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Quaternary Geology of the Woodstock Area

Southern Ontario

By

W. R. Cowan

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ABSTRACT

Centrally located in the southern Ontario Peninsula, the Woodstock area was subjected to glacial outflows from the Ontario-Erie, Huron, and Georgian Bay basins during the Pleistocene. Up to 250 feet of glacial drift, mainly of Wisconsinan age, overlies Silurian dolostone and shale, and Devonian limestone.

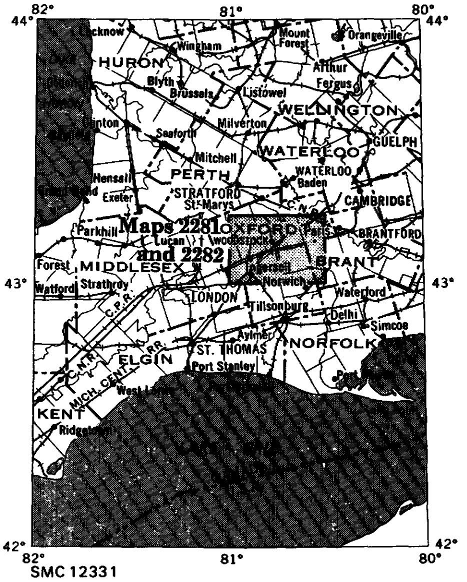


Figure 1–Key map showing location of the Woodstock area. Scale: 1 inch to 50 miles.

Early Wisconsinan glaciation from the southeast resulted in the deposition of Canning Till and possibly an older till. Middle Wisconsinan events are largely unknown and no till of this age, lithologically separable from the younger Catfish Creek Till, was identified. However, a water-well record indicates possible buried organic material of probable Port Talbot or Plum Point Interstadial affiliation near Ingersoll and material of this age has been recovered near Innerkip. Late Wisconsinan events include a major initial advance (Nissouri Stadial) with the deposition of up to three units of Catfish Creek Till, retreat during the Erie Interstadial with accompanying deposition of glaciolacustrine sediments, concurrent advance of the Erie and Huron lobes during the Port Bruce Stadial with the deposition of Port Stanley Till and Zorra till respectively, a hiatus during the Mackinaw Interstadial, and finally deposition of Glacial Lake Whittlesey sediments during the Port Huron Stadial.

Granular resources are mainly related to Catfish Creek Till and Zorra till. The townships of Blenheim, North Oxford, West Zorra, East Zorra, and East Nissouri contain resources capable of sustaining limited commercial production. The township of West Oxford contains granular resources supporting extensive commercial extraction and appears to be most suitable for locating future resources which are largely buried. Chert is deleterious in gravel throughout the area.

Quaternary Geology
of the
Woodstock Area
Southern Ontario

by

W. R. Cowan[1]

INTRODUCTION

The Woodstock area (Fig. 1) is bounded by latitude 43°00′ to 43°15′ north and longitudes 80°30′ to 81°00′ west. It contains about 430 square miles occurring largely in Oxford County but also in the counties of Brant and Middlesex. The City of Woodstock and the Town of Ingersoll are the principal urban centres within the map-area.

Access to the area is available via provincial highways 2, 19, 53, 59, and 401; a close network of county and township roads supports the above routes. The Canadian National and Canadian Pacific Railways also provide access.

The area is noted for its high quality limestone which comprises an important segment of the mineral resource base of southern Ontario. Oil, gas, sand and gravel, and clay are geologic commodities of lesser importance presently being extracted from the rocks of the map-area.

Present Geological Survey

Mapping of the Quaternary geology is intended to provide information on the distribution, properties, stratigraphy, and history of surficial materials for use in planning, engineering, hydrologic, geologic, and environmental studies. The present reconnaissance survey was initiated during the summer of 1969 and completed in the summer of 1970. Field data were obtained through examination of roadcuts, stream and river banks, excavations, and by test pitting or hand augering where necessary. Additional information was obtained from water-well records and from records made available by various, provincial, municipal, or private agencies. A preliminary map of the area was published previously (Cowan 1971a).

[1]Geologist, Phanerozoic Geology Section, Geological Branch, Division of Mines. Manuscript approved for publication by the Chief, Phanerozoic Geology Section, 7 December 1972.

Acknowledgments

Capable field assistance was provided in 1969 by K. K. Chiang (senior assistant), R. N. W. DiLabio, and D. N. Allen and in 1970 by R. N. W. DiLabio (senior), D. R. Sharpe, F. E. Baechler and R. A. Brinsmead. Chiang was responsible for areal mapping of most of the area bounded by Highways 53 and 59 and DiLabio for a large part of the west sheet and part of the east sheet.

Additional information was provided by H. E. Jones of Woodstock Engineering Consultants Limited; C. Hevenor and G. Ede of the Woodstock Engineering Office; J. F. Rousom of the Woodstock Public Utilities Commission; and K. J. Goff of the Water Quantity Management Branch, Ministry of the Environment.

Water Well records were provided by the Water Resources Division, Ministry of the Environment. Pit and quarry operators, and many private landowners kindly permitted access to their properties.

Shell samples were identified by Rev. H. B. Herrington of Westbrook, Ontario, and by Mrs. M. F. I. Smith of the National Museum of Natural Sciences, Ottawa. Palynological study was carried out by Professor J. Terasmae of Brock University. Radiocarbon dates were provided by Professor Terasmae and by Dr. W. Blake Jr. of the Geological Survey of Canada.

Professors P. F. Karrow of the University of Waterloo and A. Dreimanis of the University of Western Ontario provided discussion and information on topics related to the area.

Trend surfaces were computed on the University of Colorado computer with the assistance of Larry D. Williams of the Institute of Arctic and Alpine Research.

Laboratory analyses were carried out by the Mineral Research Branch, Division of Mines.

To the above individuals and institutions the writer extends his thanks and appreciation.

Previous Work

A number of publications describing geological aspects of the map-area are available; a few of these will be mentioned here but specific articles will be detailed in the appropriate sections of the text.

Caley (1941) mapped the Paleozoic rocks underlying the Woodstock area. More recently information obtained from oil and gas wells has led to some revision of Caley's contacts, particularly through the use of information outlining the topography of the bedrock surface beneath the glacial drift. Sanford (1969) has produced a compilation map of the rocks underlying the area, and in addition, Sibul (1969) and Yakutchik and Lammers (1970) have produced bedrock maps of those areas lying within the Big Otter Creek and Big Creek drainage basins. Information on subsurface stratigraphy is available in Sanford and Quillian (1959), Sanford (1961), and Beards (1967). Economic aspects of the Paleozoic rocks are described in Guillet (1964), Hewitt (1960; 1964) and Beards *et al.* (1969).

Topography of the bedrock surface has been mapped by Davies and McClymont (1962); Sibul (1969) and Yakutchik and Lammers (1970) provided bedrock topography maps for the Big Otter Creek and Big Creek areas. Drift thickness maps were included in these latter two reports and in Hewitt (1960); drift thickness may be obtained from the map of Davies and McClymont.

Information on ground water resources is available from files maintained by the Ministry of the Environment and for portions of the area in the reports of Sibul (1969) and Yakutchik and Lammers (1970).

Early work on the Pleistocene geology of the area was largely that of Taylor (1913), who outlined the major end moraines. Subsequently Chapman and Putnam (1951; 1966) carried out small scale physiographic mapping and provided a synthesis of the deglaciation of the southern part of Ontario. Important recent contributions to the glacial stratigraphy of adjacent areas have been made by Karrow (1963; 1968a and b; 1971) working to the north and east, by Dreimanis (1964; 1970b), and by Dreimanis *et al.* (1966). Within the area a detailed stratigraphic examination of overburden at the Canada Cement quarry (Zorra) was made by Westgate and Dreimanis (1967). Lithologic properties of surface tills in surrounding areas have been reported by Dreimanis (1961) and Dreimanis *et al.* (1957). Prest (1970) has recently summarized late glacial and post-glacial events in the southern part of the province. New stratigraphic terminology for the Wisconsinan Stage in southern Ontario has been put forward by Dreimanis and Karrow (1972) and their nomenclature is used herein.

Major sand and gravel operations were described by Hewitt and Karrow (1963) and this was subsequently revised by Hewitt and Cowan (1969a); lesser operations were reported by Hewitt and Cowan (1969b). Guillet (1967) has described the only producing clay pit within the area.

Wicklund and Richards (1961) published a map and report of the agricultural soils of Oxford County. New soil maps are presently being prepared by the Ontario Soil Survey for those parts of the map-area lying outside of Oxford County.

Physiography and Drainage

The Woodstock map-area comprises a flat to gently rolling surface broken by a few major negative features in the form of deeply incised glacial meltwater channels (principally those channels now occupied by Mud Creek and Thames River) and by a few positive features in the form of rolling hummocky end moraines or isolated kames. Maximum relief in the map-area is about 400 feet; the highest point in the map-area is about one mile south of Woodstock with an elevation of about 1250 feet and the lowest point is south of Hatchley at about 825 feet. Local relief rarely exceeds 50 feet except near major valleys or end moraines where relief may exceed 200 feet.

Chapman and Putnam (1951) mapped the physiography of the area at a scale of approximately one inch to four miles. Much of the map-area consists of ground moraine plains or drumlinized ground moraine. These units occur largely between the Norwich and St. Thomas Moraines and over most of the west half of the map-area. Major end moraines include the Ingersoll, St. Thomas, and Norwich Moraines laid down by the Erie lobe. Of these the Ingersoll Moraine is best developed and most continuous but the Norwich Moraine is discontinuous and difficult to trace. Lesser moraine fragments and kames marking ice marginal positions occur in the map-area; these will be described more fully elsewhere in this report. Abandoned meltwater channels containing underfit streams are perhaps the most striking landforms in the area, particularly those now occupied by Thames River and Mud Creek. Others include Nith River, Horner Creek, and Cedar Creek. Sand plains of glaciofluvial or glaciolacustrine deltaic origin occupy much of the east half of the map-area. Small patches of outwash sand or glaciolacustrine sand and silt occur throughout the map-area, usually overlying ground moraine.

The drainage system of the Woodstock map-area is characterized by low gradient streams except where draining the slopes of end moraines or where drainage is into deeply incised meltwater channels. Drainage patterns are not well developed and large areas of poorly drained swamp exist, particularly in the northeastern part of the map-area. In general, drainage of the western part of the map-area is dominated by glacial meltwater channels whereas in the eastern part drainage is primarily controlled by the end moraine system.

Surface waters drain either to Lake St. Clair via the Thames River basin or to Lake Erie via the Grand River, Big Creek, or Big Otter Creek basins. The Grand River basin drains about one quarter of the northeastern part of the map-area via Nith River, Horner Creek, and Kenny Creek, all of which drain into the Grand River in the Brantford area to the east.

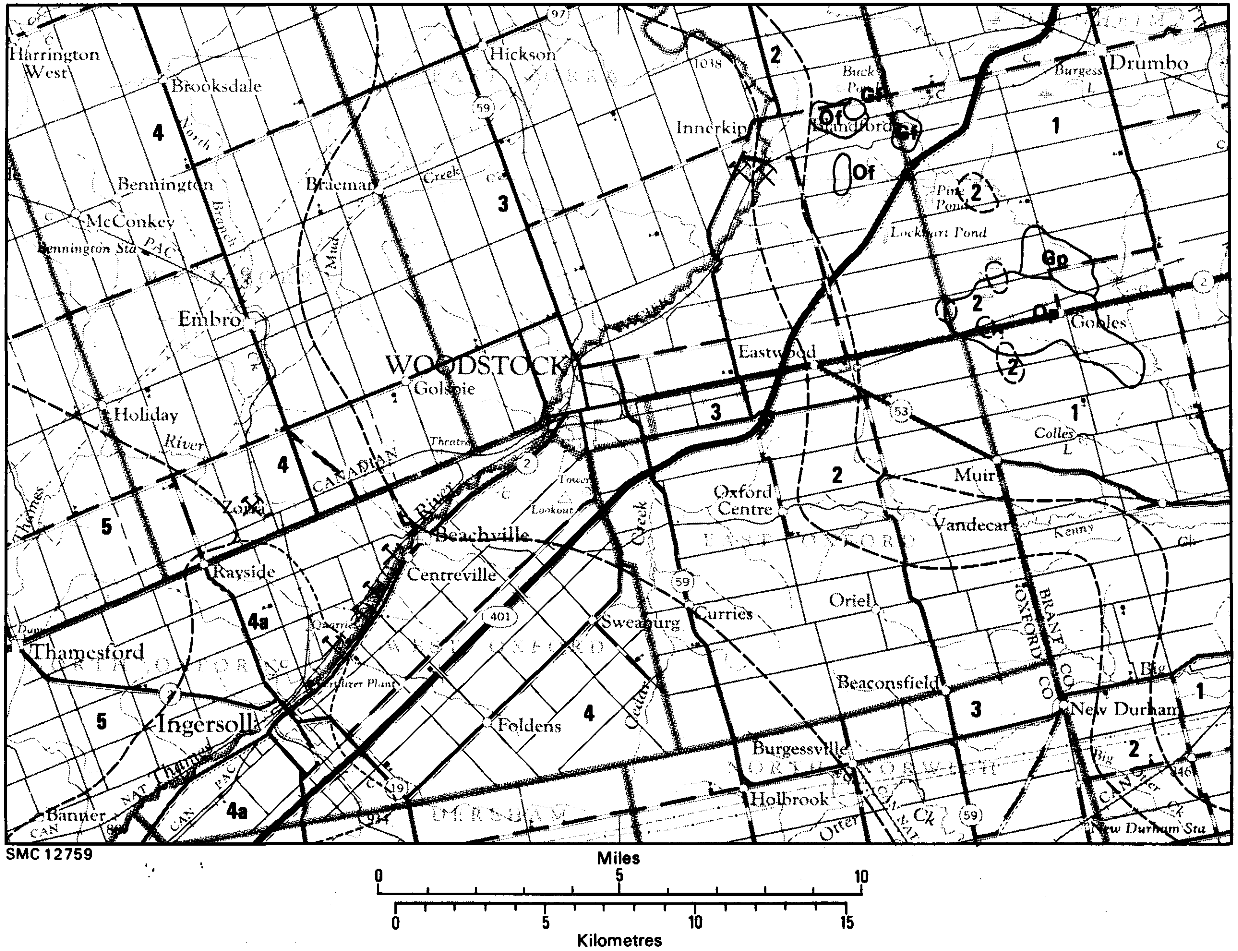
The Big Creek basin drains about 40-50 square miles of the southeastern part of the map-area. Its headwaters are located on the east slope of the St. Thomas Moraine and within the map-area it has an average gradient of about 11 feet per mile. Beyond the Woodstock area Big Creek turns south and drains into Lake Erie south of Port Rowan.

The Big Otter Creek basin drains only a very small area in the southeastern part of the map-area via Big Otter Creek and its Otter Creek tributary. The former drains mainly flat ground with low gradient streams whereas Otter Creek has its headwaters on the Ingersoll Moraine and has an average gradient of 20-25 feet per mile within the map-area. After leaving the Woodstock area Big Otter Creek flows southerly to Lake Erie.

