds of orange brown sand, 1 to 6 cm thick. *Glaciofluvial.*

Station 5 UTM 341400m.E. 4649300m.N.

0.00- 0.66 Orange fine sand; massive, loose; rare limestone clasts; lower contact sharp. *Glaciolacustrine.*

0.66- 2.00	Pale brown silty clay; laminated, compact; beds of sand, 1 to 3 cm thick; common red clay clasts; common limestone, granite and shale clasts within bedding planes; lower contact diffuse. *Glaciofluvial.*
2.00- 3.50	Brown silty clay; massive, compact; common limestone, granite, shale and tillite; lower contact diffuse. *Tavistock Till.*
3.50- 3.70	Dark brown sand with clay stringers and clasts; lower contact diffuse. *Glaciofluvial.*
3.70- 3.80	Pale brown fine sand; massive with rare planar beds; abundant red and grey clay clasts. *Glaciofluvial.*

Station 6 UTM 341900m.E. 4649400m.N.

0.00- 1.20	Brown sand; planar sand beds dipping 10°, paleocurrent 190°; lower contact sharp. *Glaciolacustrine.*
1.20- 4.60	Reddish brown clay; laminated with abundant red clay clasts; lower contact diffuse. *Glaciolacustrine.*
4.60- 4.68	Pale brown sand; massive, loose. *Glaciofluvial.*

Station 7 UTM 342000m.E. 4649400m.N.

0.00- 9.46	Brown sand; planar sand beds dipping 15°; paleocurrent 190°; lower contact sharp. *Glaciolacustrine.*
9.46- 10.60	Reddish brown clay; laminated with abundant red clay clasts; lower contact diffuse. *Glaciolacustrine.*
10.60- 11.80	Brown sand; planar bedded; lower contact gradational. *Glaciofluvial.*
11.80- 12.40	Grey silty clay; massive, compact; common limestone, granite and shale. *Tavistock Till.*

Station 8 UTM 359900m.E. 4654500m.N.

0.00- 1.00	Brown sand; poorly defined laminations; abundant limestone clasts; lower contact diffuse. *Glaciolacustrine.*
1.00- 3.00	Grey silty clay; flow structure; abundant limestone, rare granite clasts; rare striated limestone clasts; lower contact sharp. *Tavistock Till.*

3.00- 3.50 Grey brown fine sand; rippled bedding, faulted; lower contact sharp. *Glaciofluvial.*

3.50- 14.7 Grey silty clay; flow structure; rare limestone clasts. *Tavistock Till.*

Station 9 UTM 359700m.E. 4654500m.N.

0.00- 1.00 Orange brown sand; massive with inclusion of clay stringers, 1 to 4 cm thick; lower contact clear. *Glaciolacustrine.*

1.00- 2.00 Brown silty clay, becoming sandier over the lower 80 cm; massive, compact; rare limestone, shale clasts; lower contact sharp. *Tavistock Till.*

2.00- 5.00 Pale brown sand; planar bedded, beds are faulted and rotated over lower 2 m; lower contact sharp. *Glaciofluvial.*

5.00- 8.00 Grey silty clay; massive compact; inclusion of sand stringer 1 to 3 cm thick; few limestone, granite and shale clasts; lower contact sharp. *Tavistock Till.*

8.00- 10.00 Pale brown sand; matrix is massive with layers of rippled sand and red clay clasts, up to 8 cm thick; lower contact sharp. *Glaciofluvial.*

10.00- Grey silty clay as described 5.00 to 8.00 m. *Tavistock Till.*

Station 10 UTM 357800m.E. 4654500m.N.

0.00- 1.80 Orange brown sand; poorly defined planar laminations; inclusions of silt clasts and stringers 1 to 3 cm thick; lower contact wavy. *Glaciolacustrine.*

1.80- 3.00 Reddish brown silty clay; laminated, compact; paleocurrent 165°; abundant red clay clasts; lower contact sharp. *Glaciolacustrine.*

3.00- 9.80 Grey silty clay; flow structure orientated 185°; rare limestone clasts, becomes massive through lower 5.40 m; lower contact diffuse; rare limestone, shale, granite. *Tavistock Till.*

McGregor Quarry Sections (*see* Figure 13).

Station 11 UTM 333600m.E. 4668900m.N.

0.00-5.60	Brown grey silty clay: massive with inclusions of sand stringers 2 to 4 cm thick, lower 20 cm more stony, inclusions of lower material sheared up into the upper, beds dip 20°, orientated 190°; common granite, intrusive, volcanic, schist, limestone and dolostone clasts; rare striated limestone clasts; lower contact sharp. *Tavistock Till.*
5.60-7.50	Brown grey stony sandy silt; massive, with inclusions of sand stringers, 1 to 3 cm thick; abundant granite, volcanic, schist, limestone and dolostone clasts; rare striated limestone clasts. *Catfish Creek Till.*

Station 12 UTM 333800m.E. 4668900m.N.

0.00-5.30	Brown grey silty clay; massive with inclusions of sand stringers 2 to 4 cm thick; common granite, intrusive volcanic, schist, limestone and dolostone clasts; rare, striated limestone clasts; lower contact sharp. *Tavistock Till.*
5.30-5.40	Brown silty clay; laminated, compact laminations are wavy towards upper and lower contacts with inclusion of abundant red clay clasts; laminations in middle of unit are planar with rare red clay clasts; lower contact is wavy. *Glaciolacustrine.*
5.40-7.50	Brown grey stony sandy silt; massive, with inclusions of sand stringers, 1 to 3 cm thick; abundant granite, volcanic, schist, limestone and dolostone clasts; rare striated limestone clasts. *Catfish Creek Till.*

Note: The above site description is typical of Stations 13 (UTM 333900m.E. 4668900m.N.), 14 (UTM 334000m.E. 4668800m.N.), 15 (UTM 334100m.E. 4668800m.N.) and 16 (UTM 334000m.E. 4668700m.N.). The only difference between the sections are the unit thicknesses. Therefore the site descriptions for Stations 13- 16 will not be repeated here.

Station 17 UTM 334300m.E. 4668700m.N.

0.00-1.00	Reddish brown silty clay; massive with occasional silt bed, 1 to 4 cm thick; lower contact diffuse. *Glaciolacustrine.*

1.00- 2.20 Reddish brown clayey silt; laminated with abundant red clay clasts; lower contact wavy. *Glaciolacustrine.*

2.20- 17.50 Brown grey silty clay; massive with inclusions of sand stringers 2 to 4 cm thick; common granite, intrusive volcanic, schist, limestone and dolostone clasts; rare, striated limestone clasts; lower contact sharp. *Tavistock Till.*

17.50- 20.50 Brown silty clay; laminated, compact laminations are wavy towards upper and lower contacts with inclusion of abundant red clay clasts; laminations in middle of unit are planar with rare red clay clasts; lower contact is wavy. *Glaciolacustrine.*

20.50- 25.20 Brown grey stony sandy silt; massive, with inclusions of sand stringers, 1 to 3 cm thick; abundant granite, volcanic, schist, limestone and dolostone clasts; rare striated limestone clasts. *Catfish Creek Till.*

Station 18 UTM 334400m.E. 4668700m.N.

0.00- 1.00 Reddish brown silty clay; massive with occasional silt bed, 1 to 4 cm thick; lower contact diffuse. *Glaciolacustrine.*

1.00- 2.50 Reddish brown clayey silt; laminated with abundant red clay clasts; lower contact wavy. *Glaciolacustrine.*

2.50- 21.90 Brown grey silty clay; massive with inclusions of sand stringers 2 to 4 cm thick; common granite, intrusive volcanic, schist, limestone and dolostone clasts; rare, striated limestone clasts; lower contact sharp. *Tavistock Till.*
19.50- 21.2 Flow and roll-up structure observed.

21.90- 23.00 Brown grey stony sandy silt; massive, with inclusions of sand stringers, 1 to 3 cm thick; abundant granite, volcanic, schist, limestone and dolostone clasts; rare striated limestone clasts. *Catfish Creek Till.*

Note: The above site description is typical of Station 19 (UTM 334500m.E. 4668700m.N.). Therefore the site description for Station 19 will not be repeated here.

Erie Sand and Gravel Aggregate Excavation (*see* Figure 14)

Station 20 UTM 363800m.E. 4660600m.N.

0.00-7.30	Brown stony sand; cross bedding and some planar bedded sand; abundant limestone, dolostone, volcanics, shale, quartz, sandstone, quartzites; lower contact sharp. *Glaciolacustrine.*
7.30-8.70	Brown medium coarse sand; planar beds of sand dipping 8°, paleocurrent 95°; lower contact diffuse. *Glaciolacustrine.*
8.70-9.38	Brown clay; massive, soft; lower part of unit has some inclusion of sand; rare limestone clast; lower contact diffuse. *Glaciolacustrine.*
9.38-13.38	Brown fine sand; wavy planar beds with occasional bed of rippled, starved rippled sand; paleocurrent direction 165°. *Glaciofluvial.*

Station 21 UTM 363800m.E. 4660600m.N.

0.00-6.00	Brown stony sand; cross bedding and some planar bedded sand; abundant limestone, dolostone, volcanics, shale, quartz, sandstone, quartzites; lower contact sharp. *Glaciolacustrine.*
6.00-7.90	Brown coarse sand and gravel; planar beds steeply dipping, 20°; paleocurrent direction 165°; abundant limestone, dolostone, volcanics, shale, quartz, sandstone, quartzite, tillite, jasper conglomerate; lower contact sharp. *Glaciolacustrine.*
7.90-8.54	Brown clay; massive, soft; lower part of unit has some inclusion of sand; rare limestone clast; lower contact diffuse. *Glaciolacustrine.*
8.54-14.04	Brown sand; trough cross-beds are cross-cut by channel sands; gravel concentrated at channel edges, flanking channel sand; trough cross-beds paleocurrent is 180° units become smaller up section; channel sands paleocurrent is 138°; common limestone, dolostone, volcanics, shale, quartz, sandstone, quartzite, tillite, jasper conglomerate. *Glaciofluvial.*

Station 22 UTM 363800m.E. 4660800.N.

0.00- 5.80	Brown stony sand; cross bedding and some planar bedded sand; abundant limestone, dolostone, volcanics, shale, quartz, sandstone, quartzites; lower contact sharp. *Glaciolacustrine.*
5.80- 7.40	Brown coarse sand and gravel; massive, loose; abundant limestone, dolostone, volcanics, shale, quartz, sandstone, quartzite, tillite, jasper conglomerate; lower contact sharp. *Glaciolacustrine.*
7.40- 8.00	Brown clay; massive, soft; lower part of unit has some inclusion of sand; rare limestone clast; lower contact diffuse. *Glaciolacustrine.*
8.00- 12.60	Brown sand; trough cross-beds, foresets preserved within troughs; paleocurrent 180°; troughs become smaller up-section; coarser sand and few clasts line troughs. *Glaciofluvial.*

Station 23 UTM 363800m.E. 4660800m.N.

0.00- 0.20	Orange brown sand and gravel; lower part of unit consists of planar beds dipping east, these grade upward into weathered massive beds, loose; common limestone, dolostone, shale, quartz, sandstone, quartzite; lower contact sharp. *Glaciolacustrine.*
0.20- 1.00	Brown sandy clay; massive, compact; few limestone and volcanic clasts; rare limestone striated; lower contact sharp. *Glaciolacustrine.*
1.00- 1.65	Brown sand; massive at top, planar laminated near base; laminations are faulted; presence of clay clasts and clay stringers; lower contact sharp. *Glaciofluvial.*
1.65- 3.45	Grey silty clay; massive, compact; few limestone, volcanic and shale clasts; rare limestone striated; *Tavistock Till.*
3.45- 5.05	Brown sand; massive, compact with clay clasts and clay stringers 10 cm thick; ball and pillow structure occurs at the top of the unit; clay stringers orientated 185°. *Glaciofluvial.*

Station 24 UTM 364000m.E. 4660700m.N.

0.00-1.20	Brown fine to medium sand; low angle planar beds, paleocurrent 126°. *Glaciolacustrine.*
1.20-1.45	Dark grey silty clay; laminated with mats of organic material. *Glaciolacustrine.*
1.45-1.95	Brown medium sand; massive, shell rich; lower contact is clear and smooth. *Glaciolacustrine.*
1.95-2.30	Dark grey silty clay; laminated with mats organic material and shell. *Glaciolacustrine.*
2.30-2.90	Brown, medium sand; planar bedded at the base of the unit, bedding destroyed by flame water escape structure at the top of the unit, becoming massive; contains shell and wood fragments. *Glaciolacustrine.*
2.90-6.60	Grey silty clay; flow structure top of unit; few limestone, volcanic and shale clasts; boulder pavement consisting of limestone boulders aligned 178°, striae on limestone clasts surface parallel to orientation of clasts long axis; lower contact of unit wavy. *Tavistock Till.*
6.60-7.46	Brown sand; massive with diamict stringers 10 cm thick; stringers orientated at 185°. *Glaciolacustrine.*

Station 25 UTM 364000m.E. 4660900m.N.

0.00-0.94	Brown fine to medium sand; low angle planar beds which grade upwards into coarser, massive sand; concentration of clasts increases upward; paleocurrent 92°; lower contact wavy. *Glaciolacustrine.*
0.94-2.14	Brown medium sand which fines upwards; massive; lower contact sharp, wavy. *Glaciolacustrine.*
2.14-3.64	Grey, clayey silt; lower part of unit consists of southward orientated flow structure which becomes massive in the top part of the unit; lower contact is smooth and clear; *Tavistock Till.*
3.64-4.64	Brown sand; massive, compact; stringers of grey diamict, 10 to 20 cm thick within unit; diamict beds orientated at 185°; *Glaciofluvial.*

Amherstburg Quarry Section UTM 327300m.E. 4664200m.N.

0.00-1.80	Fill
1.80-2.40	Light brown silty clay; some evidence of lamination, 1 to 2 cm thick, compact; abundant weathered limestone clasts, few rare subrounded limestone and shield clasts; lower contact diffuse. *Weathered glaciolacustrine.*
2.40-3.40	Light brown clayey silt; massive, compact; abundant weathered limestone clasts; few-rare subrounded limestone and shield clasts; lower contact diffuse. *Glaciolacustrine.*
3.40-6.90	Grey stony clayey silt; massive, with balls of lower unit incorporated, base of unit there are common red clay clasts, very compact; abundant limestone, dolostone, granite, volcanics, quartzite, jasper conglomerate, tillite, Lorraine sandstone, calcite, shale, gneiss, schist; lower contact diffuse. *Tavistock Till.*
6.90-8.60	Grey stony silty clay; laminated, orientation random and even folded, abundant red clay balls; clast make up the same as grey stony clayey silt described above. *Deformable bed, Tavistock Till.*

APPENDIX "C"

Summary list of laboratory analysis by material type

Notes:

1) Except for pebble counts, analysis were carried out by the Geoscience Laboratories, Ministry of Northern development and Mines.

2) Sand- silt boundary 0.062 mm; silt- clay boundary 0.002 mm.

3) Carbonate analysis on minus 200 mesh (0.074) fraction using Chittick apparatus.

4) Heavy mineral separation on the < 60 to ≥ 140 mesh fraction. Acetylene tetrabromide (S.G. 2.96) was the heavy liquid used.

5) For geochemical analysis, a total extraction (HNO_3-HF) was used. Concentrations were determined by Atomic Absorption.

6) Clay mineralogy determined using X-ray diffraction.

7) Total garnets refers to the number of red and purple garnets identified from 100 heavy minerals counted.

WEATHERED UPPER SILTY CLAY

U.T.M. Reference		Sample	Geochemistry							Carbonate			
Easting	Northing	No.	Co ppm	Cr ppm	Cu ppm	Ni ppm	Pb ppm	Zn ppm	Fe ppm	% Ca	% Dol	Total	Ratio
372800	4651600	SWEL 3	14.0	80.0	31.0	36.0	20.0	109.0	-5.0	0.6	0.8	1.4	0.7
371100	4653900	SWEL 25	10.0	73.0	19.0	28.0	16.0	120.0	-5.0	0.7	0.8	1.5	0.9
372400	4654200	SWEL 27	13.0	75.0	32.0	36.0	15.0	102.0	-5.0	9.7	5.4	15.2	1.8
374500	4654200	SWEL 28	17.0	90.0	39.0	47.0	-10.0	114.0	-5.0	0.6	1.1	1.7	0.5
374400	4654400	SWEL 29	12.0	78.0	35.0	33.0	26.0	125.0	-5.0	0.6	1.2	1.8	0.4
374700	4675100	SWEC 36	18.0	87.0	32.0	50.0	17.0	131.0	-5.0	2.4	9.0	11.4	0.3
368300	4678700	SWESP 44	16.0	94.0	40.0	56.0	18.0	130.0	-5.0	0.4	1.1	1.6	0.4
361000	4683300	SWEBR 45	15.0	84.0	25.0	42.0	14.0	107.0	-5.0	0.5	0.4	0.8	1.3
360800	4676700	SWEW 50	11.0	75.0	30.0	40.0	13.0	103.0	-5.0	1.0	9.7	10.7	0.1
357600	4675600	SWEW 52	12.0	68.0	30.0	36.0	16.0	98.0	-5.0	11.1	14.0	25.1	0.8
362100	4672100	SWEW 53	13.0	73.0	33.0	44.0	18.0	123.0	-5.0	0.9	3.8	4.8	0.2
360500	4668400	SWEW 57a	12.0	81.0	29.0	43.0	17.0	107.0	-5.0	8.9	11.8	20.7	0.8
363200	4666600	SWEW 61	16.0	112.0	50.0	81.0	23.0	198.0	-5.0	0.7	0.6	1.2	1.2
362200	4663300	SWEK 66	11.0	66.0	32.0	35.0	17.0	137.0	-5.0	15.0	14.8	29.8	1.0
363300	4661400	SWEK 71	17.0	93.0	55.0	54.0	72.0	238.0	-5.0	0.5	0.7	1.1	0.7
362100	4655500	SWEK 85	11.0	68.0	34.0	34.0	13.0	106.0	-5.0	11.5	10.7	22.2	1.1
363200	4665800	SWEK 90	16.0	76.0	31.0	44.0	15.0	95.0	-5.0	10.4	12.4	22.8	0.8
364000	4660700	SWEK 99	14.0	64.0	39.0	37.0	90.0	198.0	-5.0	0.6	1.4	2.0	0.5
352600	4671300	SWEE 130	12.0	68.0	29.0	41.0	15.0	142.0	-5.0	11.4	10.4	21.8	1.1
352800	4669600	SWEE 134	16.0	90.0	32.0	52.0	16.0	132.0	-5.0	0.6	0.8	1.4	0.7
351300	4656000	SWEE 138	15.0	94.0	30.0	44.0	19.0	147.0	-5.0	0.6	1.5	2.1	0.4
351200	4662800	SWECC 139	14.0	77.0	31.0	45.0	16.0	114.0	-5.0	5.2	9.7	14.9	0.5
353000	4658400	SWECC 142	13.0	79.0	36.0	42.0	16.0	133.0	-5.0	3.3	9.0	12.3	0.4
367800	4660200	SWE 150	11.0	76.0	36.0	40.0	15.0	120.0	-5.0	3.0	10.7	13.7	0.3
374400	4660700	SWE 151	14.0	69.0	33.0	38.0	15.0	92.0	-5.0	14.4	7.8	22.2	1.8
368200	4665700	SWE 153	13.0	83.0	16.0	35.0	17.0	134.0	-5.0	0.5	0.6	1.0	0.8
366300	4678600	SWE 154	14.0	88.0	33.0	44.0	22.0	139.0	-5.0	0.5	1.3	1.8	0.4
372200	4683100	SWE 156	17.0	92.0	37.0	55.0	17.0	139.0	-5.0	0.4	2.0	2.4	0.2
349700	4683700	SWE 158	15.0	75.0	29.0	45.0	17.0	88.0	-5.0	0.4	1.2	1.7	0.4
348500	4680000	SWE 159	8.0	50.0	22.0	23.0	12.0	49.0	-5.0	10.6	12.9	23.5	0.8
331400	4683900	SWEWI 11	5.0	48.0	19.0	19.0	12.0	51.0	-5.0	15.0	21.0	36.0	0.7
330300	4676900	SWERC 16	6.0	56.0	14.0	23.0	21.0	76.0	-5.0	0.8	1.0	1.8	0.8
329200	4671700	SWERC 19	10.0	75.0	32.0	38.0	12.0	95.0	-5.0	3.0	6.0	1.0	0.5
326700	4665700	SWERC 20	10.0	82.0	30.0	48.0	15.0	104.0	-5.0	1.0	0.0	2.0	2.1
326400	4658500	SWEAM 21	15.0	88.0	28.0	44.0	17.0	92.0	-5.0	1.0	1.0	14.0	1.0
332300	4658200	SWEAM 22	7.0	54.0	30.0	27.0	21.0	94.0	-5.0	5.0	9.0	33.0	0.6
335100	4653600	SWEHA 23	10.0	59.0	28.0	29.0	11.0	78.0	-5.0	22.0	11.0	23.0	2.0
337600	4663900	SWEHA 27	19.0	109.0	20.0	43.0	14.0	110.0	-5.0	1.0	1.0	2.0	1.0
344300	4662600	SWEHA 28	14.0	80.0	29.0	42.0	18.0	90.0	-5.0	6.0	9.0	15.0	0.7
346200	4658200	SWECC 32	16.0	98.0	28.0	48.0	14.0	100.0	-5.0	1.0	1.0	2.0	1.0
344900	4668500	SWEMA 35	10.0	70.0	26.0	31.0	15.0	98.0	-5.0	13.0	12.0	25.0	1.1
337200	4675800	SWEMA 39	14.0	84.0	20.0	40.0	17.0	109.0	-5.0	1.0	0.0	1.0	0.0
340300	4680500	SWERS 40	13.0	59.0	28.0	35.0	13.0	82.0	-5.0	3.0	15.0	18.0	0.2
345000	4680200	SWERS 41	18.0	90.0	31.0	48.0	15.0	100.0	-5.0	1.0	1.0	2.0	1.0
344100	4687300	SWERS 42	14.0	70.0	28.0	36.0	12.0	79.0	-5.0	10.0	14.0	24.0	0.7
341600	4688800	SWERS 43	11.0	60.0	22.0	30.0	12.0	68.0	-5.0	0.0	6.0	6.0	0.0
334400	4660200	SWEAM 49	11.0	63.0	52.0	37.0	26.0	130.0	-5.0	1.0	4.0	5.0	0.2
344000	4669300	SWEAM 50	13.0	74.0	32.0	35.0	21.0	130.0	-5.0	1.0	1.0	2.0	1.0