The Thames River system drains more than 50 percent of the map-area, primarily the west half. Thames River (south branch) enters the map-area north of Innerkip and had an average gradient about 7 feet per mile before being dammed and diverted. Its present state is that of a very underfit stream occupying a large glacial meltwater channel. The Thames River flows southwest beyond the map-area to Lake St. Clair.

Northwest of Thames River is a second major meltwater channel containing the present day Mud Creek. This creek becomes the Thames River (middle branch) at the juncture of North Branch Creek south of Embro. Mud Creek has an average gradient of 4-5 feet per mile whereas its principal tributary, North Branch Creek, has an average gradient of about 20 feet per mile. Most of the area drained by Mud Creek consists of gently rolling to drumlinized ground moraine.

A small area near Harrington West in the northwesternmost part of the map-area is drained by Trout Creek. This Creek flows west into the North Branch of the Thames River and thence to Lake St. Clair.



LEGEND

PALEOZOIC

DEVONIAN

Dundee Formation.
5 *Limestone.*

Detroit River Formation.
4 *High-calcium limestone.*
4a *Sandy cap-rock facies.*

Bois Blanc Formation.
3 *Cherty limestone.*

SILURIAN

Bass Islands Formation.
2 *Dolostone.*

Salina Formation.
1 *Dolostone, shale, gypsum.*

SYMBOLS

Op *Oil pool.*
Of *Oil field.*
Gp *Gas pool.*
Gf *Gas field.*
All in subsurface Cambrian rocks.

Quarry.

Figure 2–Paleozoic geology of the Woodstock area (from maps of GSC and ODMNA).

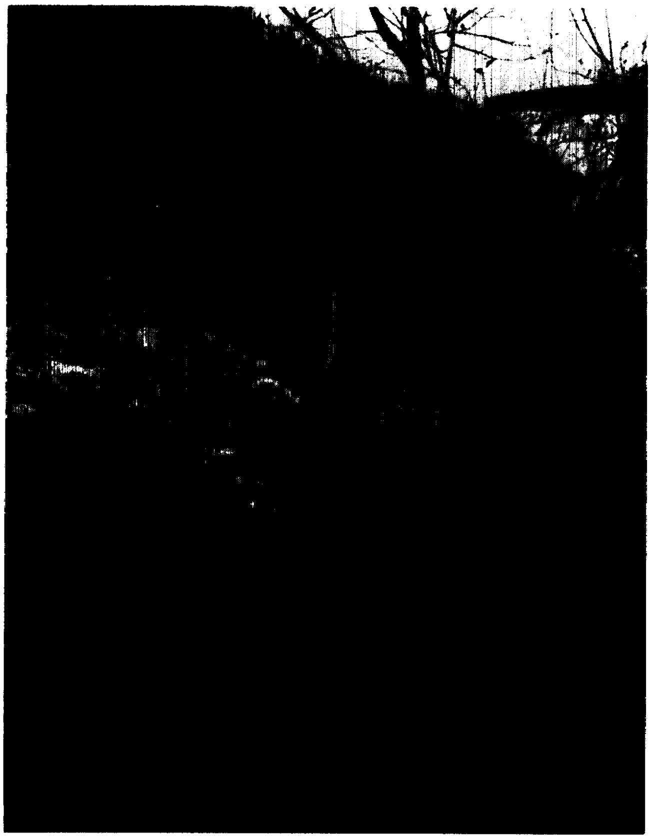


Photo 1 – Contact between dolomite of Bass Islands Formation and overlying cherty limestone of Bois Blanc Formation at Innerkip quarry.

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PALEOZOIC GEOLOGY

Silurian

The oldest rocks occurring in subcrop beneath the glacial drift are those of the Salina Formation of Upper Silurian age. These rocks consist of non-fossiliferous grey to greenish grey shales and shaly dolomites containing gypsum lenses. The lower contact with the Guelph Formation is transitional. The Salina Formation does not outcrop at the surface in the Woodstock area. According to Caley (1941, p.42) thicknesses range from 390-405 feet in Dereham Township, to 390 feet in North Oxford Township, and 410 feet in East Nissouri Township. Guillet (1964, p.92) reports thicknesses of 200-250 feet for the Salina Formation in the subcrop area of Blenheim Township. He also has described the gypsum bearing Salina rocks in detail (Guillet 1964).

Conformably overlying the Salina Formation, is the Bass Islands Formation[1] (Fig. 2). These rocks, consisting of brown to buff, fine grained to dense dolomite

[1]Bass Island is commonly used in Michigan and Ontario (Liberty and Bolton, 1971) though the original Bass Islands is still retained by the United States Geological Survey (Keroher *et al.* 1966, p.232-233).

and argillaceous dolomite, may be observed beneath the Bois Blanc Formation in an old quarry at Innerkip (Photo 1). Thicknesses reported by Caley (1941) indicate 40-85 feet in Dereham Township, 105 feet in East-Nissouri Township and 50 feet in North Oxford Township. Goudge (1938, p.259) measured 55½ feet of Bass Islands Dolomite at an Innerkip quarry.

Devonian

Overlying the Upper Silurian Bass Islands Formation with unconformity is the Bois Blanc Formation of Middle Devonian age. The rocks of this formation consist of medium-crystalline, highly fossiliferous, cherty limestones occurring in a band trending southeast-northwest across the map-area. Outcrops occur in the banks of the Thames River near Innerkip and near Woodstock, and about 10 feet of the formation overlies the Bass Islands Formation in the rehabilitated Innerkip quarry. According to Hewitt (1960, p.128) this formation is about 125 feet thick at Ingersoll and thins in a southerly direction to 102 feet at Norwich and thickens northward to 195 feet at St. Marys. The upper contact with the Detroit River Formation is marked by a chemical unconformity in the Beachville area (Hewitt 1960, p.148).

The Detroit River Formation has generally been accorded group status and subdivided into the Amherstburg Formation (lower) and Lucas Formation (upper). This division in much of Ontario has been based on faunal evidence (Liberty and Bolton 1971, p.63; Hewitt 1960, p.147). According to Liberty and Bolton (1971) subdivision by lithologic means is not feasible in the London-Bruce Peninsula area, nor is it possible in the Beachville-Ingersoll area (Hewitt 1960, p.147). For this reason Liberty and Bolton (1971) suggested that the Detroit River only have group status in the Michigan area where individual rock units may be divided into formations, and that for most of the Ontario Peninsula the Detroit River rocks should only be accorded formational status. However, Sanford (1969) made lithologic separations in compiling his map and Beards (1967) states that a contact can be placed between the Amherstburg and Lucas Formations using drill-hole cuttings but not mechanical logs.

Within the Woodstock map-area the rocks of the Detroit River Formation are of the southern facies consisting primarily of limestones having a thickness of 100-110 feet at Beachville; these thin to the southeast and thicken to about 200 feet at St. Marys north of the area (Hewitt 1960). The rocks consist of very fine grained, light brown to grey high-calcium limestone containing numerous corals and stromatoporoids. In the Ingersoll area the Detroit River is capped by up to 30 feet of sandy limestone formerly known as the Columbus Limestone. Sanford (1967) has pointed out that this caprock is not the equivalent of the Columbus Formation of Ohio and that it is actually a facies of the upper Detroit River Lucas Formation. He further suggested that 'Columbus' be omitted from Ontario nomenclature. Ehlers and Stumm (1951, p.1881) however described a disconformity between the Columbus Limestone and the Lucas Limestone at Beachville.

The mid-Devonian Dundee Formation overlies the Detroit River Formation with major disconformity (Sanford 1967) and like the Detroit River gives way to the Onondaga Formation towards New York State (Sanford 1967; Liberty and Bolton

1971). On Caley's early map of the area (Caley 1941) the Dundee was included with all pre-Hamilton Devonian rocks in the Norfolk Formation due to lack of outcrops and the similarity of rock units within well cuttings.

The Dundee Formation does not outcrop within the Woodstock area but 50 feet of it is exposed at St. Marys to the north (Hewitt 1960). Elsewhere it has a thickness ranging from 85 to 160 feet. It consists of light brown to grey, medium to fine grained, crystalline to sublithographic limestone and, following the work of Best, is usually divided into upper and lower members, e.g. Sanford (1968), Liberty and Bolton (1971). The lower member contains sand grains, chert, and minor bioclastic material and is coarser than the upper member. The Dundee Formation is overlain to the southwest (beyond the present area) by the shales of the Hamilton Formation.

Economic Geology

LIMESTONE

Quarrying of limestone and dolomite has a long history within the area. Early quarrying took place at Innerkip, Woodstock, and Beachville but present day quarrying is carried out in the Beachville-Ingersoll area and at Zorra.

Quarrying from Silurian rocks has been limited to the Bass Islands Formation at Innerkip. Here lime was produced until 1916 (Goudge 1938, p.258) from two quarries located on lot 9, concession XVII, East Zorra Township; these quarries are presently under water. On the northwest side of the Canadian Pacific Railway (lot 9, concession XVII, East Zorra Township) a large quarry operated by Innerkip Quarries Ltd. formerly produced crushed stone primarily for use as railway ballast. According to Goudge this quarry operated between 1929 and 1933. The rock consists of 5 to 10 feet of cherty Bois Blanc Limestone overlying 55½ feet of Bass Islands Dolomite. This quarry is largely under water and now used for recreation (Photo 2). The section measured by Goudge at this quarry remains a reference section for the Bois Blanc-Bass Islands contact (Liberty and Bolton 1971, p.56). A third quarry area at Innerkip was located on the west side of the highway leading into Innerkip from the south (Goudge 1938, p.56). This site is filled and now used for recreation.

At Woodstock small quarries in Devonian rock were formerly worked near the southern edge of town. Two of these reported by Stauffer (1915, p.109-112) were located on the west bank of the Thames River (Weir quarry) opposite the Canadian Pacific Railway depot and on the east bank of the river (Rapson quarry) about one-quarter mile below the Grand Trunk (CNR) bridge. About five feet of cherty limestone was exposed at the Weir quarry and about eight feet (mainly under water) was exposed at the Rapson quarry. Stauffer placed these rocks within the Onondaga Formation, Caley (1941) the Norfolk Formation, Hewitt (1960) the Bois Blanc Formation, and Sanford (1969) the Amherstburg Formation (Detroit River). According to Goudge (1938, p.258) the cherty nature of the rocks in the Woodstock quarries made them suitable for use as road metal only.

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Photo 2–Rehabilitated quarry at Innerkip.

In the Beachville-Ingersoll area the high-calcium limestone of the Detroit River Formation has long been recognized "as one of the most important centres in Canada for the production of chemical limestone and chemical lime" (Goudge 1938, p.260). Until recently most quarry operations have been carried out within the valley of the Thames River where drift thicknesses are minimal. However, in 1957 the Canada Cement Company Limited, went into production at Zorra Station where they had to remove 70-80 feet of drift. In the early 1960's Domtar Chemicals Ltd. of Beachville expanded their quarry operations westward necessitating the removal of about 60 feet of overburden. Much of the land underlain by the Detroit River Formation has been taken up despite the expense of removing this thick overburden and to date no underground operations as forecast by Goudge (1938, p.260) have come to fruition. The thinner drift in the Mud Creek valley has resulted in recent interest in possible quarry operations in that area. To the south the upper sandy facies (Columbus cap-rock) of the Detroit River Formation is limiting as it too must be stripped. Detailed descriptions of quarry operations in the Detroit River Formation are given in Hewitt (1960; 1964).

Production from the quarries operating in the Woodstock map-area in 1970 was as follows: limestone—more than one million tons valued at more than $500,000; lime—more than 500,000 tons valued at more than $6,000,000; and portland cement—more than 500,000 tons valued at more than $9,000,000. Building stone is not produced in the area today though it was at one time (Parks 1912, p.277).

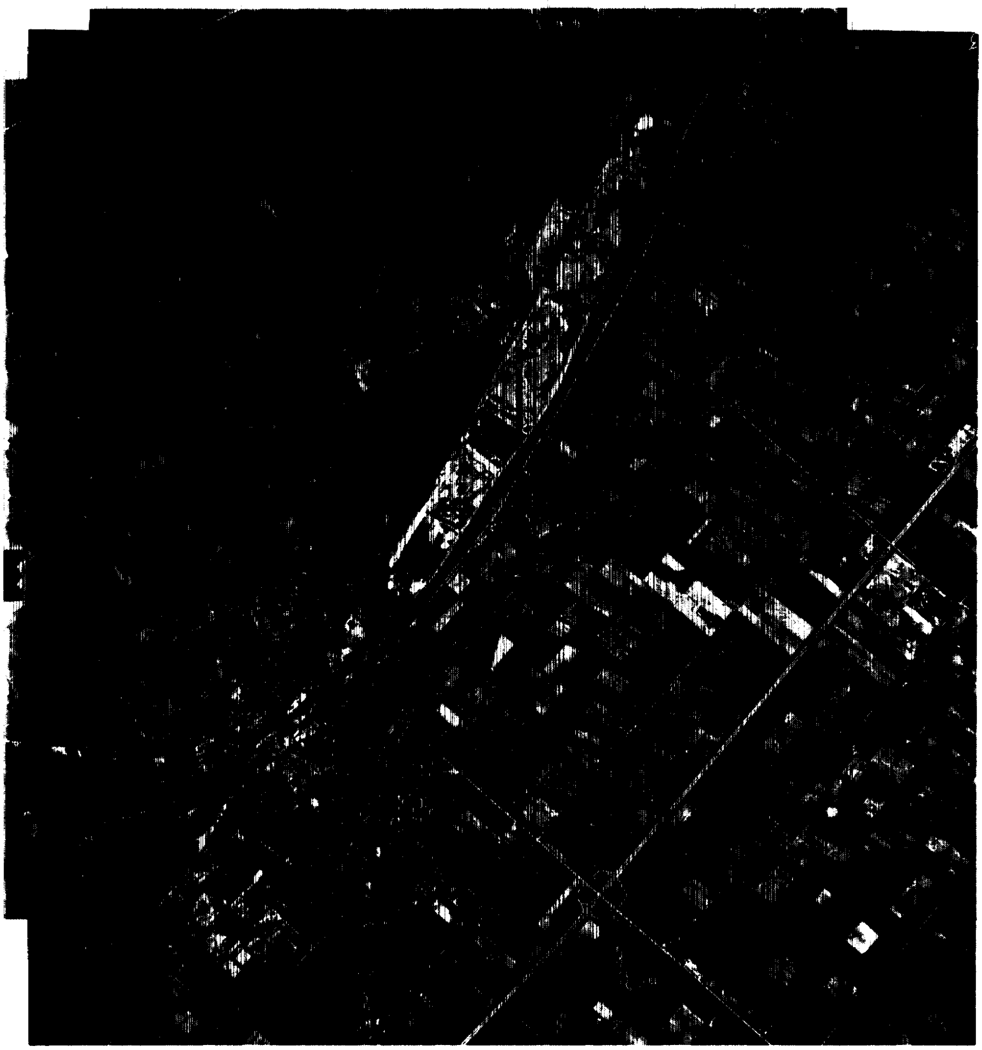

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Photo 3–Air photo of quarry operations in the Beachville area 1966. Note drumlinized terrain in the northwest (upper left) part of photo. (National Air Photo Library Photo No. A 19410 (23).)