WEATHERED UPPER SILTY CLAY (CON'T)

Sample No.	Heavy %	Minerals Non. Mag.	Mag.	Garnet %Purple	%Red	Total	Ratio	Grain Size % Cl	% Si	% Ss
SWEL 3	3.9	0.1	2.0	8.7	2.7	11.4	3.2	45.0	38.0	17.0
SWEL 25	3.0	0.1	2.7	nd	nd	nd	nd	36.0	48.0	16.0
SWEL 27	3.3	0.0	5.0	9.4	2.9	12.3	3.2	52.0	34.0	14.0
SWEL 28	3.9	0.0	5.0	nd	nd	nd	nd	62.0	31.0	7.0
SWEL 29	3.1	0.1	2.2	8.0	2.7	10.7	3.0	34.0	32.0	34.0
SWEC 36	1.6	0.1	3.3	nd	nd	nd	nd	48.0	33.0	19.0
SWESP 44	1.1	0.0	3.1	nd	nd	nd	nd	48.0	26.0	26.0
SWEBR 45	0.9	0.0	4.4	3.7	2.0	5.7	1.8	59.0	36.0	5.0
SWEW 50	1.4	0.1	3.6	4.7	2.0	6.7	2.4	43.0	34.0	23.0
SWEW 52	1.4	0.1	9.2	nd	nd	nd	nd	38.0	35.0	27.0
SWEW 53	1.2	0.1	4.1	3.3	0.3	3.6	11.0	37.0	40.0	23.0
SWEW 57a	1.3	0.0	15.0	4.0	0.3	4.3	13.3	48.0	38.0	14.0
SWEW 61	3.3	0.2	2.8	nd	nd	nd	nd	9.0	6.0	85.0
SWEK 66	4.7	0.3	6.7	nd	nd	nd	nd	15.0	23.0	62.0
SWEK 71	6.4	0.4	16.3	5.0	5.0	10.0	1.0	17.0	1.0	82.0
SWEK 85	1.3	0.0	3.7	4.0	1.7	5.7	2.4	37.0	43.0	20.0
SWEK 90	2.5	0.1	8.9	nd	nd	nd	nd	39.0	37.0	24.0
SWEK 99	7.5	0.6	12.3	nd	nd	nd	nd	8.0	10.0	82.0
SWEE 130	1.6	0.1	5.7	nd	nd	nd	nd	51.0	33.0	16.0
SWEE 134	1.8	0.1	3.9	nd	nd	nd	nd	49.0	21.0	30.0
SWEE 138	1.4	0.0	6.5	3.3	2.0	5.3	1.6	51.0	34.0	15.0
SWECC 139	1.2	0.1	9.2	3.7	0.3	4.0	12.3	42.0	38.0	20.0
SWECC 142	0.9	0.0	7.1	2.7	1.3	4.0	2.1	44.0	37.0	19.0
SWE 150	1.5	0.1	9.6	nd	nd	nd	nd	45.0	39.0	16.0
SWE 151	3.0	0.0	5.7	7.0	3.7	10.6	1.9	50.0	38.0	12.0
SWE 153	1.2	0.1	3.4	nd	nd	nd	nd	35.0	31.0	34.0
SWE 154	1.2	0.1	3.6	nd	nd	nd	nd	50.0	37.0	13.0
SWE 156	1.4	0.1	4.0	nd	nd	nd	nd	54.0	28.0	18.0
SWE 158	2.6	0.1	7.6	7.3	3.7	11.0	2.0	49.0	44.0	7.0
SWE 159	1.5	0.1	8.0	3.0	2.7	5.7	1.1	42.0	31.0	27.0
SWEWI 11	1.3	0.1	6.0	1.0	3.0	4.0	0.3	25.0	52.0	23.0
SWERC 16	0.4	0.0	0.0	nd	nd	nd	nd	15.5	47.0	37.5
SWERC 19	3.0	0.1	8.1	2.5	2.5	5.0	1.0	35.0	48.0	17.0
SWERC 20	2.4	0.1	7.3	1.0	8.0	9.0	0.1	38.0	46.0	16.0
SWEAM 21	1.0	0.0	6.7	4.0	2.5	6.5	1.6	38.0	46.0	16.0
SWEAM 22	4.6	0.1	7.5	1.0	7.5	8.5	0.1	12.0	68.0	20.0
SWEHA 23	3.8	0.1	10.0	1.0	4.0	5.0	0.3	20.0	55.0	25.0
SWEHA 27	1.7	0.1	4.2	4.0	6.0	10.0	0.7	46.0	32.0	22.0
SWEHA 28	1.3	0.1	5.7	0.5	2.5	3.0	0.2	46.0	44.0	10.0
SWECC 32	1.5	0.1	2.0	2.5	2.0	4.5	1.3	56.0	38.0	6.0
SWEMA 35	1.3	0.0	9.1	1.0	4.0	5.0	0.3	31.0	48.0	21.0
SWEMA 39	1.4	0.1	4.9	2.5	4.5	7.0	0.6	28.0	40.0	32.0
SWERS 40	1.4	0.1	3.3	3.0	6.0	9.0	0.5	27.0	48.0	26.0
SWERS 41	1.3	0.1	5.1	3.0	2.5	5.5	1.2	36.0	40.0	24.0
SWERS 42	1.3	0.1	3.3	1.0	3.0	4.0	0.3	28.0	42.0	29.0
SWERS 43	0.8	0.0	10.0	0.0	0.5	0.5	0.0	19.0	56.0	25.0
SWEAM 49	2.7	0.3	1.9	4.0	4.5	8.5	0.9	11.0	36.0	52.0
SWEAM 50	1.4	0.1	4.6	3.0	4.0	7.0	0.8	25.0	48.0	26.0

WEATHERED UPPER SILTY CLAY (CON'T)

Sample No.	Calcite	Chlorite	Dolomite	Clay Feldspar	Minerology Illite	Kaolinite	Quartz	Smectite	Vermic.
SWEL 3	-	X	-	-	X	-	-	-	X
SWEL 25	-	X	-	-	X	X	-	-	X
SWEL 27	X	X	-	-	X	X	-	-	X
SWEL 28	-	-	-	-	X	X	-	-	X
SWEL 29	-	X	-	-	X	X	-	-	X
SWEC 36	-	X	-	-	X	X	-	-	X
SWESP 44	-	-	-	-	X	X	-	-	X
SWEBR 45	-	-	-	-	X	X	-	-	X
SWEW 50	-	X	-	-	X	X	X	-	X
SWEW 52	X	X	-	-	X	X	X	-	-
SWEW 53	-	X	-	-	X	X	X	-	-
SWEW 57a	X	X	-	-	X	X	X	-	-
SWEW 61	-	X	-	-	X	-	X	-	-
SWEK 66	-	X	-	-	X	X	X	X	-
SWEK 71	-	X	-	-	X	-	X	-	-
SWEK 85	-	X	-	-	X	X	X	-	-
SWEK 90	X	X	-	-	X	X	X	-	-
SWEK 99	-	X	-	-	X	-	X	-	-
SWEE 130	X	X	-	-	X	X	X	X	X
SWEE 134	-	X	-	-	X	X	X	X	X
SWEE 138	-	X	-	-	X	X	X	X	X
SWECC 139	-	X	-	-	X	X	X	X	X
SWECC 142	-	X	-	-	X	X	X	-	X
SWE 150	-	X	-	-	X	X	X	X	X
SWE 151	-	X	-	-	X	-	X	-	X
SWE 153	-	X	-	-	X	X	X	X	X
SWE 154	-	X	-	-	X	X	X	X	X
SWE 156	-	X	-	-	X	X	X	X	X
SWE 158	-	X	-	-	X	X	X	-	X
SWE 159	X	X	-	-	X	X	X	-	X
SWEWI 11	X	-	X	X	X	X	X	-	X
SWERC 16	-	-	-	-	X	X	X	X	-
SWERC 19	X	X	-	X	X	X	X	-	-
SWERC 20	X	X	X	X	X	X	X	-	X
SWEAM 21	X	X	-	X	X	X	X	-	X
SWEAM 22	X	X	X	X	X	-	X	-	X
SWEHA 23	X	X	-	-	X	X	X	-	X
SWEHA 27	X	-	X	X	X	X	X	-	X
SWEHA 28	X	X	X	X	X	X	X	-	X
SWECC 32	X	-	X	X	X	-	X	-	X
SWEMA 35	X	X	X	X	X	X	X	-	X
SWEMA 39	X	X	X	X	X	X	X	-	X
SWERS 40	X	X	X	-	X	X	X	-	X
SWERS 41	X	X	-	X	X	X	X	-	X
SWERS 42	X	X	X	X	X	X	X	-	X
SWERS 43	X	X	-	-	X	X	X	-	X
SWEAM 49	-	X	-	-	X	X	X	X	X
SWEAM 50	X	-	-	-	X	X	X	-	X