GYPSUM

Small amounts of gypsum occur within the Salina Formation, particularly the shaly units, in the form of lenses and thin layers. Where concentrations of this material are sufficient it may be mined. Within the Woodstock area no gypsum has been mined to date though Guillet (1964, p.92) reports that exploration work was carried out during the 1960's on lots 20-22, concession VI-IX, Blenheim Township by Western Gypsum Products Limited. This resulted in the sinking of a 42-inch vertical shaft on lot 21, concession VI for sampling purposes. A 6-7 foot gypsum seam was encountered at about 375 feet. No commercial extraction has resulted. Guillet (1964, p.30-31) compiled oil and gas well information on gypsum in the Salina Formation and listed all gypsum intersections exceeding 10 percent.

OIL AND GAS

Since 1959 hydrocarbons have been extracted from subsurface Cambrian rocks within the area. Areas of principal interest are the Gobles gas and oil pools located in the extreme southwest part of Blenheim Township and the extreme northwest part of Burford Township; the Innerkip gas and oil field located in Blandford Township two miles east of Innerkip; and the Innerkip East gas pool located in Blenheim Township four miles east of Innerkip (Beards *et al.* 1969). Production of crude oil in 1970 was about 71,100 barrels from the Gobles pool and about 3,500 barrels from the Innerkip field (totalling about 7.1 percent of Ontario production). The Gobles gas pool produced about 12.4 MMcf of natural gas and the Innerkip area about 98.5 MMcf (totalling less than one percent of Ontario production).

Bedrock Topography

The bedrock surface of the Woodstock area was previously contoured by Davies and McClymont (1962) using water, oil and gas well records. The reports of Sibul (1969) and Yakutchik and Lammers (1970) contain bedrock topography maps of their respective areas. Figure 3 represents a revised and generalized version of Davies' and McClymont's map after field checking water-well records during the present survey.

Relief of the bedrock surface ranges from 725 feet in the eastern part of the area to 1000 or 1025 feet in the northwest. Davies and McClymont reported more extreme values than these giving minimal elevations of about 670 feet near Holbrook and a maximum elevation of 1090 feet immediately south of the City of Woodstock. Local relief is generally less than 50 feet.

In general the bedrock surface is south sloping and flat to gently rolling with few drainage indentations. Pre-glacial drainage in the northeast quadrant underlain by the Salina Formation was easterly to the Ontario basin but the remainder of the area drained southerly to the Erie basin. The Onondaga Escarpment is not clearly defined but undoubtedly marked the pre-glacial drainage divide.

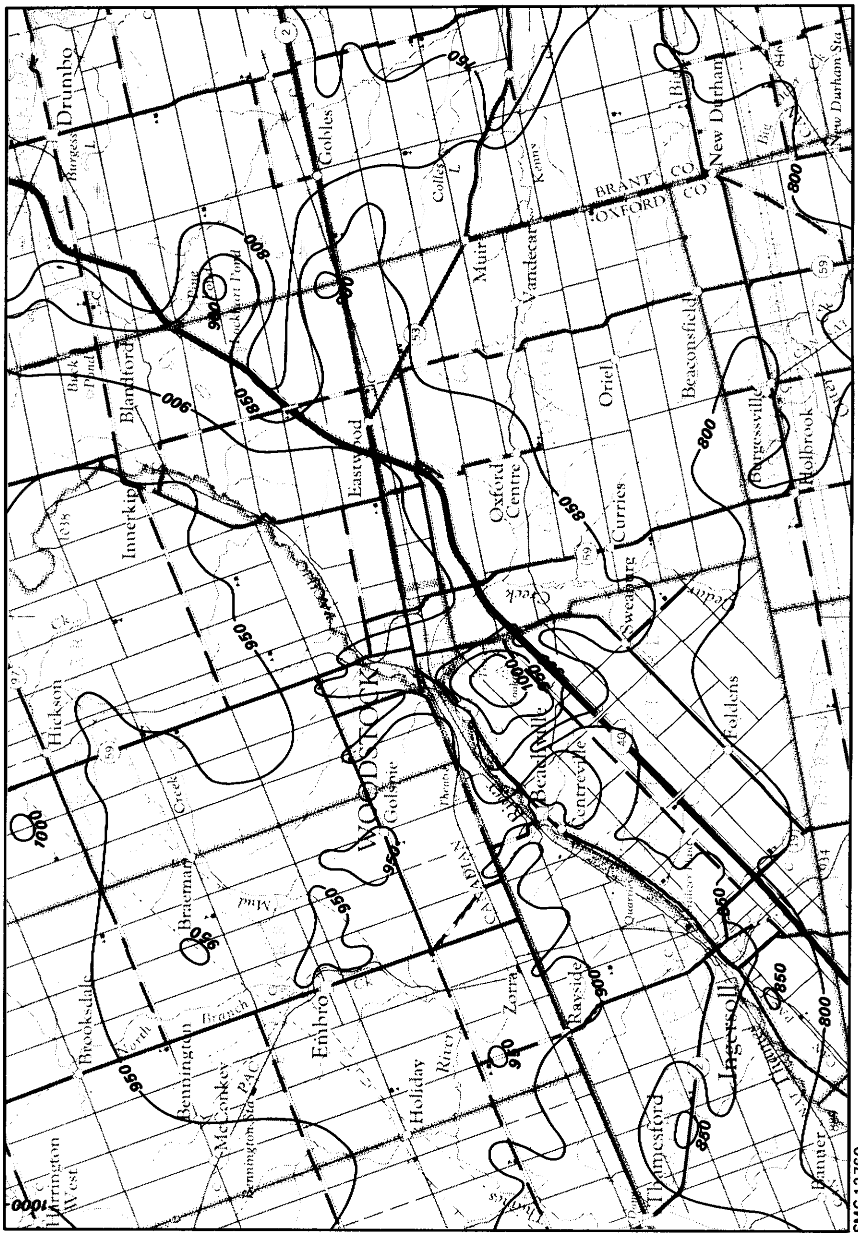

Figure 3–Bedrock topography in Woodstock area. Revised from Davies and McClymont (1962).

QUATERNARY GEOLOGY AND GEOMORPHOLOGY

Drift Thickness

Hewitt (1960) has prepared drift thickness maps for the area underlain by the economically important Detroit River and Dundee Formations and Sibul (1969) and Yakutchick and Lammers (1970) have published drift thickness maps of the Big Otter Creek and Big Creek areas respectively. Drift thickness can also be obtained indirectly from the map of Davies and McClymont (1962) and from Fig. 3 of this report. For specific areas the reader is referred to the files of the Ministry of the Environment for the most recent data on drift thickness.

Throughout most of the Woodstock area overburden or drift thicknesses are considerable. Exceptions to this are the deeply incised valleys of Thames River and Mud Creek, and at Innerkip where bedrock occurs at the surface. In the Thames River valley drift ranges from 20-40 feet in thickness and in the Mud Creek valley from 20-45 feet; at Innerkip a small area in and around the town has drift ranging from 0-25 feet thick. Elsewhere drift thicknesses vary from 50-250 feet.

Till Stratigraphy

GENERAL

The Woodstock area includes terrain referred to as the interlobate zone, i.e. an area located in the central part of the southern Ontario peninsula effected by glaciers flowing out of the Huron basin, the Erie-Ontario basin, and perhaps Georgian Bay. Because of its location and altitude, the area became ice free relatively early during the retreat and lobation of covering ice sheets; this may, in some instances, give rise to an island of land in a sea of ice which Taylor (1913) called 'Ontario Island'. In applying this concept to the retreat of the last major ice sheet (Late Wisconsinan), Chapman and Putnam (1951, 1966) envisaged early lobation and continued existence of 'Ontario Island'. Recent work, including that reported herein, indicates that the interlobate zone has perhaps been subject to glacier fluctuations even during periods of general glacier retreat. Consequently, the area was seldom without some glacier activity during glacial periods.

The net result of several ice lobes alternatively invading the interlobate zone is an overall mixing of sediments, originally having distinct source areas and lithologies, and the production of lithologically similar tills. This mixing provides a stratigraphic and mapping problem which is difficult to resolve, e.g. the data provided by Westgate and Dreimanis (1967, table 1) portray this problem well as five of the nine tills are lithologically quite similar (Figure 4). The interlobate zone is also marked by the preservation of numerous till sheets which Karrow (1971, p.6) suggested implies reduced glacial erosion in such areas.

As far as is known, all tills within the Woodstock map-area are of Wisconsinan age; this is not to say that older tills are not present but that they have yet to be found.

Table 1 QUATERNARY DEPOSITS AND EVENTS OF THE WOODSTOCK AREA

STAGE	DEPOSIT OR EVENT	LITHOLOGY	MORPHOLOGIC EXPRESSION
Recent	modern alluvium	sand, silt, gravel	present day floodplain and channel deposits
	bog deposits	peat, muck, marl	filled depressions
	older alluvium	sand and gravel	remnant stream and river terraces
Late Wisconsinan	Lake Whittlesey	sand, some silt	deltaic sand plains
	local glacial lakes or ponds	silt and fine sand	veneer on ground moraine
	eolian sediments	silt and fine sand	veneer on ground moraine or end moraine
	glaciofluvial sediments	gravel and sand	outwash terraces, kames
	Zorra till (Huron lobe)	sandy silt till	ground moraine plains, and drumlins
	glaciofluvial sediments	gravel and sand	buried kames and outwash
	ablation till (Erie lobe)	stony to bouldery till	local veneer on kames or till ridges
	glaciofluvial sediments	sand and gravelly sand	outwash terraces and morainal aprons
	Port Stanley Till (Erie lobe)	silt till	ground moraine plains, and moraines
	Erie Interstadial	glaciolacustrine sand, silt, and clay	buried lake beds
	glaciofluvial sediments	gravel and sand	buried outwash and kames
	Catfish Creek Till (Erie-Ontario-Huron lobes)	stony sandy silt till	mainly buried ground moraine
	glaciofluvial sediments	gravel and sand	buried outwash and kames
Middle Wisconsinan	till 'C' of Westgate and Dreimanis (1967)	silt till (Huron-Georgian Bay lobe)	
	Lake and pond sediments	silt and organic mud	buried
Early? Wisconsinan	**Canning Till** (Erie-Ontario lobes)	clayey silt till	buried ground moraine
	till'A' of Westgate and Dreimanis (1967)	silt till (Erie lobe)	

Formal rock units are in bold face.

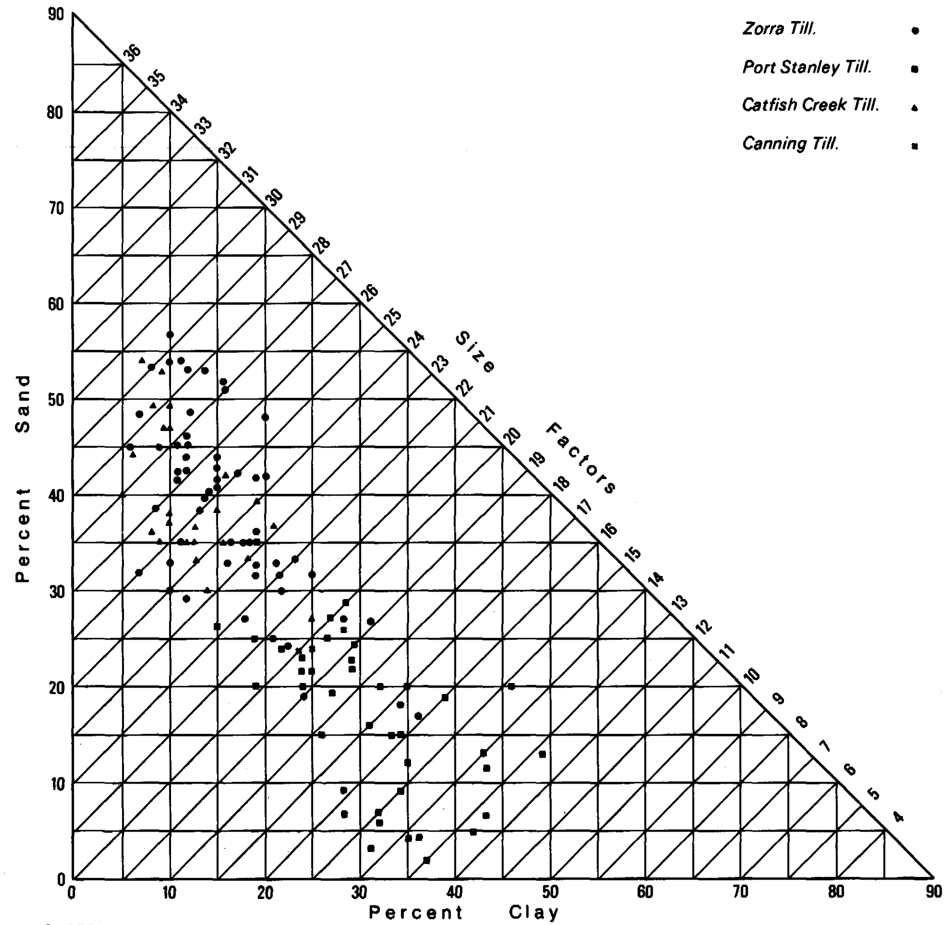

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Figure 4–Textural diagram for Woodstock area tills.

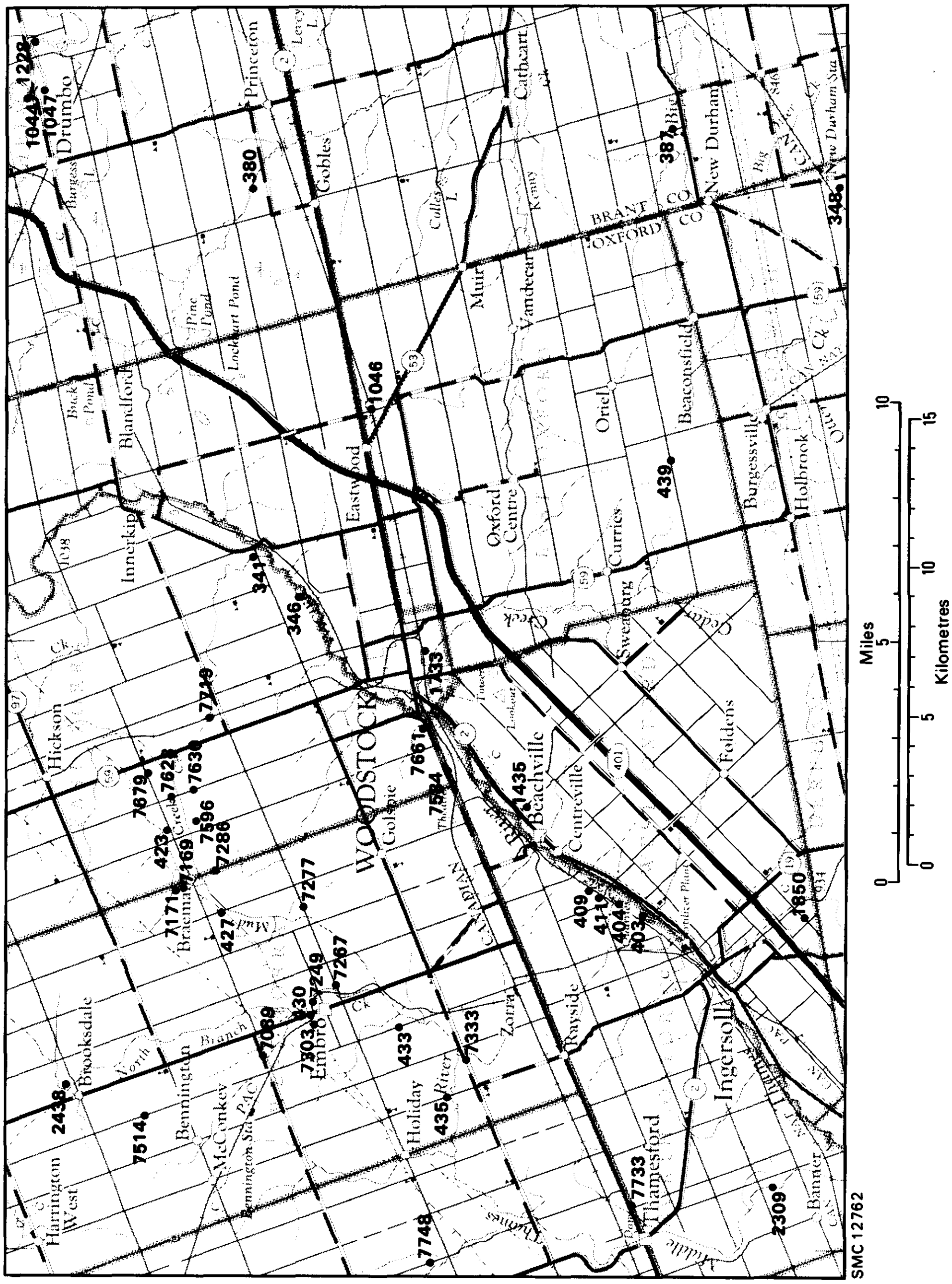

Figure 5—Locations of measured Pleistocene sections in Woodstock area.

The most relevant literature on till stratigraphic problems related to this report is that of Westgate and Dreimanis (1967) within the present map-area, and that of Karrow (1963a; 1968; 1971) in adjacent areas. The work of Karrow (1967) and Dreimanis *et al.* (1966) is important for regional correlation and the work of Dreimanis (1961) and Dreimanis *et al.* (1957) provides a basis for till lithology study. Lithology of tills examined during the present study is summarized in table 2 and more detailed information is given in Appendix B. Significant stratigraphic sections are given in Appendix A and their locations in Figure 5.

EARLY WISCONSINAN TILL(S)

At the Canada Cement quarry, Westgate and Dreimanis (1967) described two tills which they suggested had an Early Wisconsinan age. The lowermost of these, 'till A', was described as a loam till deposited by the Erie lobe moving from south to north. This till was correlated with the 'lower beds' of Karrow (1963a) but no equivalent is known in the Lake Erie area. No further outcrops of this till were found during the present survey.

The second unit of Early Wisconsinan age described by Westgate and Dreimanis consisted of interbedded loam to silt-loam tills (till B) and stratified sediments; the tills were assigned to the Erie Lobe on the basis of lithology and ice flow features, and correlated with the Canning Till (Karrow 1963a) of the Brantford area and with the Bradtville Drift of the Lake Erie area (Dreimanis *et al.* 1966).

Canning Till

This till was defined by Karrow (1963a) as a fine grained till occurring beneath Catfish Creek Till in the Brantford area. It outcrops at only a few places within the Woodstock area where correlation between localities is primarily by color, texture, stratigraphic position, compaction, and the manner in which pebbles and grit break cleanly from enclosing matrix. It is generally a dark greyish brown (10YR 3/2 – 10YR 4/2) clayey silt[1] till which is very stiff to extremely stiff and contains about 5 percent pebbles and grit. DiLabio (1971) found scant organic material in Canning Till from the Domtar quarry. Most occurrences of this till appear to represent remnant ground moraine. Observed thickness ranges from 2 to 18 feet; no estimates of maximum thickness are available though it probably does not exceed 30 feet in many instances. It was observed at sections W-1047, Domtar quarry (Figure 6, Photo 4) and possibly at W-380 where poorly exposed pebbly till-like material occurs beneath the Catfish Creek Till. Karrow (1963a) interpreted the lowest unit at his section P-4 (approximately W-1228 of this report) as Canning Till. No distinct break was found between this till and the overlying Catfish Creek Till and it is not known whether in fact it is Canning Till or fine grained Catfish Creek Till e.g. Karrow (1968a).

[1]Textural descriptions follow the scheme of Elson (1961), although granulometric boundaries (between sand and silt 0.062 mm. and between silt and clay 0.002 mm) used here differ from those of Elson.

Table 2 SUMMARY OF TILL ANALYSES IN WOODSTOCK AREA
(N=sample size, R=range, M—mean)

Till	Grain Size Analysis								Carbonates				
		Clay %		Silt %		Sand %		Md. mm		Total %		Ratio Cal:Dol	
	N	R	M	R	M	R	M	R	N	R	M	R	M
Zorra	48	7–36	16.5	32–59	44.9	17–57	37.9	0.0049–0.10	48	30–53	40.8	0.4–1.7	0.85
Port Stanley	36	15–46	30.2	39–63	53.0	2–29	16.8	0.0006–0.023	36	30–43	35.8	0.7–3.1	1.49
Catfish Creek	23	7–25	12.6	38–56	47.8	27–54	39.6	0.012 –0.080	23	36–53	44.6	0.3–1.2	0.69
Canning	3	23–28	25.3	46–54	50.3	23–26	24.3	0.008 –0.010	3	34–42	37.9	1.0–1.6	1.22

Till	Heavy Minerals					Pebble Lithology %													
		Total %		Magnetics %			Limestone		Dolostone		Chert		Clastic		Precamb.		Ratio Ls.:Dol	
	N	R	M	R	M	N	R	M	R	M	R	M	R	M	R	M	R	M
Zorra	48	1.1–6.7	4.8	5.2–15.7	10.1	42	22–68	46	13–75	39	0–21	6	0–9	2	2–20	7	0.3–4.0	1.5
Port Stanley	35	1.9–6.5	4.1	4.6–13.5	8.4	20	5–49	32	42–91	61	0–13	2	0–4	1	0–9	4	0.1–1.1	0.6
Catfish Creek	23	1.5–6.9	4.1	5.1–18.2	10.0	21	20–64	41	24–72	44	0–12	5	0–8	2	1–15	8	0.3–2.3	1.2
Canning	3	1.7–4.4	3.3	5.9–10.2	8.1	2	30–34	—	38–60	—	2–5	-	1–6	-	7–15	-	0.5–0.9	—

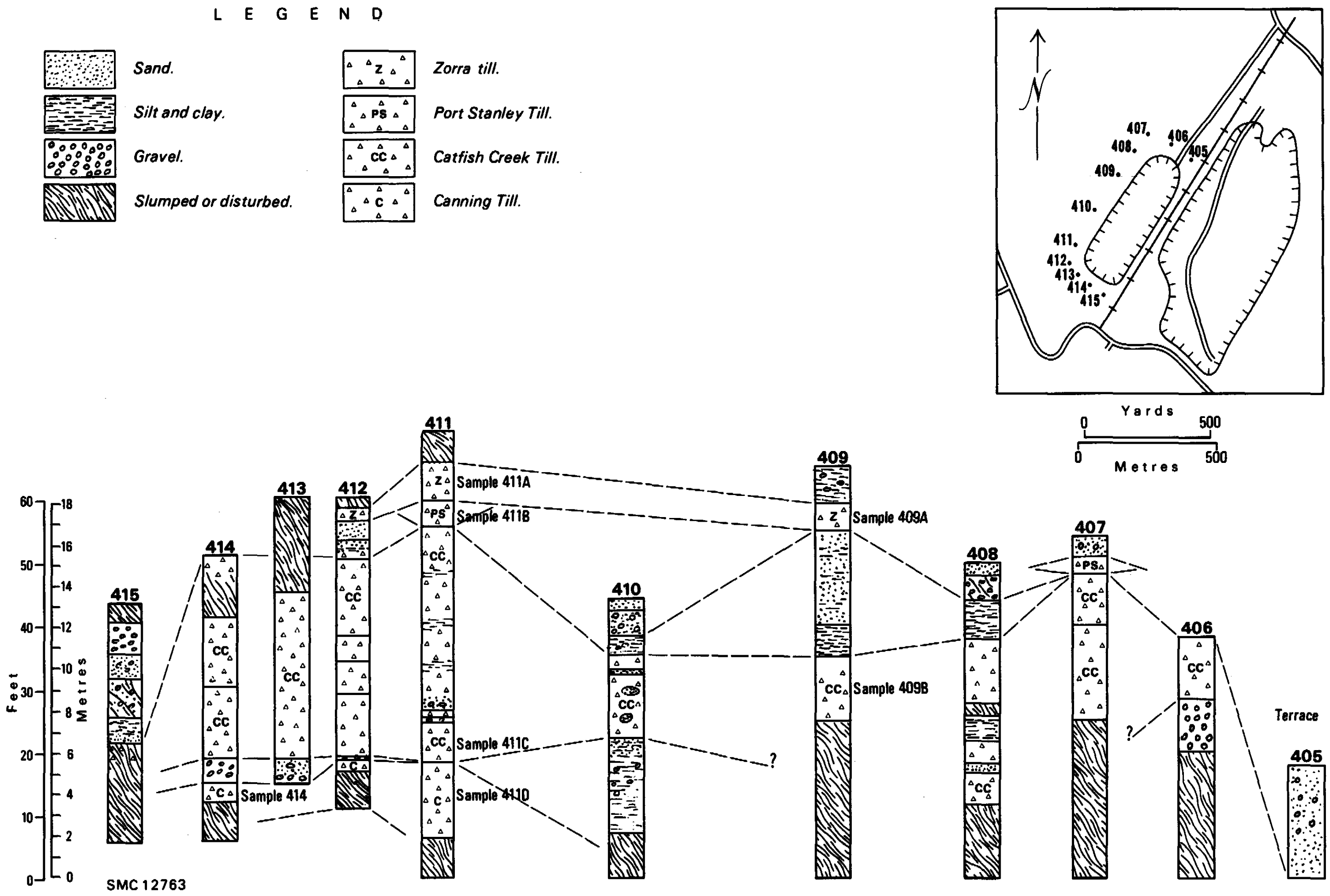

Figure 6–Late Pleistocene stratigraphy at Domtar quarry, Beachville.

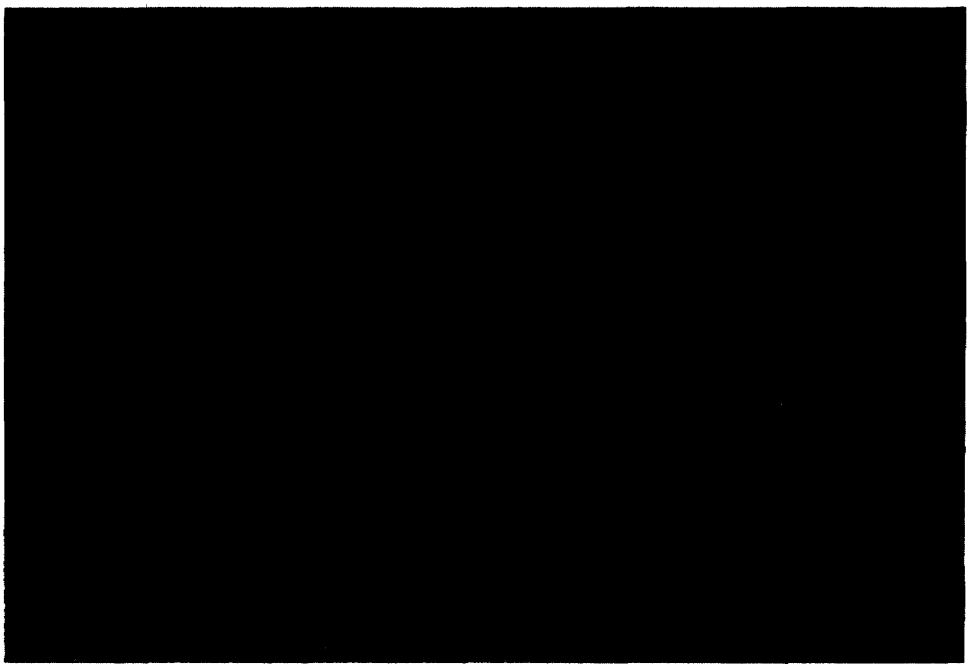

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Photo 4–Canning Till (a) outcropping at the Domtar quarry, Beachville (1969). Area shown is approximately that of Sections 411 and 412 Figure 6.

Westgate and Dreimanis (1967) correlated till 'B' at the Zorra quarry with the Canning Till. The intercalated stratified drift observed by them was not observed elsewhere during the present survey. The Canning Till is probably present to the north where Karrow (1971) has reported several pre-Catfish Creek tills.

The till is believed to result from ice flowing from the south or southeast (Erie lobe) during Early Wisconsinan time (Karrow 1963a). Striations on bedrock beneath the till at the Domtar quarry give ice flow directions ranging from 168 to 177°E but the till fabric at this site has a mean vector of 130 degrees. A small sample (25 pebbles) from section W-1047 gave a fabric with a mean vector direction of 035°E. Westgate and Dreimanis (1967, p.1137) suggest a flow direction of 105-150 degrees for till 'B' at Zorra.

This till has most recently been assigned to the Guildwood Stadial during the Early Wisconsinan Substage (Dreimanis and Karrow 1972).

MIDDLE WISCONSINAN TILL(S)

Middle Wisconsinan events (about 53,000 to 22,000 years B.P.; Dreimanis 1970a) within the southern Ontario region are best known at Port Talbot on Lake Erie (Dreimanis *et al.* 1966) and at Toronto (Karrow 1967; 1969). McDonald (1971) has summarized the present knowledge of this time interval for eastern Canada.

Within the Woodstock area very little is known about this interval. Westgate and Dreimanis (1967) considered tills 'C' and 'D' of the Canada Cement quarry to be of Middle Wisconsinan age. The lowermost of these, 'C', was described as a silt till, with high total carbonate content, and a possible Georgian Bay lobe origin. It was tentatively correlated with the Dunwich Till of the Port Talbot area. During the present survey no evidence of this till was encountered, however, it may be represented at section W-1047 by the till immediately overlying the Canning Till (sample 71047B) which was tentatively identified as Catfish Creek Till.