UPPER GLACIOLACUSTRINE CLAYEY SILT

U.T.M. Easting	Reference Northing	Sample No.	Geochemistry Co ppm	Cr ppm	Cu ppm	Ni ppm	Pb ppm	Zn ppm	Fe ppm
357700	4654500	SWEL 11	9.0	46.0	30.0	24.0	12.0	81.0	2.5
357700	4654500	SWEL 14	11.0	44.0	30.0	26.0	15.0	83.0	2.9
357700	4654500	SWEL 15	14.0	76.0	37.0	40.0	12.0	104.0	3.9
361000	4683300	SWEBR 46	13.0	71.0	29.0	38.0	12.0	87.0	3.2
359700	4654600	SWEW 51	13.0	68.0	28.0	36.0	10.0	84.0	3.3
356300	4658300	SWEK 77	10.0	48.0	38.0	28.0	13.0	100.0	3.3
359800	4655900	SWEK 81	6.0	39.0	28.0	20.0	12.0	77.0	2.4
349700	4683700	SWEPC 111	12.0	82.0	29.0	39.0	18.0	88.0	3.6
348800	4682700	SWEPC 115	12.0	73.0	28.0	34.0	15.0	105.0	3.2
346900	4674300	SWEE 121	13.0	74.0	29.0	38.0	14.0	100.0	3.4
351300	4656000	SWECC 143	15.0	72.0	29.0	41.0	17.0	132.0	3.4
349700	4683700	SWE 161	8.0	50.0	22.0	23.0	12.0	49.0	2.1
371000	4652100	E89-01-01	13.0	73.0	32.0	37.0	12.0	81.0	3.6
371000	4652100	E89-01-03	13.0	73.0	29.0	35.0	10.0	85.0	3.6
363400	4660800	E89-02-24	9.0	48.0	28.0	26.0	10.0	63.0	2.6
357800	4655500	E89-03-02	13.0	70.0	32.0	38.0	12.0	87.0	3.4
337800	4653200	E89-05-02	8.0	54.0	29.0	26.0	-10.0	89.0	2.6
337800	4653200	E89-05-03	10.0	65.0	29.0	31.0	11.0	84.0	3.2
337500	4663800	E89-06-01	11.0	64.0	30.0	35.0	11.0	90.0	3.5
353900	4667300	E89-07-05	14.0	78.0	29.0	42.0	12.0	85.0	3.7
353900	4667300	E89-07-07	14.0	80.0	29.0	44.0	12.0	82.0	3.7
353900	4667300	E89-07-08	13.0	69.0	28.0	34.0	11.0	73.0	3.5
348300	4668500	E89-09-01	10.0	80.0	29.0	36.0	13.0	99.0	3.6
358100	4677300	E89-10-01	9.0	71.0	29.0	34.0	11.0	94.0	3.4
351300	4681400	E89-11-02	11.0	75.0	27.0	37.0	11.0	88.0	3.3
363500	4675900	E89-12-02	13.0	77.0	29.0	40.0	12.0	88.0	3.5
363500	4675900	E89-12-07	12.0	72.0	29.0	34.0	15.0	73.0	3.6
334300	4668700	SWERC 15	7.0	62.0	26.0	27.0	16.0	66.0	2.8

Sample No.	% Ca	Carbonate % Dol	Total	Ratio	Heavy Minerals %	Non. Mag.	Mag.
SWEL 11	4.3	22.0	26.3	0.2	0.6	0.0	12.5
SWEL 14	4.3	21.8	26.1	0.2	2.1	0.0	12.9
SWEL 15	5.9	5.8	11.7	1.0	2.6	0.0	7.3
SWEBR 46	3.0	13.1	16.1	0.2	1.2	0.0	12.5
SWEW 51	16.3	9.4	25.7	1.7	4.7	0.2	7.9
SWEK 77	12.1	8.9	21.0	1.4	2.9	0.1	6.0
SWEK 81	13.0	17.9	30.9	0.7	1.5	0.1	3.3
SWEPC 111	7.4	9.7	17.1	0.8	1.2	0.0	7.7
SWEPC 115	9.6	14.1	23.7	0.7	1.4	0.1	6.2
SWEE 121	10.0	11.1	21.1	0.9	1.3	0.0	7.3
SWECC 143	1.5	2.0	3.5	0.7	4.6	0.2	5.2
SWE 161	6.1	17.8	23.9	0.3	1.3	0.1	10.0
E89-01-01	14.6	8.0	22.6	1.8	4.4	0.1	8.8
E89-01-03	14.9	7.7	22.6	1.8	4.4	0.0	8.5
E89-02-24	19.6	14.1	33.7	1.4	0.0	0.0	0.0
E89-03-02	8.0	11.3	19.3	0.7	2.3	0.0	8.7
E89-05-02	17.3	13.5	20.8	1.3	3.0	0.1	7.8
E89-05-03	11.4	12.8	24.2	0.9	3.6	0.1	9.8
E89-06-01	10.3	12.0	22.3	0.9	2.8	0.0	9.8
E89-07-05	6.4	11.9	18.3	0.5	1.5	0.0	10.5
E89-07-07	6.8	11.7	18.5	0.6	1.5	0.0	10.3
E89-07-08	14.5	9.8	24.3	1.5	4.0	0.1	8.4
E89-09-01	9.6	11.5	21.1	0.8	1.3	0.0	9.1
E89-10-01	10.8	12.1	22.9	0.9	1.4	0.0	13.2
E89-11-02	11.0	12.3	23.3	0.9	1.5	0.0	11.1
E89-12-02	10.4	11.4	21.8	0.9	1.9	0.0	8.2
E89-12-07	14.2	9.8	24.0	1.5	4.2	0.1	9.9
SWERC 15	8.0	14.0	23.0	0.6	3.4	0.1	9.1

UPPER GLACIOLACUSTRINE CLAYEY SILT (CON'T)

Sample No.	Garnet %Purple	%Red	Total	Ratio	Grain Size % Cl	% Si	% Ss
SWEL 11	nd	nd	nd	nd	8.0	39.0	53.0
SWEL 14	3.0	0.7	3.7	4.3	15.0	76.0	9.0
SWEL 15	7.0	0.7	7.7	10.0	44.0	44.0	12.0
SWEBR 46	2.7	1.0	3.7	2.7	57.0	43.0	6.0
SWEW 51	5.7	1.0	6.7	5.7	40.0	31.0	29.0
SWEK 77	6.3	5.0	11.3	1.3	11.0	51.0	38.0
SWEK 81	3.7	1.7	5.4	2.2	14.0	67.0	19.0
SWEPC 111	2.7	1.0	3.7	2.7	72.0	25.0	3.0
SWEPC 115	5.0	2.7	7.7	1.8	38.0	33.0	29.0
SWEE 121	3.7	1.3	5.0	2.8	49.0	3.0	18.0
SWECC 143	7.7	5.7	13.4	1.4	44.0	36.0	20.0
SWE 161	nd	nd	nd	nd	19.0	26.0	55.0
E89-01-01	7.4	2.5	9.9	3.0	49.5	39.0	11.5
E89-01-03	nd	nd	nd	nd	48.5	38.5	13.0
E89-02-24	nd	nd	nd	nd	34.0	62.0	4.0
E89-03-02	3.3	2.4	5.7	1.4	37.5	53.5	9.0
E89-05-02	nd	nd	nd	nd	21.0	48.0	31.0
E89-05-03	nd	nd	nd	nd	37.5	47.5	15.0
E89-06-01	4.3	3.2	7.5	1.3	39.0	47.0	14.0
E89-07-05	nd	nd	nd	nd	41.0	44.5	14.5
E89-07-07	nd	nd	nd	nd	43.5	42.5	14.0
E89-07-08	nd	nd	nd	nd	43.0	41.0	16.0
E89-09-01	2.9	1.5	4.4	1.9	44.5	37.5	18.0
E89-10-01	1.0	0.7	1.7	1.4	40.0	44.0	16.0
E89-11-02	2.0	2.3	4.3	0.9	42.0	42.0	16.0
E89-12-02	nd	nd	nd	nd	42.0	44.0	14.0
E89-12-07	3.9	3.0	6.9	0.7	61.0	31.0	8.0
SWERC 15	6.0	1.0	10.0	0.8	44.0	51.0	5.0

Sample No.	Amphibole	Calcite	Chlorite	Dolomite	Feldspar	Clay Minerology Illite	Kaolinite	Quartz	Smectite	Vermic.
SWEL 11	-	-	X	-	-	X	-	-	-	X
SWEL 14	-	-	X	-	-	X	X	-	-	X
SWEL 15	-	X	X	-	-	X	X	-	-	X
SWEBR 46	-	-	X	-	-	X	X	-	-	-
SWEW 51	-	X	X	-	-	X	-	X	-	-
SWEK 77	-	-	X	-	-	X	-	X	-	-
SWEK 81	-	-	X	-	-	X	X	X	-	-
SWEPC 111	-	X	X	-	-	X	X	X	-	-
SWEPC 115	-	X	X	-	-	X	X	X	X	-
SWEE 121	-	X	X	-	-	X	X	X	X	-
SWECC 143	-	-	X	-	-	X	X	X	-	X
SWE 161	-	X	X	X	-	X	X	X	-	X
E89-01-01	-	X	X	X	X	X	-	X	-	-
E89-01-03	X	X	X	X	X	X	X	X	-	-
E89-02-24	X	X	X	X	X	X	-	X	-	-
E89-03-02	X	X	X	X	X	X	X	X	-	-
E89-05-02	-	X	X	X	X	X	-	X	-	-
E89-05-03	-	X	X	X	X	X	X	X	-	-
E89-06-01	X	X	X	X	X	X	X	X	-	-
E89-07-05	X	X	X	X	X	X	X	X	-	-
E89-07-07	X	X	X	X	X	X	X	X	-	-
E89-07-08	X	X	X	X	X	X	-	X	-	-
E89-09-01	-	X	X	X	X	X	X	X	-	-
E89-10-01	-	X	X	X	X	X	X	X	-	-
E89-11-02	-	X	X	X	X	X	-	X	-	-
E89-12-02	X	X	X	X	X	X	X	X	-	-
E89-12-07	X	X	X	X	X	X	-	X	-	-
SWERC 15	-	X	X	X	X	X	X	X	-	-