Till 'D' of Westgate and Dreimanis (1967) was also assigned to the Middle Wisconsinan Substage; for the purpose of this report this till is considered to be an early phase of the Catfish Creek Till.

LATE WISCONSINAN TILLS

Catfish Creek Till

The Catfish Creek Till was defined by Dreimanis (deVries and Dreimanis 1960) as the till sheet deposited by the earliest advance of the Late Wisconsinan glacier (Nissouri Stadial) following the Port Talbot Interstadial (*sensu lato*). Since then this till has been described throughout much of southern Ontario (e.g. Karrow 1963a; 1968a; 1971; Westgate and Dreimanis 1967; and Cowan 1972) and a physically similar till has been observed by the writer as far north as Grand Valley in the Orangeville area (Cowan 1971b). Throughout its outcrop area the Catfish Creek Till demonstrates a remarkable homogeneity of appearance and lithology which has rendered it invaluable as a stratigraphic marker horizon.

Due to shifting centres of dispersal during growth and decay of the ice sheet which deposited Catfish Creek Till the till displays varied fabric orientations, especially near Lake Erie. During maximum ice sheet development the ice apparently flowed from a northerly to northeasterly direction (Karrow 1963a; 1968a) and later, following lobation and a readvance from the Erie basin, a southeasterly fabric was imparted to the upper part of the till sheet (Westgate and Dreimanis 1967). Dreimanis (1961; 1970a) believed this last thrust formed the Dorchester Moraine which occurs in the Woodstock area at Banner. Recently Dreimanis (1971, p.159) has reported a still earlier phase of Catfish Creek Till containing northerly to northwesterly icethrust features. This has led the writer to relate till 'D' of Westgate and Dreimanis (1967) to the Catfish Creek Drift for the purposes of this report as it is lithologically and physically very similar.

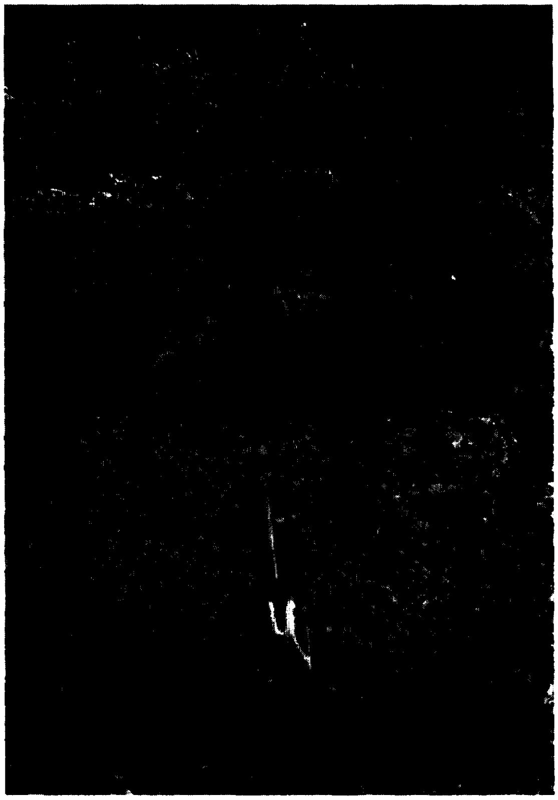
Within the Woodstock area Catfish Creek Till is a very stiff to extremely stiff, silt or sandy silt till containing lenses or stringers of sand; pebble lithologies (Table

Table 3

GRAIN SIZE DISTRIBUTION PARAMETERS FOR PRINCIPAL WOODSTOCK AREA TILLS.
(Mz is Graphic Mean grain size; σI is Inclusive Graphic Standard Deviation — a measure of sorting; SkI is Inclusive Graphic Skewness; and KG′ is Normalized Kurtosis calculated from Graphic Kurtosis: methods after Folk 1968 using extrapolated curves)

Till	Sample size	Mz(ϕ) $\overline{X}$	Mz(ϕ) S	Mz(ϕ) Range	$\sigma I(\phi)$ $\overline{X}$	$\sigma I(\phi)$ S	$\sigma I(\phi)$ Range	SkI $\overline{X}$	SkI S	SkI Range	KG′ $\overline{X}$	KG′ S	KG′ Range
Zorra	48	5.36	0.8	4.0 – 7.2	3.17	0.2	2.5 – 3.6	0.08	0.14	−0.24 – +0.32	0.47	0.03	0.42 – 0.59
Port Stanley	36	7.09	0.8	5.7 – 8.3	2.78	0.4	2.0 – 3.4	−0.09	0.10	−0.28 – +0.22	0.47	0.02	0.42 – 0.53
Catfish Creek	22	5.07	0.5	4.3 – 6.3	3.08	0.3	2.5 – 3.6	0.06	0.10	−0.21 – +0.28	0.49	0.03	0.43 – 0.54
Canning	3	6.53	—	6.4 – 6.8	3.17	—	3.0 – 3.3	−0.10	—	−0.05 – −0.15	0.43	—	0.40 – 0.46

Photo 5—Photograph of section W-348 (Appendix A). A is Port Stanley Till; B—Erie Interstadial lake beds; C—Catfish Creek Till; D—gravel.



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2) are similar to those reported elsewhere (e.g. Dreimanis and Karrow 1965). Its colour was observed to be quite variable ranging from greyish brown (10YR 5/2 – 2.5Y5/3)[1] to brown (10YR 4/3), yellowish brown (10YR 5/5), pale brown (10YR 6.5/3) or light olive brown (2.5Y 5/4). The till is generally less than 20 feet thick up to 40 feet has been observed. It occurs as remnant ground moraine, as cores of overridden drumlins, and in the Dorchester Moraine.

Grain size parameters (Table 3) show this till to be very poorly sorted, coarse skewed to fine skewed, platykurtic to leptokurtic, and having mean grain sizes within the fine to coarse silt range.

The Catfish Creek Till is frequently associated with glaciofluvial sands and gravels (Photo 5) and many economic deposits of such materials are related to this till. Its stoniness and generally coarse texture appear to be favourable for reworking into gravels of a suitable size grading.

As reported in the Brantford area (Cowan 1972, p.13) a reddish brown till-like material may occur at the upper surface of this till. This material is present in the Woodstock area and was observed in detail at sections W-348 and W-380. At W-348 the material was a reddish brown (5YR 5/4) substratified clayey silt till (?) containing silt balls and having a remarkably high content of magnetic material in the heavy minerals (Sample 348B). At section W-380 the material was a gritty clayey silt having a high concentration of red shale fragments. This material is now considered to be englacial debris deposited subaqueously into a proglacial lake as the ice sheet which deposited Catfish Creek Till retreated into the Erie basin at the start of the Erie Interstadial.

[1]Munsell Soil Color Charts, 1954, Munsell Color Company, Baltimore.

Port Stanley Till

Port Stanley Till was defined by Dreimanis (deVries and Dreimanis 1960) as a fine-grained till deposited during an Erie lobe advance following the Erie Interstadial. This till is generally correlated with the Hiram Till of northeastern Ohio and New York (Goldthwait *et al.* 1965) and is now assigned to the Port Bruce Stadial (Dreimanis and Karrow 1972). Within the Woodstock area it is a stiff to very stiff clayey silt or silt till usually 4 to 20 feet thick with a maximum observed thickness of 35 feet; up to 90 feet is indicated by well records in end moraines. It occurs as rolling to hummocky end moraine or as ground moraine plains.

The lateral extent of this till sheet is not fully determined but it extends from near Brantford on the east and Lake Erie on the south to west of Woodstock. In the area west of Thames River this till apparently outcrops at the Domtar quarry (Figure 6) and was interpreted as occurring at the Canada Cement quarry by Westgate and Dreimanis (1967). Dreimanis (1959, p.28) suggested that the till sheet extends to St. Marys northwest of the Woodstock map-area, however, more recently he reports (Dreimanis 1970b) that the Port Stanley Till has its outer limit at the Ingersoll Moraine in the St. Thomas map-area. From the present survey it would appear that the ice that deposited this till sheet may have advanced as far west as Embro but this is not entirely certain.

Lithologically the till (Table 2) generally contains less clay and has a lower carbonate ratio than reported by Dreimanis and Karrow (1965) but is similar to that of the Brantford area (Cowan 1972). Trend surface analysis of the carbonate content (Fig. 7) indicates a general increase in calcite and total carbonates from east to west (data used only include that as far west as the Domtar quarry). This is believed to result in part from the higher calcite content of the underlying Devonian terrain as the Devonian-Silurian contact is crossed (Fig. 2) in contrast to the lower carbonate content of the Salina Formation, especially the shale units (Parks 1903). Though statistically significant at the 95 percent level, the surfaces provide low explanation percentages indicating a considerable scatter of data about the trend.

The till varies in colour from dark grey or grey (10YR 4/1–5/1) to dark brown (10YR 3/3), brown (10YR 4/3) or yellowish brown (10YR 5/4). The colour changes are primarily the result of oxidation which extends to a depth varying from 7 to 15 feet. In upper weathered parts black, pink, or bluish grey clay films may occur on bed surfaces.

Grain size properties (Table 3) indicate that mean grain sizes fall in the medium silt to coarse clay grades, and that the till is very poorly sorted, coarse skewed to fine skewed, and platykurtic to leptokurtic.

Vertical variations in the texture of the Port Stanley Till are common within the area. Examples of this are sample sites 379 and 72565. At the former locality about 35 feet of Port Stanley Till is exposed; sample 379A, taken about 5 feet below the surface contains 25 percent sand and 27 percent clay but sample 379B, obtained 15 feet below the surface contains 7 percent sand and 43 percent clay. Also the calcite to dolomite ratio of the lower sample is considerably greater than that of the upper sample. Translocation of clay was not apparent at the upper sample

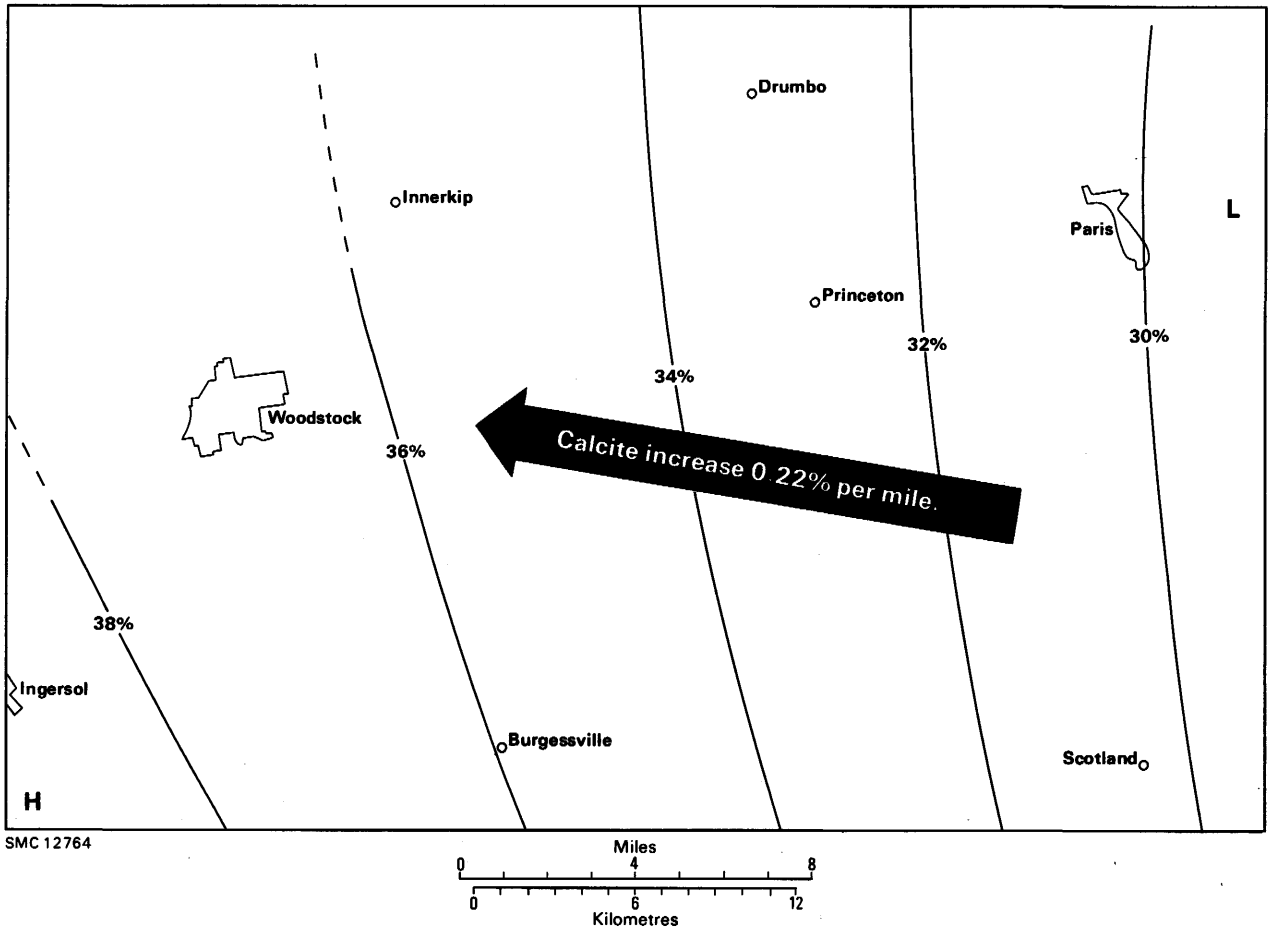

Figure 7–Second order trend surface of total carbonate content (minus 200 mesh) in Port Stanley Till. Arrow superimposed indicates direction and rate of increase of calcite from first order trend surface. Second order surface is statistically significant at the 99 percent level with a 28 percent explanation; the first order surface is significant at the 95 percent level.

site though clay films are present on ped surfaces elsewhere. At sample site 72565 a similar occurrence was recorded. Here the upper sample taken four feet below the surface contains 19 percent clay, whereas the lower sample taken 8 feet below the surface contains 42 percent clay. Similarly samples 395, 396 and 397 were taken from a series of adjacent road cuts in which the till was noticeably coarser upwards. Samples 395 and 397, taken from the upper part of the exposures, contain 12-16 percent less clay than sample 396 from the lower part; in these samples the silt content remained relatively constant.

These textural variations are of considerable interest. As observed by the writer, only one till unit comprises Port Stanley Till in the Woodstock and Brantford areas whereas closer to Lake Erie Dreimanis (1959; 1971) has delimited three major till units in the Port Stanley Drift. North of the Woodstock area Karrow (1968c, 1971) has considered the possibility that two till units may constitute the Port Stanley Till; a lower clay till and a possible upper silty sandy unit not dissimilar to the Wentworth Till. As no sections have been reported by Karrow (1971, p.7) establishing this relationship, consideration must be given to the data presented herein to the effect that texture may vary considerably within the Port Stanley Till at a single sample site and that a consistent vertical variation could exist over an extensive area.