UPPER GLACIOLACUSTRINE SILTY SAND

U.T.M. Easting	Reference Northing	Sample No.	Geochemistry Co ppm	Cr ppm	Cu ppm	Ni ppm	Pb ppm	Zn ppm	Fe ppm
347100	4654700	SWECC 31	10.0	84.0	24.0	31.0	17.0	88.0	-5.0
346500	4651700	SWECC 146	12.0	57.0	21.0	27.0	34.0	149.0	-5.0
337800	4652800	SWEHA 24	10.0	52.0	36.0	27.0	10.0	96.0	-5.0
341500	4649300	SWECH 2	10.0	54.0	34.0	26.0	17.0	77.0	-5.0
340700	4649300	SWECH 6	8.0	47.0	30.0	24.0	14.0	73.0	-5.0
340700	4649300	SWECH 8	16.0	60.0	32.0	36.0	13.0	74.0	-5.0

Sample No.	Carbonate %Ca	%Dol	Total	Ratio	Heavy Minerals %	Non. Mags	Mag.
SWECC 31	1.0	1.0	2.0	1.0	2.1	0.2	3.6
SWECC 146	0.3	0.9	1.2	0.4	3.9	0.4	3.0
SWEHA 24	12.0	12.0	24.0	1.0	3.8	0.1	5.5
SWECH 2	17.0	14.0	32.0	1.2	4.0	0.1	8.5
SWECH 6	17.0	15.0	33.0	1.1	4.1	0.1	11.3
SWECH 8	12.0	11.0	24.0	1.1	5.3	0.2	10.3

Sample No.	Garnet %Purple	%Red	Total	Ratio	Grain Size % Cl	% Si	% Ss
SWECC 31	4.5	7.0	11.5	0.6	32.0	34.0	34.0
SWECC 146	nd	nd	nd	nd	8.0	17.0	75.0
SWEHA 24	2.5	4.5	7.0	0.6	14.0	53.0	33.0
SWECH 2	3.0	7.0	10.0	0.4	15.0	55.0	30.0
SWECH 6	5.0	2.0	7.0	2.5	12.0	57.0	31.0
SWECH 8	4.0	4.0	8.0	1.0	14.0	28.0	58.0

Sample No.	Clay Minerology Amphibole	Calcite	Chlorite	Dolomite	Feldspar	Illite	Kaolinite	Quartz	Smectite	Vermic.
SWECC 31	-	X	-	X	X	X	X	X	-	X
SWECC 146	-	-	X	-	-	X	-	-	-	-
SWEHA 24	-	X	X	-	X	X	X	X	-	X
SWECH 2	-	X	X	X	X	X	X	X	-	X
SWECH 6	-	X	X	X	X	X	X	X	-	-
SWECH 8	-	X	X	X	X	X	X	X	-	-

TAVISTOCK TILL; RECESSIONAL MORAINE

U.T.M. Easting	Reference Northing	Sample No.	Geochemistry Co (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)
374700	4675100	SWEC 34	20.00	79.00	27.00	41.00	18.00	148.00	-5.00
356500	4680600	SWEBR 48	12.00	85.00	31.00	43.00	21.00	140.00	-5.00
374000	4665300	SWE 152	13.00	67.00	42.00	52.00	19.00	140.00	-5.00
339300	4659600	SWEHA 29	10.00	63.00	25.00	29.00	13.00	73.00	-5.00
341500	4648100	SWEHA 30	11.00	63.00	25.00	30.00	14.00	83.00	-5.00
342300	4669400	SWEMA 36	12.00	67.00	28.00	31.00	11.00	78.00	-5.00
341700	4674100	SWEMA 37	13.00	73.00	28.00	34.00	13.00	75.00	-5.00
339900	4672900	SWEMA 38	13.00	75.00	28.00	37.00	14.00	86.00	-5.00

Sample No.	% Ca	Carbonate % Dol	Total	Ratio	Heavy Minerals %	Non. Mag.	Mag.
SWEC 34	0.8	1.0	1.8	0.8	1.3	0.1	2.0
SWEBR 48	0.7	1.1	1.8	0.6	1.3	0.1	6.1
SWE 152	1.5	7.0	8.5	0.2	1.2	0.1	5.6
SWEHA 29	4.0	16.0	20.0	0.2	1.4	0.1	5.9
SWEHA 30	7.0	16.0	23.0	0.5	1.6	0.1	12.8
SWEMA 36	14.0	12.0	26.0	1.2	1.6	0.1	8.6
SWEMA 37	4.0	14.0	18.0	0.3	1.7	0.0	6.4
SWEMA 38	7.0	12.0	19.0	0.5	1.3	0.1	5.4

Sample No.	%Purple	Garnet %Red	Total	Ratio	Grain Size % Cl	% Si	% Ss
SWEC 34	nd	nd	nd	nd	25.0	20.0	55.0
SWEBR 48	nd	nd	nd	nd	39.0	40.0	21.0
SWE 152	nd	nd	nd	nd	36.0	36.0	28.0
SWEHA 29	3.0	4.0	7.0	0.8	23.0	46.0	31.0
SWEHA 30	2.5	3.5	6.0	0.7	22.0	48.0	30.0
SWEMA 36	1.5	2.0	3.5	0.8	33.0	44.0	23.0
SWEMA 37	1.5	3.5	5.0	0.4	30.0	54.0	23.0
SWEMA 38	2.5	4.0	6.5	0.6	30.0	42.0	27.0

Sample No.	Clay Minerology Calcite	Chlorite	Dolomite	Feldspar	Illite	Kaolinite	Quartz	Smectite	Vermic.
SWEC 34	-	-	-	-	X	X	-	-	X
SWEBR 48	-	X	-	-	X	X	X	-	X
SWE 152	-	X	-	-	X	X	X	-	X
SWEHA 29	X	X	X	X	X	X	X	-	X
SWEHA 30	X	X	X	X	X	X	X	-	X
SWEMA 36	X	X	X	X	X	X	X	-	-
SWEMA 37	X	X	X	X	X	X	X	-	X
SWEMA 38	X	X	X	X	X	X	X	-	X

TAVISTOCK TILL

U.T.M. Easting	Reference Northing	Sample No.	Geochemistry Co (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)	% Ca	Carbonate % Dol	Total	Ratio
357700	4654400	SWEL 12	2.7	62.0	28.0	33.0	10.0	77.0	-5.0	16.50	8.50	25.00	1.9
357700	4654500	SWEL 16	14.0	67.0	38.0	37.0	25.0	136.0	-5.0	4.40	8.20	12.60	0.5
359700	4654600	SWEL 19	12.0	63.0	31.0	35.0	12.0	95.0	-5.0	12.40	10.30	22.70	1.2
359700	4654600	SWEL 21	13.0	65.0	27.0	35.0	12.0	79.0	-5.0	15.20	12.30	27.50	1.2
375400	4675800	SWEC 41	14.0	85.0	43.0	52.0	17.0	154.0	-5.0	0.70	0.80	1.50	0.8
361000	4683300	SWEBR 47	14.0	78.0	29.0	42.0	15.0	100.0	-5.0	9.90	12.70	22.60	0.8
359800	4659900	SWEK 80	6.0	31.0	28.0	17.0	10.0	80.0	-5.0	13.90	15.80	29.70	0.9
363500	4660700	SWEK 94	13.0	71.0	29.0	41.0	22.0	96.0	-5.0	9.90	12.60	22.50	0.8
349700	4683700	SWEPC 110	15.0	78.0	27.0	40.0	21.0	85.0	-5.0	9.40	15.20	24.60	0.6
348800	4682600	SWEPC 116	14.0	74.0	27.0	40.0	16.0	105.0	-5.0	10.60	13.10	23.70	0.8
346900	4674300	SWEE 121	13.0	74.0	29.0	38.0	14.0	100.0	-5.0	10.00	11.00	21.00	0.9
343000	4653800	E89-04-09	8.0	34.0	26.0	18.0	0.0	57.0	-5.0	19.70	17.80	37.50	1.1
337800	4653200	E89-05-04	12.0	63.0	28.0	32.0	11.0	75.0	-5.0	14.80	13.50	28.30	1.1
337800	4653200	E89-05-05	12.0	66.0	27.0	35.0	10.0	75.0	-5.0	14.50	13.30	27.80	1.1
337500	4663800	E89-06-03	11.0	61.0	28.0	34.0	11.0	73.0	-5.0	17.80	11.90	29.70	1.5
337500	4663800	E89-06-04	12.0	65.0	27.0	35.0	11.0	75.0	-5.0	15.40	12.50	27.90	1.2
353900	4667300	E89-07-09	12.0	67.0	28.0	38.0	11.0	76.0	-5.0	6.87	15.40	22.30	0.4
353900	4667300	E89-07-18	12.0	63.0	28.0	34.0	10.0	79.0	-5.0	13.80	15.30	29.10	0.9
361900	4663400	E89-08-06	11.0	50.0	29.0	28.0	10.0	70.0	-5.0	21.10	13.00	34.00	1.7
361900	4663400	E89-08-09	11.0	54.0	34.0	30.0	12.0	77.0	-5.0	19.50	11.50	31.00	1.7
348300	4668500	E89-09-02	14.0	75.0	27.0	40.0	12.0	81.0	-5.0	9.71	12.20	21.90	0.8
348300	4668500	E89-09-05	14.0	72.0	29.0	36.0	12.0	81.0	-5.0	10.20	12.10	22.30	0.8
348300	4668500	E89-09-07	13.0	72.0	28.0	36.0	12.0	77.0	-5.0	6.98	14.80	21.80	0.5
348300	4668500	E89-09-15	10.0	49.0	29.0	27.0	11.0	72.0	-5.0	17.40	15.50	32.90	1.1
358100	4677300	E89-10-04	11.0	57.0	30.0	36.0	13.0	92.0	-5.0	7.85	17.60	25.50	0.4
351300	4681400	E89-11-04	14.0	78.0	26.0	37.0	11.0	78.0	-5.0	10.00	12.90	22.90	0.8
351300	4681400	E89-11-10	10.0	54.0	24.0	27.0	0.0	59.0	-5.0	17.70	17.00	35.00	1.0
351300	4681400	E89-11-11	10.0	57.0	26.0	30.0	10.0	65.0	-5.0	17.20	17.70	34.90	1.0
363500	4675900	E89-12-02	13.0	77.0	29.0	40.0	12.0	88.0	-5.0	10.00	11.00	22.00	0.9
363500	4660700	BONDI PIT	17.0	64.0	29.0	40.0	12.0	90.0	-5.0	11.80	11.80	23.60	1.0
359700	4654600	GOS SOUTH	13.0	58.0	27.0	32.0	12.0	79.0	-5.0	15.30	12.00	27.50	1.3
341500	4649300	SWECH 3	10.0	52.0	29.0	30.0	13.0	80.0	-5.0	14.00	15.00	29.00	0.9
341500	4649300	SWEHA 5	12.0	58.0	30.0	39.0	12.0	86.0	-5.0	6.00	17.00	23.00	0.4
340700	4649300	SWECH 9	10.0	46.0	26.0	25.0	13.0	60.0	-5.0	16.00	17.00	33.00	1.0
334300	4668700	SWERC 14	11.0	69.0	26.0	28.0	12.0	70.0	-5.0	11.00	18.00	28.50	0.6
327600	4662100	SWEAM 45	13.0	60.0	23.0	32.0	0.0	59.0	-5.0	10.00	21.00	30.00	0.5

TAVISTOCK TILL (CON'T)

Sample	Heavy	Minerals			Garnet				Grain	Size
No.	%	Non. Mag.	Mag.	%Purple	%Red	Total	Ratio	% Cl	% Si	% Ss
SWEL 12	4.9	0.1	8.6	7.3	4.0	11.3	1.8	35.0	51.0	14.0
SWEL 16	2.5	0.1	6.7	7.0	4.0	11.0	1.8	22.0	52.0	26.0
SWEL 19	3.5	0.1	8.4	5.7	1.7	7.4	3.4	26.0	54.0	20.0
SWEL 21	3.8	0.1	8.3	4.7	3.0	7.7	1.6	26.0	48.0	12.0
SWEC 41	1.9	0.1	4.3	2.3	1.7	4.0	1.4	28.0	41.0	31.0
SWEBR 47	1.6	0.1	8.2	3.4	1.4	4.8	2.4	42.0	36.0	22.0
SWEK 80	1.8	0.1	3.7	4.3	0.7	5.0	6.1	5.0	65.0	30.0
SWEK 94	3.1	0.1	7.8	5.7	1.3	7.0	4.4	26.0	41.0	33.0
SWEPC 110	1.7	0.1	11.6	3.0	0.7	3.7	4.3	29.0	40.0	31.0
SWEPC 116	1.5	0.0	8.7	2.3	1.7	4.0	1.4	39.0	44.0	17.0
SWEE 121	1.0	0.0	7.0	nd	nd	nd	nd	35.0	47.0	18.0
E89-04-09	1.6	0.0	5.7	nd	nd	nd	nd	5.0	73.0	22.0
E89-05-04	3.7	0.1	10.0	nd	nd	nd	nd	27.5	47.5	25.0
E89-05-05	3.4	0.1	9.3	nd	nd	nd	nd	27.5	42.5	30.0
E89-06-03	3.9	0.1	8.6	nd	nd	nd	nd	37.5	47.5	15.0
E89-06-04	3.4	0.1	9.3	5.0	2.0	7.0	2.5	33.0	45.0	22.0
E89-07-09	1.8	0.0	9.5	2.4	0.5	2.9	4.8	31.0	54.0	15.0
E89-07-18	4.1	0.1	9.1	nd	nd	nd	nd	25.0	52.0	22.0
E89-08-06	3.2	0.0	3.1	nd	nd	nd	nd	21.0	69.0	10.0
E89-08-09	4.5	0.2	7.0	nd	nd	nd	nd	17.0	51.5	31.5
E89-09-02	1.6	0.0	8.7	3.4	2.0	5.4	1.7	41.0	41.0	18.0
E89-09-05	2.8	0.1	9.8	nd	nd	nd	nd	43.0	45.0	12.0
E89-09-07	2.4	0.1	8.9	nd	nd	nd	nd	33.5	55.5	11.0
E89-09-15	4.4	0.2	8.4	nd	nd	nd	nd	12.5	52.0	35.5
E89-10-04	1.8	0.1	9.4	nd	nd	nd	nd	18.5	56.5	25.0
E89-11-04	1.6	0.0	6.8	4.7	0.3	5.0	15.7	54.0	28.0	18.0
E89-11-10	2.5	0.0	11.0	nd	nd	nd	nd	20.0	66.0	14.0
E89-11-11	3.1	0.1	9.9	nd	nd	nd	nd	15.0	47.0	38.0
E89-12-02	2.0	0.0	8.0	3.0	0.4	3.4	8.5	42.0	42.0	16.0
BONDI PIT	4.3	0.1	8.4	7.7	2.3	10.0	3.3	20.0	51.0	29.0
GOS SOUTH	4.1	0.1	10.9	5.7	0.7	6.4	8.1	28.0	47.0	25.0
SWECH 3	3.0	0.1	7.0	2.5	5.5	8.0	0.5	17.0	53.0	30.0
SWEHA 5	2.0	0.0	11.0	2.0	3.0	5.0	0.7	26.0	60.0	14.0
SWECH 9	4.0	0.2	7.0	nd	nd	nd	nd	18.0	72.0	10.0
SWERC 14	3.0	0.1	9.0	2.0	6.0	8.0	0.3	30.0	50.0	20.0
SWEAM 45	2.0	0.1	12.0	nd	nd	nd	nd	25.0	45.0	30.0

Sample				Clay	Minerology				
No.	Amphibole	Calcite	Chlorite	Dolomite	Feldspar	Illite	Kaolinite	Quartz	Smectite	Vermic.
SWEL 12	-	X	X	X	-	X	X	-	-	-
SWEL 16	-	-	X	-	-	X	X	-	-	X
SWEL 19	-	X	X	-	-	X	-	-	-	-
SWEL 21	-	X	X	X	-	X	-	-	-	-
SWEC 41	-	-	-	-	-	X	X	-	-	X
SWEBR 47	-	X	X	-	-	X	X	-	-	-
SWEK 80	-	-	X	-	-	X	X	X	-	-
SWEK 94	-	X	X	-	-	X	X	X	-	-
SWEPC 110	-	X	X	-	-	X	-	X	-	-
SWEPC 116	-	X	X	-	-	X	-	X	X	-
SWEE 121	-	X	X	X	-	X	X	X	X	-
E89-04-09	X	X	X	X	X	X	-	X	-	-
E89-05-04	X	X	X	X	X	X	X	X	-	-
E89-05-05	X	X	X	X	X	X	-	X	-	-
E89-06-03	X	X	X	X	X	X	-	X	-	-
E89-06-04	X	X	X	X	X	X	-	X	-	-
E89-07-09	X	X	X	X	X	X	X	X	-	-
E89-07-18	X	X	X	X	X	X	X	X	-	-
E89-08-06	-	X	X	X	X	X	-	X	-	-
E89-08-09	X	X	X	X	X	X	X	X	-	-
E89-09-02	X	X	X	X	X	X	X	X	-	-
E89-09-05	X	X	X	X	X	X	-	X	-	-
E89-09-07	X	X	X	X	X	X	-	X	-	-
E89-09-15	X	X	X	X	X	X	-	X	-	-
E89-10-04	X	X	X	X	X	X	-	X	-	-
E89-11-04	X	X	X	X	X	X	X	X	-	-
E89-11-10	X	X	X	X	X	X	-	X	-	-
E89-11-11	-	X	X	X	X	X	-	X	-	-
E89-12-02	X	X	X	X	X	X	X	X	-	-
BONDI PIT	-	X	X	X	-	X	X	X	X	-
GOS SOUTH	-	X	X	X	-	X	X	X	X	-
SWECH 3	-	X	X	X	X	X	-	X	-	-
SWEHA 5	-	X	X	X	X	X	X	X	-	-
SWECH 9	-	X	X	X	X	X	X	X	-	-
SWERC 14	-	X	X	X	X	X	X	X	-	-
SWEAM 45	-	X	X	X	X	X	X	X	-	-

PORT STANLEY- TAVISTOCK HYBRID TILL

U.T.M. Easting	Reference Northing	Sample No.	Co (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)
			Geochemistry						
362500	4629700	SWEPI 107	19.0	83.0	34.0	46.0	22.0	115.0	-5.0
361800	4626500	SWEPI 109	23.0	84.0	33.0	46.0	22.0	105.0	-5.0

Sample No.	% Ca	Carbonate % Dol	Total	Ratio	Heavy Minerals %	Non.Mag.	Mag.
SWEPI 107	0.6	1.8	2.0	0.5	4.3	0.1	2.6
SWEPI 109	1.7	15.2	3.5	0.9	5.6	0.1	4.6

Sample No.	% Purple	Garnets %Red	Total	Ratio	Grain Size % Cl	% Si	% Ss
SWEPI 107	7.7	2.0	9.7	3.8	37.0	49.5	13.5
SWEPI 109	7.0	2.0	9.0	3.5	38.0	47.5	14.5

Sample No.	Amphibole	Calcite	Chlorite	Dolomite	Feldspar	Illite	Kaolinite	Quartz	Smectite	Vermic.
					Clay Minerology					
SWEPI 107	-	-	X	-	-	X	X	X	X	-
SWEPI 109	-	-	X	-	-	X	-	-	X	-

LOWER GLACIOLACUSTRINE CLAYEY SILT

U.T.M. Easting	Reference Northing	Sample No.	Co (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)
			Geochemistry						
357800	4655500	E89-03-05	12.0	59.0	29.0	30.0	12.0	72.0	-5.0
337800	4653200	E89-05-10	12.0	61.0	27.0	32.0	11.0	71.0	-5.0
353900	4667300	E89-07-18	12.0	63.0	28.0	34.0	10.0	79.0	-5.0
334300	4668700	SWERC 13	9.0	56.0	22.0	30.0	14.0	59.0	-5.0

Sample No.	% Ca	Carbonate % Dol	Total	Ratio	Heavy Minerals %	Non.Mag.	Mag.
E89-03-05	18.9	9.5	28.4	2.0	4.8	0.2	9.4
E89-05-10	16.4	8.3	28.8	2.0	5.1	0.1	12.0
E89-07-18	13.8	15.3	29.1	0.9	4.1	0.1	9.1
SWERC 13	13.8	18.2	32.0	0.8	2.1	0.0	10.0

Sample No.	%Purple	Garnet %Red	Total	Ratio	Grain Size % Cl	% Si	% Ss
E89-03-05	6.0	2.0	8.0	3.0	39.0	55.0	6.0
E89-05-10	7.0	5.0	12.0	1.4	40.0	54.5	5.5
E89-07-18	6.0	6.0	12.0	1.0	25.0	53.0	22.0
SWERC 13	1.0	3.0	4.0	0.3	36.0	48.0	16.0