Throughout much of the area Port Stanley Till overlies undisturbed Erie Interstadial glaciolacustrine sediments (Photos 5 and 8). However, at section 1046 the underlying stratified sediments are overturned towards the northwest indicating ice flow from the southeast. This agrees with end moraine orientation; till fabrics on the other hand vary from northeasterly to southeasterly though all have an easterly component.

Distinguishing properties of this till are its low sand content, low dolomite content in the silt-clay grade, and skewness. It is however difficult to separate this till from Canning Till or Zorra till in certain situations.

Port Stanley Till was used for the impermeable core of the new dam recently constructed at Woodstock.

Ablation Till

A number of small patches of ablation till were mapped in the area south and east of New Durham. Generally this material was observed to be stony to bouldery loam (Photo 6) overlying either sand ridges of probable ice-contact origin or Port Stanley Till. It generally ranged from one to four feet in thickness and was quite sporadic in distribution. The only exposure sampled (sample 349B) was three to four feet thick and overlay Port Stanley Till (sample 349A). At this location it appears to be substratified near its base, has a carbonate ratio significantly different from the underlying till and has an anomolously high chert content in the pebble grade. Taken together with the high angularity of much of the boulder fraction the material is believed to represent englacial debris deposited as ablation till during local wastage of the ice sheet which deposited the Port Stanley Till, probably at the time of construction of the Norwich Moraine.

An alternate origin for the material occurring at lower elevations is that of reworking of underlying till by Glacial Lake Whittlesey. This might be feasible for

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Photo 6–Bouldery ablation till overlying glaciofluvial sands one mile southwest of New Durham. Till is about 2½ feet thick.

part of the material but would not account for the material shown in Photo 6 or for the lithologic differences evident in samples 349a and b.

Similar material has been mapped by Dreimanis (1972) in the Port Stanley area.

Zorra Till

The name Zorra till is here used informally[1] for a till sheet mantling much of east and West Zorra Townships. The till was first described by Westgate and Dreimanis (1967) as the uppermost till, till 'I', at the Canada Cement quarry, Zorra, where it occurs as a thin sandy silt till of Huron lobe affinity overlying a till of similar lithology referred to as till 'H' in their report. The Canada Cement quarry is a principal reference section for this till. Though defined as the mappable surface till, Zorra till is believed to include both 'H' and 'I' of Westgate and Dreimanis (1967) as no strong evidence for two Huron lobe till sheets younger than Catfish Creek Till was found. However, interbedded stratified drift is common. Support for this interpretation is found in the Stratford area to the north where Karrow (1971) reports that adjacent to the Woodstock area, only one till, till 'T', overlies Catfish Creek Till.

[1]This till is to be formally named Tavistock Till by P. F. Karrow in Geol. Soc. America Bull., vol. 85, p.761-768, May 1974.

ODM 8936

Photo 7–Fissile structure in Zorra till.

Zorra till is a very stiff, commonly fissile (Photo 7), stony, silt or sandy silt till, which is locally quite clayey near its base. It is usually leached of carbonates to a depth of about one foot and partially leached to a depth of 3½ feet. Its colour varies from dark brown (10YR 4/3) to brown (10YR 5.5/3), dark yellowish brown (10YR 4/4) or yellowish brown (10YR 5/4); it is observed most frequently in an oxidized state. Mean grain sizes fall within the coarse to fine silt range. The till is very poorly sorted, coarse skewed to strongly fine skewed, and platykurtic to leptokurtic (Table 3). The till occurs as ground moraine or in drumlins and is usually less than 20 feet thick.

Tillite pebbles and cobbles are commonly observed erratic materials within this till; these also occur in Catfish Creek Till but are not as common. Black to dark brown shale fragments believed to be derived from the Kettle Point Formation (Devonian) beneath Lake Huron occur in the till. These erratics are believed to be distinctive of the Zorra till. Although the same rock unit occurs beneath Lake Erie the shale fragments have not been identified in Erie lobe tills during the present survey though Dreimanis (1959, p.28) reports that black shale is common in the Port Stanley Till near Lake Erie. However it may occur in the sand fraction of gravels in the Woodstock map-area (Table 6).

During field mapping it was noted that the till was somewhat finer textured in the western part of the map-area, where it was commonly observed overlying silts and clays, than in the eastern part of the area where it overlies glaciofluvial sand and gravels. Trend surface analysis (Figure 8) partially substantiates this field interpretation. The surfaces show a decrease in silt content and an increase in sand content from northwest to southeast. The second order surface is statistically significant at the 95 percent level whereas both first order surfaces are significant at the 99 percent level; explanation percentages are low indicating a considerable scatter within the trends. The surfaces are dependent on field interpretation of lateral extent of the till sheet for input data.

Near its eastern margins, where deposition took place under thin ice conditions, the till frequently overlies sand and occurs in a soft condition where it is best described as a pebbly, gritty sand or loam. In these circumstances the till may only be identified by its lateral continuity and by the lack of sorting of the matrix.

Lateral limits of this till sheet are not entirely certain. The southwestern boundary occurs at a meltwater channel just east of the present day Thames River (Middle Branch). East of Thames River mapping was based mainly on lateral continuity from a few suitable outcrops as multiple till sections are rare (e.g. Section 1435). Water-well records lend support to the present interpretation but these are considered weak evidence.

Two water-well records and their interpretations are given below (data from Ontario Ministry of Environment).

(1) lot 5, Concession IV, West Oxford Township (G.R. 195680)

Thickness (Feet)		Well Log	Writer's Interpretation
48	0- 48	gritty brown clay	Zorra till
5	48- 53	dirty gravel	gravel
51	53-104	gritty grey clay	Port Stanley Till
30	104-134	gritty hard pan	Catfish Creek Till
9	134-143	grey clay	clay or till
5	143-148	grey limestone	limestone

(2) lot 16, Concession IV, West Oxford Township (G.R. 151622)

Thickness (Feet)		Well Log	Writer's Interpretation
15	0- 15	brown clay	Zorra till
60	15- 75	blue clay	Port Stanley Till or/and lacustrine sediments
115	75-190	hardpan stones	Catfish Creek Till and other tills
34	190-224	limestone	limestone

A third well giving further information is reported in a later section.

The lithologic similarity of Zorra till to Catfish Creek Till (Table 2) in some areas indicates that allowance must be made for unmapped inliers of the older till within the area mapped as Zorra till. Discriminant analysis between these two tills

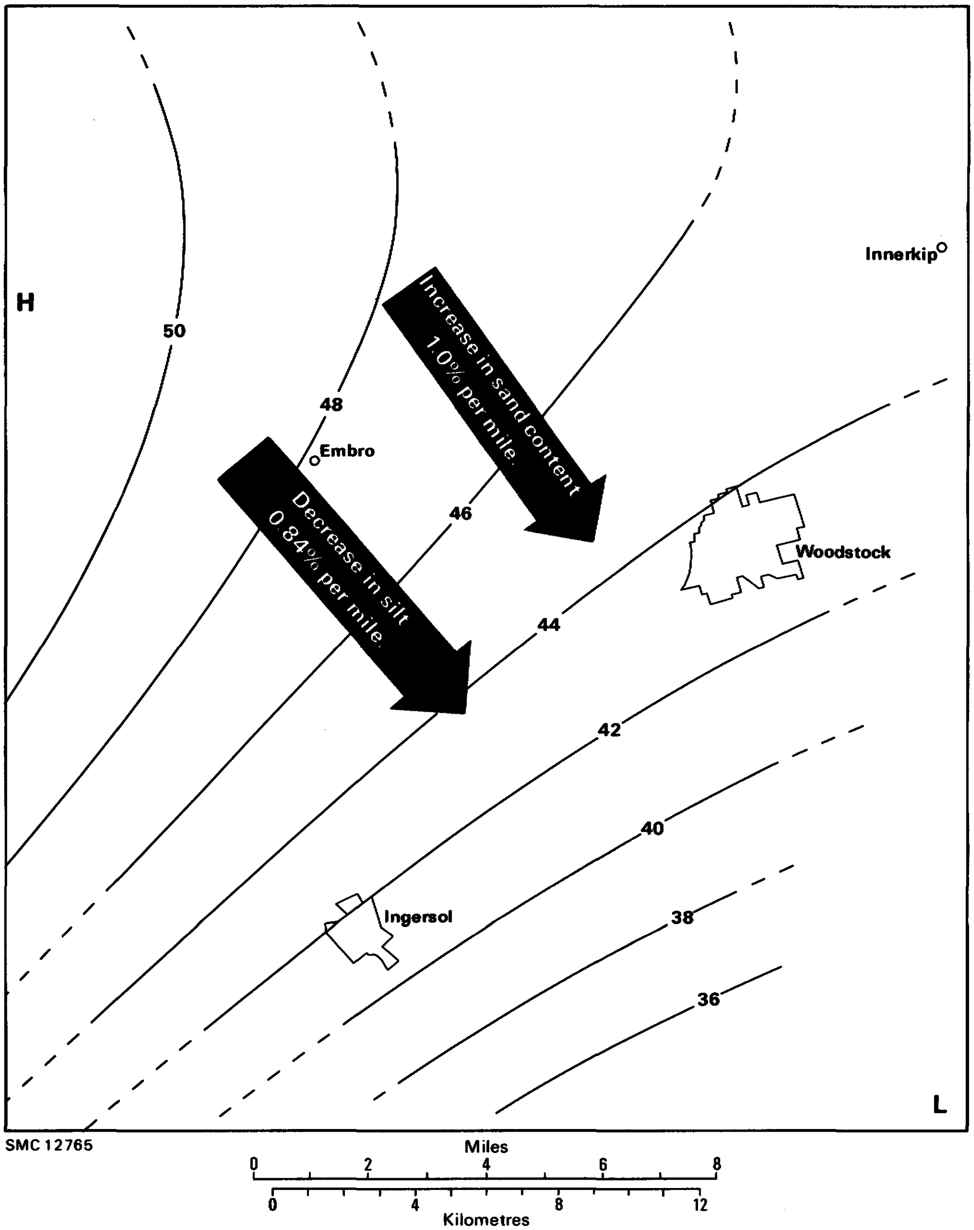

Figure 8–Second order trend surface for silt content (percent) in Zorra Till. Superimposed arrows give rates and directions of first order surfaces for silt decrease and sand increase.
Second order surface for silt is significant at the 95 percent level with a 31 percent explanation. Both first order surfaces are statistically significant at the 99 percent level.

provides only about 60 percent separation with the following parameters being most useful discriminators in descending order; percent clay, skewness, mean grain size, total heavy mineral content, total carbonate content, and percent magnetics in heavy mineral fraction. Zorra till usually may be distinguished from Port Stanley Till by differences in sand content, dolomite content, percent magnetics in heavy mineral fraction, and sorting.

Zorra till is thought to have been laid down by an advance of the Huron lobe during and perhaps following the advance of the Erie lobe which deposited Port Stanley Till (Port Bruce Stadial). The two ice sheets may well have met between Thames River and the Ingersoll Moraine. Correlation of the Zorra till beyond the area is indefinite, but recent work in the Orangeville area to the north (Cowan 1971b) suggests that Zorra till is approximately equivalent in age to that till flanking the west side of the Orangeville Interlobate Moraine ('northern till' of Karrow 1968a; till 'C' of Karrow 1971). This interpretation is also held by Karrow (personal communication 1971; Terasmae *et al.* 1972). No correlative till from Michigan is known at this time.

Age relationships in the Woodstock area are derived from a few exposures where Port Stanley Till is believed to underlie Zorra till. These occur at the Domtar quarry, the Canada Cement quarry (Westgate and Dreimanis 1967), possibly section W-1435, and others. In addition a few localities were noted where inclusions of possible Port Stanley Till were found in Zorra till near its eastern margin. These interpretations are subject to future revision however. In any case, Zorra till in the Woodstock area is younger than Catfish Creek Till and approximately contemporaneous with Port Stanley Till though possibly overlying it at its outer margin. In the Guelph area to the north, Karrow (1968a; Terasmae *et al.* 1972) reports that till equivalent to the Port Stanley Till overlies Georgian Bay lobe till (till 'C') near its outermost margin which, as stated above, is believed equivalent to the Zorra till. This relationship was further confirmed by the writer during the summer of 1972. The discrepancy in relationships between the Woodstock and Guelph areas is not considered problematic in view of the fluctuating nature of the ice sheet margins at this time and the distance between the two areas, but it does suggest that drilling and more detailed work would be helpful in confirming relationships.

Unclassified Till

A number of areas shown on Map 2281 consist of till not assigned to stratigraphic units. These assignments have not been made due to mixed lithologies in the interlobate area, the occurrence of inliers or outliers having intermediate lithologies, uncertainties about stratigraphic relationships, and due to uncertainties regarding outer limits of certain till sheets i.e. glacial advances.

These tills fall into two groups, sandy silt tills and clayey silt to silty clay tills. The sandy silt till areas occur near or beyond the interpreted outer limit of Zorra till to which some of these areas presumably relate; the remainder are inliers of Catfish Creek Till. Fine-grained tills occurring in the northwesternmost part of the map-area are possibly a more clayey basal facies of Zorra till while those of the Embro-Ingersoll area may be Port Stanley Till. Some or all of these fine-grained till areas may correlate with till 'H' of the Stratford-Conestogo area (Karrow 1971) which has not been identified by the writer within the Woodstock area.

Glacial Land Forms

END MORAINES

A number of end moraines are present within the Woodstock area. Taylor (1913) traced the Ingersoll Moraine into the Woodstock area and Chapman and Putnam (1943a) extended Taylor's St. Thomas Moraine into the map-area and named and mapped the Norwich Moraine and its extension into the present map-area. More recently Dreimanis (1961; 1970b; Westgate and Dreimanis 1967) has mapped a moraine in the northeastern part of the St. Thomas area, the Dorchester Moraine, which extends into the Woodstock map-area at Banner. In addition a number of remnants of morainal materials are present within the map-area suggesting local ice marginal positions.

The Dorchester Moraine is apparently the oldest moraine within the map-area. In the St. Thomas area this moraine consists primarily of Catfish Creek Till and Dreimanis (1970b) considers the moraine to represent a late thrust of the Erie lobe during the Nissouri Stadial. At Banner the moraine consists primarily of ice-contact stratified drift (mainly sand) with till outcropping locally. East and northeast of the middle branch of the Thames River the extension of the Dorchester Moraine is somewhat uncertain. One possibility is that it occurs beneath the till cover mapped in West Oxford Township and follows a northeasterly trend east of the Thames River finally occurring as scattered kames in the area west of Drumbo. In any case it is believed that a buried moraine containing large quantities of stratified drift is present in the area mentioned and will be discussed later. Chapman and Putnam (1966, p.231) considered this zone to be an overridden older moraine.