Sample No.	Amphibole	Calcite	Chlorite	Dolomite	Feldspar	Illite	Kaolinite	Quartz	Smectite	Vermic.
					Clay Minerology					
E89-03-05	X	X	X	X	X	X	-	X	-	-
E89-05-10	X	X	X	X	X	X	-	X	-	-
E89-07-18	X	X	X	X	X	X	X	X	-	-
SWERC 13	-	X	X	X	X	X	X	X	-	-

CATFISH CREEK TILL

U.T.M. Easting	Reference Northing	Sample No.	Co (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)
			Geochemistry						
371000	4652100	E89-01-07	11.0	55.0	28.0	25.0	11.0	66.0	-5.0
357800	4655500	E89-03-08	7.0	34.0	27.0	21.0	-10.0	63.0	-5.0
343000	4653800	E89-04-11	6.0	29.0	20.0	16.0	-10.0	47.0	-5.0
337800	4653200	E89-05-11	-5.0	13.0	6.0	8.0	-10.0	23.0	-5.0
337500	4663800	E89-06-10	-5.0	22.0	11.0	13.0	10.0	28.0	-5.0
353900	4667300	E89-07-19	12.0	57.0	33.0	33.0	12.0	79.0	-5.0
353900	4667300	E89-07-22	10.0	60.0	31.0	34.0	11.0	91.0	-5.0
361900	4663400	E89-08-10	6.0	48.0	22.0	21.0	-10.0	65.0	-5.0
348300	4668500	E89-09-18	9.0	44.0	29.0	25.0	12.0	85.0	-5.0
358100	4677300	E89-10-13	12.0	65.0	26.0	37.0	10.0	76.0	-5.0
351300	4681400	E89-11-13	10.0	61.0	26.0	29.0	11.0	71.0	-5.0
363500	4675900	E89-12-08	-5.0	26.0	14.0	14.0	-10.0	42.0	-5.0
334300	4668700	SWERC 12	10.0	51.0	24.0	30.0	18.0	62.0	-5.0

Sample No.	% Ca	% Dol	Total	Ratio	%	Non. Mag.	Mag.
	Carbonate				Heavy Minerals		
E89-01-07	20.3	10.8	31.1	2.0	5.0	0.2	9.6
E89-03-08	25.0	19.5	44.5	1.3	4.6	0.3	6.2
E89-04-11	19.0	39.2	58.2	0.5	9.1	0.4	4.2
E89-05-11	46.9	36.9	83.8	1.3	0.7	0.0	9.1
E89-06-10	34.8	43.6	78.4	0.8	1.5	0.0	5.0
E89-07-19	20.2	11.3	31.5	1.8	4.7	0.3	8.0
E89-07-22	39.6	12.6	52.2	3.1	2.7	0.0	12.5
E89-08-10	39.4	24.3	63.7	1.6	5.0	0.2	5.9
E89-09-18	22.5	15.8	38.3	1.4	4.8	0.3	8.8
E89-10-13	13.7	16.1	29.8	0.9	2.9	0.2	9.5
E89-11-13	29.6	12.8	42.4	2.3	4.4	0.1	7.8
E89-12-08	54.4	16.2	70.6	3.4	4.5	0.1	12.3
SWERC 12	17.8	22.4	40.2	0.8	3.2	0.3	9.1

Sample No.	%Purple	%Red	Total	Ratio	% Cl	% Si	% Ss
	Garnet				Grain Size		
E89-01-07	4.3	4.7	9.0	0.9	18.0	46.0	36.0
E89-03-08	4.3	8.0	12.3	0.5	12.0	42.0	46.0
E89-04-11	3.0	3.0	6.0	1.0	9.0	47.5	43.5
E89-05-11	4.7	5.3	10.0	0.9	19.5	59.5	21.0
E89-06-10	7.3	4.3	11.6	1.7	18.5	59.0	22.5
E89-07-19	5.0	5.3	10.3	0.9	18.0	41.0	41.0
E89-07-22	0.7	1.7	2.4	0.4	17.5	40.0	42.5
E89-08-10	5.3	7.7	13.0	0.7	12.0	38.5	49.5
E89-09-18	7.3	7.7	15.0	0.9	10.0	39.0	51.0
E89-10-13	5.3	3.3	8.6	1.6	18.0	37.5	44.5
E89-11-13	5.3	6.7	12.0	0.8	16.0	39.0	44.0
E89-12-08	5.3	7.3	12.6	0.7	31.0	43.0	26.0
SWERC 12	2.5	5.0	7.5	0.5	10.0	46.0	54.0

Sample No.	Amphibole	Calcite	Chlorite	Dolomite	Feldspar	Illite	Kaolinite	Quartz	Smectite	Vermic.
					Clay Minerals					
E89-01-07	X	X	X	X	X	X	-	X	-	-
E89-03-08	X	X	X	X	X	X	-	X	-	-
E89-04-11	-	X	X	X	X	X	X	X	-	-
E89-05-11	-	X	X	X	-	X	-	X	-	-
E89-06-10	-	X	-	X	X	X	X	X	-	-
E89-07-19	-	X	X	X	X	X	-	X	-	-
E89-07-22	-	X	-	X	X	X	X	X	-	-
E89-08-10	-	X	X	X	X	X	-	X	-	-
E89-09-18	-	X	X	X	X	X	-	X	-	-
E89-10-13	-	X	X	X	X	X	-	X	-	-
E89-11-13	X	X	X	X	X	X	X	X	-	-
E89-12-08	-	X	X	X	X	X	-	X	-	-
SWERC 12	-	X	X	X	X	X	X	X	-	-

GLACIOFLUVIAL SAND

U.T.M. Reference Easting	Northing	Sample No.	Grain Size % Cl	% Si	% Ss	Heavy Minerals %	Non. Mag.	Mag.
359700	4654600	SWEL 20	2.0	27.0	71.0	2.4	0.2	4.7
362400	4666600	SWEW 58	3.0	2.0	95.0	2.2	0.1	3.1
364200	4664700	SWEK 63	2.0	2.0	96.0	2.4	0.2	7.2
359800	4655900	SWEK 83	6.0	11.0	83.0	1.3	0.1	2.5
363500	4660700	SWEK 96	2.0	2.0	96.0	2.0	0.1	5.7
363500	4660700	SWEK 97	1.0	5.0	94.0	14.3	0.7	24.1
363400	4660800	E89-02-07	3.5	7.5	89.0	8.4	0.5	9.6
363400	4660800	E89-02-18	6.0	12.0	82.0	10.5	0.5	15.0
363400	4660800	E89-02-25	2.5	23.0	74.5	0.4	0.0	4.6
363400	4660800	E89-02-26	2.0	4.5	93.5	5.2	0.3	3.8
343000	4653800	E89-04-03	1.5	3.5	95.0	4.1	0.3	4.0
343000	4653800	E89-04-05	1.5	3.0	95.5	5.9	0.3	6.5
343000	4653800	E89-04-06	2.0	18.0	80.0	0.7	0.0	3.1
343000	4653800	E89-04-10	2.0	3.5	94.5	6.1	0.3	7.3
353900	4667300	E89-07-16	3.0	8.0	89.0	4.3	0.4	4.9
361900	4663400	E89-08-02	2.5	20.5	77.0	3.7	0.3	4.8
361900	4663400	E89-08-03	6.0	27.0	67.0	3.4	0.3	5.1
361900	4663400	E89-08-04	1.0	6.0	93.0	3.0	0.2	4.6
361900	4663400	E89-08-05	1.0	9.5	89.5	1.6	0.1	3.8
348300	4668500	E89-09-11	4.0	13.0	83.0	4.5	0.4	4.5
358100	4677300	E89-10-12	3.0	5.0	92.0	2.5	0.2	4.6
363500	4660700	BONDI P 1	3.0	12.0	85.0	4.9	0.2	8.1
363500	4660700	BONDI P 3	2.0	4.0	94.0	0.7	0.0	5.6
359700	4654600	GOS STH 1	2.0	4.0	94.0	7.9	0.4	7.9
359700	4654600	GOS STH 4	2.0	21.0	77.0	1.4	0.1	7.1
357700	4654500	SWEL 10	7.0	23.0	70.0	0.7	0.0	8.6
359700	4654600	SWEL 18	5.0	8.0	87.0	1.9	0.1	3.1
368400	4654300	SWEL 22	8.0	13.0	79.0	3.6	0.3	5.7
366600	4661000	SWEL 30	6.0	13.0	81.0	0.9	0.1	3.2
366600	4661000	SWEL 32	13.0	13.0	74.0	9.5	0.4	2.1
357600	4662600	SWEK 68	13.0	45.0	42.0	4.1	0.2	3.6
362800	4659200	SWEK 73	2.0	3.0	95.0	3.5	0.1	8.2
361100	4657200	SWEK 79	10.0	18.0	72.0	4.1	0.2	6.7
362800	4657800	SWEK 89	4.0	4.0	92.0	4.5	0.3	8.7
363200	4665800	SWEK 91	5.0	11.0	84.0	3.6	0.3	9.0
363500	4660700	SWEK 95	4.0	2.0	94.0	9.9	0.5	14.0
363800	4656500	SWEK 104	2.0	3.0	95.0	20.2	0.6	13.2
363800	4656500	SWEK 105	3.0	2.0	95.0	10.5	0.3	20.5
363800	4656500	SWEK 106	3.0	1.0	96.0	4.1	0.1	22.1
346900	4674300	SWEE 119	2.0	4.0	94.0	2.7	0.2	3.5
365600	4661200	SWE 149	6.0	8.0	86.0	7.2	0.4	20.0
371600	4663300	SWE 160	3.0	3.0	94.0	1.8	0.1	7.5
363400	4660800	E89-02-01	5.0	5.0	90.0	5.7	0.5	7.1
343200	4650000	SWEHA 1	5.0	54.0	41.0	0.9	0.1	4.1
341500	4649300	SWECH 4	2.0	18.0	80.0	3.2	0.3	5.8
340700	4649300	SWECH 7	2.0	8.0	90.0	0.8	0.1	3.0
340700	4649300	SWECH 10	2.0	59.0	39.0	0.9	0.0	4.8
327500	4677100	SWERC 18	8.0	51.0	41.0	1.2	0.1	3.7
340300	4651600	SWEHA 25	4.0	24.0	72.0	2.2	0.2	1.1
334400	4660200	SWEAM 48	8.0	29.0	63.0	2.3	0.2	2.2
363800	4660800	SWEK 54	2.0	3.0	95.0	0.7	0.1	6.1

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial / **Conversion from Imperial to SI**

SI Unit	*Multiplied By*	*Gives*	*Imperial Unit*	*Multiplied By*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	**20.116 8**	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^3	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	t
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy) ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