The Erie lobe advance which deposited the Port Stanley Till left three end moraines within the Woodstock area, the Ingersoll, St. Thomas and Norwich Moraines. Within the map-area all are believed to represent stillstands during retreat of the ice from its maximum extent. The eldest and best developed of these, the Ingersoll Moraine, enters the map-area west of Holbrook, swings northerly and broadens west of Oriel and Eastwood and continues northeasterly toward Drumbo. It is breached by meltwater channels north of Holbrook, near Oxford Centre, and by Horner Creek north of Gobles. In the bulky sections of the moraine well records indicate that up to 90 feet of Port Stanley Till is present southwest of Eastwood and up to 75 feet two miles south of Oxford Centre. Near Drumbo the Port Stanley Till capping the Ingersoll Moraine is frequently thin overlying stratified drift; till thickness here is generally less than 35 feet and in some instances was found to be only two or three feet.

St. Thomas Moraine enters the map-area south Burgessville and abutts against the Ingersoll Moraine near Oriel. It is poorly defined and difficult to trace and north of Highway 2 it is absent. Either the Moraine was never built in this area or the ice stood at the Ingersoll Moraine for a longer period in the north while retreating to the St. Thomas Moraine position to the south. The Port Stanley Till is up to 90 feet thick in parts of this moraine north of Vandecar.

The next youngest moraine, the Norwich Moraine, is not well defined within the area. In the New Durham area it comprises a weakly developed ridge and much of the material mapped as ablation till is associated with it. North of New Durham the moraine is largely buried by the sands of Lake Whittlesey where it consists of till islands within these sands. South of Princeton the moraine consists of a number of kames.

No well defined moraine marks the outer margin of the Huron lobe advance which deposited the Zorra till. Locally small areas of kames on outwash deposits mark the outer margin though for the most part the drift border is attenuated. As mentioned previously, a buried moraine is believed to exist east of the Thames River beneath the till cover. If the extension of the Zorra till east of the Thames River is accepted, then a second origin for the buried moraine may be suggested. At the Innes pit on Gore lot, concession I, West Oxford Township jasper conglomerate of presumed Huron lobe affinity was found in the gravels; similarly, numerous tillite boulders, again of presumed Huron lobe origin, were found in a stone pile at a former gravel pit on lot 1, concession I, West Oxford Township at an elevation of 1200 feet. These sediments are considered to be part of the buried moraine. From this and other evidence it might be suggested that much of the buried moraine may be related to a Huron lobe source and has since been overridden. A further speculation is that the moraine may be interlobate between the ice sheets which deposited the Port Stanley Till and the Zorra till, and later overridden by the Huron lobe. As stated previously Zorra till is believed to be approximately time equivalent to the till flanking the west side of the Orangeville Moraine to the north (northern till of Karrow 1968a); this would make a hypothetical buried interlobate moraine approximately correlative with the Orangeville Moraine.

Other morainal materials occur in the northwesternmost part of the Woodstock area. In the Harrington West area, ice-contact stratified drift apparently represents ice-marginal processes associated with meltwater channels. These deposits are part of the Lakeside Moraine mapped by Chapman and Putnam (1951). Ice-contact deposits mapped adjacent to a meltwater channel running east from Brooksdale appear to represent a zone of weakness in the Huron lobe ice sheet during retreat.

GROUND MORAINE

Much of the surface topography of the Woodstock area is characteristic of ground moraine or ground moraine plains. These areas comprise much of the terrain mapped as Port Stanley Till and Zorra till.

Within the Port Stanley Till sheet two principal areas of ground moraine plain exist, both located between St. Thomas and Norwich Moraines. The first of these lies north and east of Princeton between Horner Creek and Nith River. Here the ground is flat to gently rolling with elevations between 925 and 1000 feet; relief is generally less than 25 feet and the till ranges from 20 to 50 feet thick. This unit is crossed by a meltwater channel running between Richwood and Princeton which apparently marks an ice marginal position intermediate between St. Thomas and Norwich Moraines. A few flutings, indicating a southeast to northwest flow direction, occur north of Princeton.

The second area of ground moraine plain underlain by Port Stanley Till lies south of Gobles between Vandecar and New Durham where it is very flat and occurs at elevations between 900 and 950 feet. Much of this area has a veneer of thin glaciolacustrine or local pond deposits which smooth the original topography considerably. The till here ranges from 15 to 50 feet thick.

Most of the west half of the area consists of Zorra till ground moraine described by Chapman and Putnam (1966) as the Oxford till plain. West of the Thames River this ground moraine occurs at elevations between 950 feet and 1175 feet. Relief is less than 25 feet except adjacent to incised meltwater channels. Scattered glacial flutings and drumlinoid ridges having northwest to southeast long axes dot the ground moraine; these rarely exceed 25 feet in relief. Locally, veneers of eolian silt or glaciolacustrine sand and silt serve to smooth the original relief of this physiographic unit.

East of Thames River the area mapped as Zorra till contains much of the Woodstock drumlin field and may be described as drumlinized ground moraine. Elevations here range between 950 and 1200 feet with somewhat lower elevations within meltwater channels. The drumlins provide a local relief of up to 75 feet. Much of this area is veneered with eolian fine sand and silt.

STREAMLINED DRIFT FORMS

Streamlined landforms indicating direction of ice flow occur as drumlins and flutings within the Woodstock area; the former form positive features above the surrounding ground moraine while the latter consist of alternating furrows and ridges which do not rise noticeably above the surrounding ground moraine plain.

The Woodstock drumlin field was mapped by Chapman and Putnam (1951) who considered the drumlins to be of Erie lobe origin, apparently because much of the till mantling them gives rise to the Guelph loam as in the Guelph drumlins, and because stoss and lee relationships indicate ice flow from southeast to northwest. Recently Westgate and Dreimanis (1967, p.1138) pointed out that the drumlins have stoss ends pointing in two directions and suggested that the drumlin field is of composite origin formed primarily by an Erie lobe advance and later modified by a Huron lobe advance. From Figure 9 it is apparent that drumlin morphology in this area is not diagnostic.

In examining Ontario drumlins Trenhaile (1971) found that nearly 20 percent have lee slopes steeper than stoss slopes. Elsewhere drumlins with reversed stoss and lee relationships are not uncommon.

During the present survey many observed drumlins were capped with a thin veneer of Zorra till and were cored with stratified drift of glaciofluvial origin or older till. Karrow (1968a) also noted drumlins cored with older tills in the Guelph drumlin field. As pointed out previously where Zorra till overlies sand or gravelly sand, as in several of the drumlins, it may be soft and loose and not distinctly recognizable.

Most of the drumlins occur within West Oxford Township south of Woodstock with lesser numbers lying between Thames River and Mud Creek. The drumlins are mainly 0.3 to 0.7 miles long, 0.25 to 0.5 miles wide, and 20 to 75 feet high though variations beyond these figures may occur. It is not known what percentage of the drumlins are simply overridden older drumlins, as many of the drumlins, particularly those cored with stratified drift, are believed to be erosional in origin and formed during the advance of the Huron lobe at the time of deposition of the Zorra till. Long axis orientations of these drumlins range from 280 to 330 degrees.

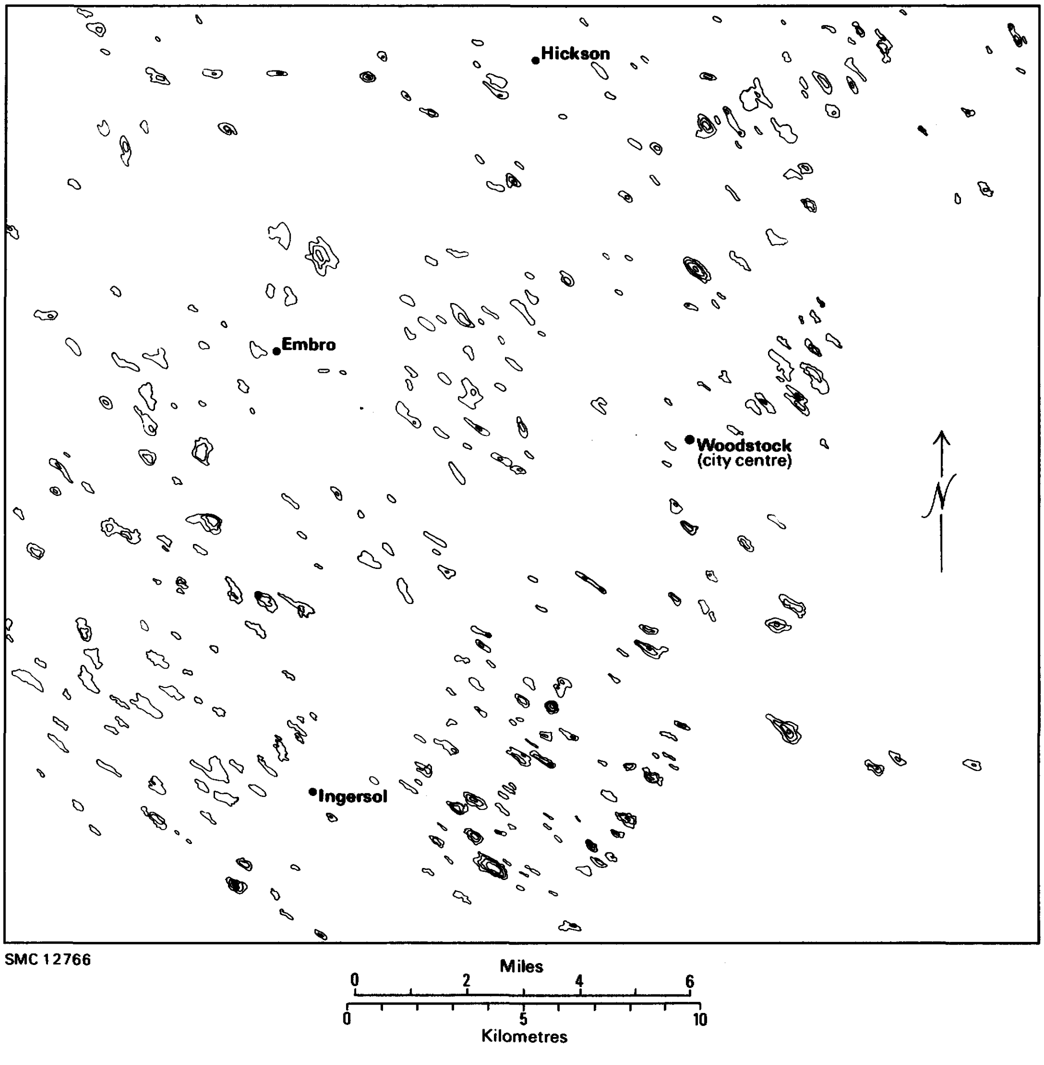

Figure 9–Sketch map of Woodstock drumlin field.

Glacial flutings occur primarily in North Oxford and East Zorra Townships with a lesser number in West Zorra, Blandford and Blenheim Townships. Except in the latter township, most of the flutings occur in Zorra till and have long axis orientations similar to the drumlins. These features are generally in the order of 0.25 to 0.5 mile long and are very narrow with minimal relief.

A few flutings occur north of Princeton on ground moraine consisting of Port Stanley Till. These indicate ice flowing along a southeast (130-150°E) to northwest axis.

Glaciolacustrine Sediments

The incursion of ice sheets into the various basins of the Great Lakes system resulted in blockage of natural drainage and formation of large proglacial lakes at numerous times during the Pleistocene. Considerable attention has been given to the history of these lakes. Dreimanis (1969) has discussed the known data on Sangamon Stage to Mackinaw Interstadial lakes in the Erie and Ontario basins and numerous papers have been written on the Glacial Great Lakes related to Port Bruce Stadial and later events. The most recent general summaries of these latter events are found in Hough (1958; 1963), Wayne and Zumberge (1965), Calkin (1970) and Prest (1970). Lacustrine sediments are found throughout the Pleistocene section in the Woodstock map-area though the area was generally subject to fewer inundations because of its relatively high topographic situation.

ERIE INTERSTADIAL BEDS

The name Erie Interstadial was proposed by Dreimanis (1958, p.81; 1959, p.28) to define a significant glacial retreat in the Erie basin during which glaciolacustrine sediments were deposited on top of the Catfish Creek Till and following which glacial advance and the deposition of the Port Stanley Till took place. Morner (1970) has since defined a type section for this interstadial near Plum Point, Ontario with a suggested date of about 15,500 years B.P. Evidence presented by Dreimanis (1969) led him to conclude that several lake phases occurred in the Erie basin during this interstadial.

Within the Woodstock map-area there is considerable evidence to indicate the presence of glacial lakes or local pondings at this time (photos 5 and 8; e.g. sections W-380, W-348, Appendix A). The sediments are either sandwiched between Port Stanley Till and Catfish Creek Till or occur beneath Port Stanley Till in shallow exposures. Many of these occurrences may represent only local pondings during advance of the ice prior to deposition of Port Stanley Till, however, those occurring along the principal drainage lines may well represent extensions or embayments of larger Erie basin events. The elevation of the sediments supports the possibility that much of the area was completely inundated during the deeper lake phases, especially in the east half of the map-area. For instance, Dreimanis (1959, p.28) reports Erie Interstadial sediments at elevations between 870 and 890 feet near London; at Woodstock, sediments in a suitable stratigraphic position occur at 950-

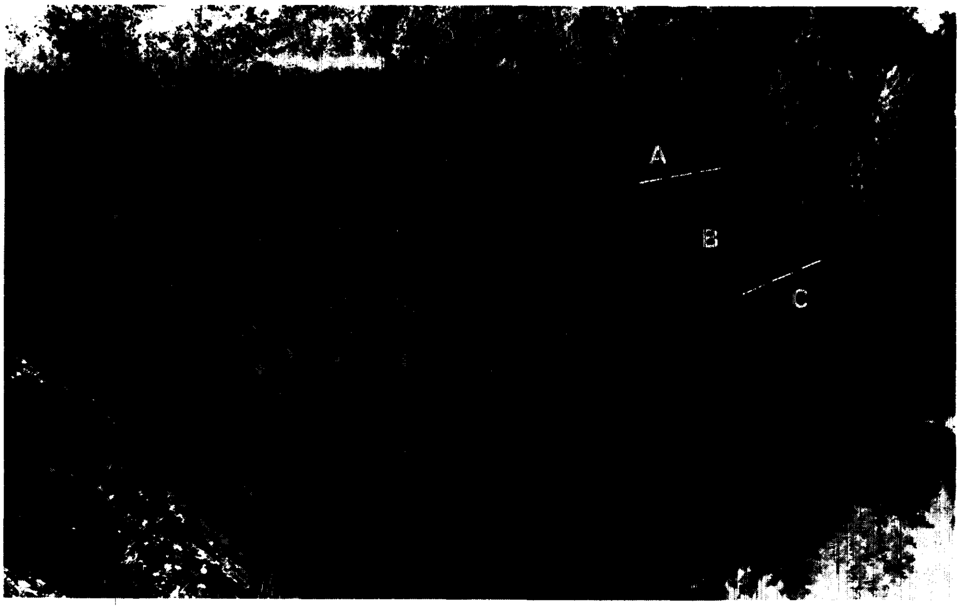

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Photo 8–Photograph of section W-380 (Appendix A). A is Port Stanley Till; B—Erie Interstadial lake beds; C—Catfish Creek Till and older sediments.