***Note:** Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

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Ontario
Ministry of Northern Development and Mines

Mines and Minerals Division
Ontario Geological Survey

Map P.3252

QUATERNARY GEOLOGY

ESSEX COUNTY AREA (EAST HALF)

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 40G/10, 40G/15, 40J/2, 40J/7

LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT

10 **Cultural Features**: quarries, landfills, mine waste, aggregate excavations and sewage lagoons

9 **Modern Alluvium**: unsubdivided clay, silt, san and muck

8 **Bog deposits**: peat and muck

7 **Modern Beach Deposits**: sand, gravel and cobbles

6 **Eolian Deposits**: fine to medium sand

PLEISTOCENE

5 **Lacustrine Beach, Bar and near shore deposits**: sand with minor gravel
5a Lacustrine sandy silt

4 **Glaciolacustrine Beach, Bar and near shore deposits**: sand with minor gravel

3 **Glaciolacustrine Silty Clay**
3a Glaciolacustrine: silty clay deposits interbedded with sand and sandy silt beds
3b Glaciolacustrine: silty clay deposits overlain by a thin sand cover
3c Glaciolacustrine: silty clay deposits overlain by thin, discontinuous sand and gravel deposits

2 **Clayey Silt Till**
2a Clayey silt till: related to recessional moraine and may be sandier material

PALEOZOIC
DEVONIAN

1 **Bedrock Outcrop**: bioclastic limestone; massive, brown, bituminous

SYMBOLS

- Glacial striae
- Intersecting glacial striae: 1 indicates the oldest, 3 the youngest
- Dunes
- Iceberg keel marks
- Abandoned shore bluff
- Abandoned beach ridge
- Abandoned channel
- Moraine crest
- Esker
- Active sand and/or gravel pit
- Active quarry
- Geological boundary

SOURCES OF INFORMATION

Base maps derived from maps 40J/2 (Essex), 40J/7 (Belle River), 40G/15 (Pelee Island) and 40G/10 (Middle Island) of the National Topographic System. Contour interval is 25 feet.

Aerial photography by the Ontario Ministry of Natural Resources, Toronto.

CREDITS

Geology by T.F. Morris and assistants, 1988, 1989.

To enable the rapid dissemination of information, this map is **unedited**. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Users should verify critical information.

Issued 1994.

Information on this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Morris, T.F. 1994. Quaternary geology, Essex County (east half)), southern Ontario; Ontario Geological Survey, Preliminary Map P.3252, scale 1:50 000.

Ministry of Northern Development and Mines
Ontario

Mines and Minerals Division

Ontario Geological Survey

Map P.3256

BEDROCK TOPOGRAPHY

ESSEX COUNTY AREA (EAST HALF)

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 40G/10, 40G/15, 40J/2, 40J/7

This map is published with the permission of the Director, Ontario Geological Survey.

SYMBOLS

- Water well that penetrates bedrock, with depth of drift in metres
- Petroleum well with depth of drift in metres
- Geotechnical borehole that penetrates bedrock, with depth of drift in metres
- Sonic borehole that penetrates bedrock (this study), with depth of drift in metres
- Contour on bedrock surface (contour interval 10 metres)
- Bedrock outcrop
- Area of exposed bedrock

SOURCES OF INFORMATION

Bedrock surface elevation contour lines were developed from point data available from water, oil and gas well, geotechnical borehole records and sonic borehole records as well as interpolation between surface and bedrock contours.

Point data was obtained from water well records supplied by the Water Resources Branch, Ontario Ministry of the Environment, from oil and gas records kept at the Petroleum Resources Section, Ontario Ministry of Natural Resources, from geotechnical borehole records supplied by the Ministry of Transportation and sonic borehole records from the drilling program associated with this project.

CREDITS

Compilation and contouring: T.F. Morris and G.R. Cousineau, 1989

Cartography by T.F. Morris and G.R. Cousineau

The bedrock surface elevation contours generated for this map should be considered as interpretive and, as such, will require revision as additional data becomes available.

To enable the rapid dissemination of information, this map is **unedited**. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Users should verify critical information.

Issued 1994.

Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Morris, T.F. and Cousineau, G.R. 1994: Bedrock topography, Essex County area (east half), southern Ontario; Ontario Geological Survey, Preliminary Map P.3256, scale 1:50 000.

Ministry of Northern Development and Mines

Ontario

Mines and Minerals Division
Ontario Geological Survey

Map P.3255

DRIFT THICKNESS

ESSEX COUNTY AREA (WEST HALF)

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 40J/2, 40J/3, 40J/6, 40J/7

This map is published with the permission of the Director, Ontario Geological Survey.

SYMBOLS

- Water well that penetrates bedrock, with depth of drift in metres
- Petroleum well with depth of drift in metres
- Geotechnical borehole that penetrates bedrock, with depth of drift in metres
- Sonic borehole that penetrates bedrock (this study), with depth of drift in metres
- Contour on bedrock surface (contour interval 10 metres)
- Bedrock outcrop
- Area of exposed bedrock

SOURCES OF INFORMATION

Drift thickness contour lines were developed from point data available from water, oil and gas well, geotechnical borehole records and sonic borehole records as well as interpolation between surface and bedrock contours.

Point data was obtained from water well records supplied by the Water Resources Branch, Ontario Ministry of the Environment, from oil and gas records kept at the Petroleum Resources Section, Ontario Ministry of Natural Resources, from geotechnical borehole records supplied by the Ministry of Transportation and sonic borehole records from the drilling program associated with this project.

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Issued 1994.

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Morris, T.F. and Cousineau, G.R. 1994. Drift thickness, Essex County area (west half)), southern Ontario; Ontario Geological Survey, Preliminary Map P.3255, scale 1:50 000.

Ministry of Northern Development and Mines
Ontario

Mines and Minerals Division
Ontario Geological Survey

Map P.3254

DRIFT THICKNESS

ESSEX COUNTY AREA (EAST HALF)

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 40G/10, 40G/15, 40J/2, 40J/7

SYMBOLS

●	Water well that penetrates bedrock, with depth of drift in metres	⌖	Sonic borehole that penetrates bedrock (this study), with depth of drift in metres
▲	Petroleum well with depth of drift in metres	10	Contour on bedrock surface (contour interval 10 metres)
◎	Geotechnical borehole that penetrates bedrock, with depth of drift in metres	⧓	Bedrock outcrop
		⚒	Area of exposed bedrock

SOURCES OF INFORMATION

Drift thickness contour lines were developed from point data available from water, oil and gas well, geotechnical borehole records and sonic borehole records as well as interpolation between surface and bedrock contours.

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Morris, T.F. and Cousineau, G.R. 1994: Drift thickness, Essex County area (east half), southern Ontario; Ontario Geological Survey, Preliminary Map P.3254, scale 1:50 000.

Ontario
Ministry of
Northern Development
and Mines

Mines and Minerals Division
Ontario Geological Survey

Map P.3253

QUATERNARY GEOLOGY

ESSEX COUNTY AREA (WEST HALF)

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 40J/2, 40J/3, 40J/6, 40J/7

LEGEND

PHANEROZOIC

CENOZOIC

QUATERNARY

RECENT

10	**Cultural Features**: quarries, landfills, mine waste, aggregate excavations and sewage lagoons
9	**Modern Alluvium**: unsubdivided clay, silt, san and muck
8	**Bog deposits**: peat and muck
7	**Modern Beach Deposits**: sand, gravel and cobbles
6	**Eolian Deposits**: fine to medium sand

PLEISTOCENE

5	**Lacustrine Beach, Bar and near shore deposits**: sand with minor gravel 5a Lacustrine sandy silt
4	**Glaciolacustrine Beach, Bar and near shore deposits**: sand with minor gravel
3	**Glaciolacustrine Silty Clay** 3a Glaciolacustrine: silty clay deposits interbedded with sand and sandy silt beds 3b Glaciolacustrine: silty clay deposits overlain by a thin sand cover 3c Glaciolacustrine: silty clay deposits overlain by thin, discontinuous sand and gravel deposits
2	**Clayey Silt Till** 2a Clayey silt till: related to recessional moraine and may be sandier material

PALEOZOIC

DEVONIAN

1	**Bedrock Outcrop**: bioclastic limestone; massive, brown, bituminous

SYMBOLS

- Glacial striae
- Intersecting glacial striae: 1 indicates the oldest, 3 the youngest
- Dunes
- Iceberg keel marks
- Abandoned shore bluff
- Abandoned beach ridge
- Abandoned channel
- Moraine crest
- Esker
- Active sand and/or gravel pit
- Active quarry
- Geological boundary

SOURCES OF INFORMATION

Base maps derived from maps 40J/6 (Windsor), 40J/3 (Amherstburg), 40J/2 (Essex), 40J/7 (Belle River) of the National Topographic System. Contour interval is 25 feet.

Aerial photography by the Ontario Ministry of Natural Resources, Toronto.

CREDITS

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Issued 1994.

Information on this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Morris, T.F. 1994. Quaternary geology, Essex County (west half), southern Ontario; Ontario Geological Survey, Preliminary Map P. 3253, scale 1:50 000.

Ministry of
Northern Development
and Mines

Ontario

Mines and Minerals Division
Ontario Geological Survey

Map P.3257

BEDROCK TOPOGRAPHY

ESSEX COUNTY AREA (WEST HALF)

SOUTHERN ONTARIO

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 40J/2, 40J/3, 40J/6, 40J/7

SYMBOLS

- Water well that penetrates bedrock, with depth of drift in metres
- Sonic borehole that penetrates bedrock (this study), with depth of drift in metres
- Petroleum well with depth of drift in metres
- Contour on bedrock surface (contour interval 10 metres)
- Geotechnical borehole that penetrates bedrock, with depth of drift in metres
- Bedrock outcrop
- Area of exposed bedrock

SOURCES OF INFORMATION

Bedrock surface elevation contour lines were developed from point data available from water, oil and gas well, geotechnical borehole records and sonic borehole records as well as interpolation between surface and bedrock contours.

Point data was obtained from water well records supplied by the Water Resources Branch, Ontario Ministry of the Environment, from oil and gas records kept at the Petroleum Resources Section, Ontario Ministry of Natural Resources, from geotechnical borehole records supplied by the Ministry of Transportation and sonic borehole records from the drilling program associated with this project.

CREDITS

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Cartography by T.F. Morris and G.R. Cousineau

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Morris, T.F. and Cousineau, G.R. 1994. Bedrock topography, Essex County area(west half), southern Ontario; Ontario Geological Survey, Preliminary Map P.3257, scale 1:50 000.