970 feet. This is a gradient within expected limits of postglacial rebound. Similarly, lacustrine sediments of presumed Erie Interstadial origin occur at about 850 feet at section W-348 (Appendix A) and at about 930 feet at section W-380 on Horner Creek which gives a gradient of about 4.5 feet per mile over a north-south distance of about 18 miles. This gradient is comparable with uplift rates given by Karrow (1963a) for Lake Warren and by Dreimanis and Karrow (1965) for several late glacial lakes in the Erie basin. These gradients, though not establishing water-plane elevations, allow the conclusion that much of the Woodstock map-area, particularly the lower parts of the east half and the Thames Valley, was inundated by glacial lakes during the Erie Interstadial.

The sediments vary from crosslaminated fine sands to laminated or varved clay and silt. Thicknesses are in the range of three to 20 feet.

LAKE MAUMEE I SEDIMENTS

Lacustrine silts observed in the Thames River valley (Middle Branch) one mile south of Thamesford are tentatively correlated with Lake Maumee I. These occur in the river bank at elevations near 900 feet. Dreimanis (Dreimanis and Karrow

1965, p.100) has reported Lake Maumee I deltaic gravels in the Thames Valley about two miles west of Thamesford. Here the gravels were deposited on Catfish Creek Till at elevations of 915 to 930 feet in an embayment of Lake Maumee I called Lake London. Dreimanis (1964) suggested that the highest Maumee level (I) probably occurred near the end of the Erie Interstadial prior to advances during the Port Bruce Stadial. Lake Maumee sediments in the area under consideration were described Chapman and Putnam (1943b; 1949; 1951; 1966).

LAKE WHITTLESEY SEDIMENTS

The large area of lacustrine sand plain mapped in the southeasternmost part of the map-area consists of medium to fine sand and silty sand largely laid down in Glacial Lake Whittlesey about 13,000 years ago. The sands are of deltaic and near-shore origin, range from five to 25 feet in thickness, and generally overlie Port Stanley Till. Abandoned shore features are extremely rare; this is related to the low slopes of the ground moraine upon which shore feature would normally develop and to the fact that the part of the Lake Whittlesey shoreline located in the Woodstock area is in the upwind position.

The sands occur at elevations of about 825 feet in the southernmost part of the area and at 875-900 feet southeast of Princeton and in the western part of the Brantford area (Cowan 1972) where the Lake Whittlesey shoreline was reported to be at an elevation of 900 feet near Paris. The elevation gradient on the sand plain is about four to five feet per mile which compares with gradients given by Karrow (1963a) for Lake Whittlesey shoreline features in the Galt area. Most of the sand mapped at higher elevations in the Gobles area is believed to be outwash deposited in front of the Norwich Moraine.

POND SEDIMENTS

Stratified fine sand or clayey silt overlie much of the poorly drained ground moraine plains occurring at lower elevations, principally in that area between the Norwich and St. Thomas Moraines south of Gobles and locally on the ground moraine northwest of Thames River. Some of these represent deposition into small glacial lakes but others, frequently shell bearing, represent the infilling of small postglacial ponds with slopewash or other locally derived materials. The sediments in most of these ponds are usually in the order of three to five feet thick but may be as much as 10 feet. Pond sediments also occur at the base of many bogs.

In addition to those areas mapped, lacustrine sediments overlie a considerably larger area, however the thickness or areal extent of these is insufficient to map as separate units at the present scale.

Glaciofluvial Features

MELTWATER CHANNELS

The most striking landforms occurring within the Woodstock map-area are deeply incised glacial meltwater channels, notably those now occupied by the underfit streams of Thames River (South Branch) and Mud Creek. These channels were first described by Chapman and Putnam (1943a) who later (1949 *et seq.*) attributed their formation to meltwaters derived from the Erie lobe as it retreated to Ingersoll Moraine from a position further west during what is now known as the Port Bruce Stadial. The present interpretation is that these two channels were eroded during recession of the Huron lobe following deposition of the Zorra till and probably mark stillstand positions during retreat. If Port Stanley Till is present in subcrop as far west as suggested herein then these meltwater channels may have been cut initially by Erie lobe meltwaters and reoccupied at a later date.

West of Thames River a number of smaller meltwater channels drained into these major channels. One channel of particular interest occurs south of Thamesford and runs parallel to the present Thames River but slightly to the northeast. This channel is believed to mark the southern boundary of the Huron lobe in this area at the time of deposition of the Zorra till.

Interpretation of the meltwater channels traversing the high ground south of Woodstock (e.g. Cedar Creek) is incomplete, however, several are thought to be reoccupied channels as glaciofluvial gravels outcrop in the valley walls whereas the surface areas surrounding the channels are mantled with till. To the east, Nith River was probably cut by meltwaters during the Port Huron Stadial. The channel between Richwood and Princeton is thought to mark an intermediate ice marginal position between the Ingersoll and Norwich Moraines in this area, perhaps replacing the St. Thomas Moraine; alternatively it may have served to carry meltwaters from the Nith River to Glacial Lake Whittlesey during the Port Huron Stadial.

Lesser channels occur throughout the area. These represent short-lived local drainage networks during recession of the various ice sheets.

OUTWASH DEPOSITS

Glaciofluvial outwash deposits comprise a relatively small percentage of the surficial materials within the Woodstock map-area. These occur as sand and gravel in terraces along major meltwater channels, as sand or gravel fill in lesser channels and small adjoining basins, as outwash aprons fronting end moraines, and as sand plains. Gravels in these deposits vary from coarse cobble or boulder gravel, containing up to 20 percent sand, to fine pebble gravel and gravelly sand. Sorting is highly variable. Sands vary from very coarse to fine in mean grain size and are poorly sorted to well sorted.

The major terrace deposits occur on the flanks of the Mud Creek and Thames River (South Branch) meltwater channels. Along the Mud Creek channel several isolated terrace remnants remain which may be up to one square mile in area.

Gravels and gravelly sands in these deposits have predominantly southwest dipping crossbeds (approximately parallel to the trend of the channel). The sediments are generally less than 25 feet thick and occur at elevations 10 to 75 feet above the modern floodplain. Along this channel the gravels consistently average 70 percent carbonates in the pebble grade with the remainder being largely chert or Precambrian materials (Figure 10).

Terrace deposits along Thames River (South Branch) north of Ingersoll occupy a narrow strip between the present floodplain and the steep containing walls of the incised channel; for the most part these terraces occur at elevations less than 50 feet above the modern floodplain. Much of the material in this area is pebbly to cobbly fine sand and only locally is it washed and graded sufficiently well to provide good aggregate. In this area carbonate rocks comprise 60-85 percent of the pebble grade with sandstone, chert, and Precambrian material making up most of the remainder.

West of Ingersoll and along the Thames River (Middle Branch) channels are less confining and outwash has spread over a much larger area and is well terraced. Here some of the material may be deltaic though this aspect was not studied in detail. Elevations are within the range of previously discussed proglacial lakes or perhaps others not yet documented.

A number of channels occurring between the two major channels discussed above contain outwash fills which are mainly sand but are locally gravelly. Where these channels are not deeply incised the outwash sands are spread over surrounding low ground. Similar situations to these occur throughout the map-area.

In the Blandford area a large sheet of outwash sand was mapped. Whether this sand is primarily derived from Erie-Ontario or Huron lobe ice is uncertain. Perhaps meltwaters from both ice sheets simultaneously deposited these sands.

The sand plain in the area around Gobles is believed to be proglacial outwash deposited in a reentrant developed in the Erie lobe as it retreated from the Ingersoll Moraine to the Norwich Moraine. Some of the upper part of the sand may have been deposited in Glacial Lake Whittlesey at a later date.

An apron of stratified drift fronts the Ingersoll Moraine one to two miles west of Drumbo which the writer chose to map as ice-contact material. However, it was debated as to whether this material (mainly pebbly to cobbly fine sand with local pockets of well washed material) should be mapped as proximal facies outwash. The contact between this deposit and the outwash sand to the west is based on topographic and sedimentary discontinuities.

Small pockets of outwash sand and gravel occur throughout the area. These simply represent local deposition by proglacial or subglacial meltwaters.

ICE-CONTACT STRATIFIED DRIFT

A number of areas were mapped as ice-contact stratified drift. Where possible these materials were mapped on a basis of internal structure and composition, i.e. presence of collapse structures, till inclusions, and extreme and abrupt changes in grain size and sorting. Elsewhere topography and variability of sediments over short distances were considered diagnostic. Designation of certain deposits as outwash or ice-contact was necessarily arbitrary.

Most stratified ice-contact deposits within the area were associated with morainic terrain. The Dorchester Moraine at Banner consists primarily of stratified sand with minor gravel and scattered islands of till; the topography is gently rolling to hummocky. Much of the area between Ingersoll and Woodstock immediately east of Thames River is covered with stratified drift believed to be of ice-contact origin. As stated previously this area is thought to contain a buried moraine. South of Princeton the Norwich Moraine consists of sand containing domes of gravel. The composition at depth is not known and more gravel may be present than is indicated.

A few miles northwest of Gobles several areas of ice-contact stratified drift were mapped. These consist of pebbly to bouldery medium to fine sand with localized masses of sorted coarse sand and gravel. The deposits are believed to occupy a re-entrant in the Erie lobe as it stood at or near the Ingersoll Moraine. The stratified drift immediately north of Blandford Station is considered to be interlobate. The material fronting the Ingersoll Moraine west of Drumbo, discussed previously, was mapped as ice-contact stratified drift because of the great variability of the sediments and because of the rolling to slightly hummocky topography. Port Stanley Till was interbedded with this drift in at least one locality. As stated previously this map unit could have been mapped as outwash, however, its present designation serves to distinguish it from the better sorted outwash to the west.

South of Harrington West, ice-contact stratified drift was mapped in an area contiguous with Chapman and Putnam's (1951) Lakeside Moraine. This drift is mainly fine sand containing considerable unmapped till; a number of gravel pits have operated in gravel knolls and kames within this unit. The topography of the sediments in this area does not rise above the general level of the surrounding ground moraine and for this reason it is thought that while the sediments probably were deposited at or near an ice margin they probably mark an area of stagnant ice with considerable subglacial drainage rather than end moraine deposits.

The ice-contact stratified drift mapped along a channel east of Brooksdale is believed to represent deposition in a reentrant in retreating Huron lobe ice.

Kames

Only a few isolated Kames occur within the map-area and most occur in areas better described as hummocky topography rather than kettle and kame topography. The best individual kames occur south of Harrington West (photo 9) where they are sources of gravel. Other kames occur in the Blandford area and southeast of Princeton.

Eskers

Only one esker was mapped in the Woodstock area. This consisted of a relatively straight ridge less than a mile long located mainly on lot 21, concession IV, Blenheim Township; small masses of ice-contact stratified-drift mapped to the northwest probably mark its extension in that area. The steepsided ridge, 25 to 40 feet high, bifurcates into two or three contributary ridges at its south end; the contributaries originate in an area of hummocky glaciofluvial sand. These deposits appear to occupy a zone of weakness or re-entrant in the ice sheet as it retreated from Ingersoll Moraine.

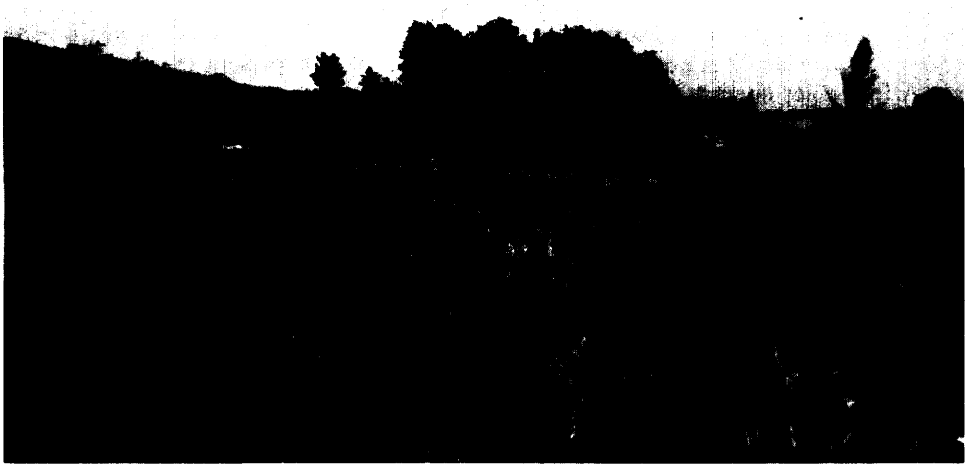

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Photo 9–Kame located one mile Southwest of Harrington West.

The sediments in the esker are believed to consist of gravel and bouldery sand. Stone piles on the esker contain angular boulders and cobbles and considerable erratic material is present; these consist of sandstone and Precambrian material, notably phlogopitic white marble of presumed Grenville Province source.

A small mass of stratified drift located one and one half miles east of Harrington West is a probable southeastern extension of a large esker present in the St. Marys area to the northwest.

NON-GLACIAL SEDIMENTS

Interstadial Deposits

During the original mapping of the map-area no interglacial or interstadial materials suitable for radiocarbon dating were observed. However in 1972 a site containing buried organic material was located two miles southwest of Innerkip immediately north of the new bridge over Timm's Creek on lot 6, concession XV,

Table 4 PRELIMINARY PALYNOLOGICAL DATA FROM BASAL ORGANIC SEDIMENTS AT INNERKIP SECTION

Depth in inches	0–3		3–6		6–9		9–12		12–15		15–18		18–21	21–24	24–28	28–30	30–32	32–34
	Count	%*	Count	%	Count	%	Count	%	Count	%	Count	%	Count	Count	Count	Count	Count	Count
Arboreal Pollen																		
Picea	31	17	65	36	29	18	22	14	53	28	37	25	1	—	1	2	1	4
Pinus	151	83	112	61	130	82	131	86	126	67	108	72	16	7	10	14	2	6
Abies	—	—	6	3	—	—	—	—	4	2	2	1	1	—	1	1	—	—
Betula	—	—	—	—	—	—	—	—	2	1	2	1	4	1	—	1	1	—
Salix	—	—	—	—	—	—	—	—	1	.5	—	—	2	—	—	1	—	—
Quercus	—	—	—	—	—	—	—	—	1	.5	1	.6	8	1	2	1	—	1
Tilia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Total	182		183		159		153		187		150		32	9	15	20	4	11
Non-Arboreal Pollen																		
Ambrosia	1		—		—		—		—		—		1	—	1	—	—	—
Artemisia	1		1		2		1		—		—		1	1	1	—	—	—
Compositae	1		—		2		—		—		—		—	—	—	—	—	—
Gramineae	—		—		—		—		—		—		—	—	—	—	—	—
Cyperaceae	1		1		—		—		—		—		—	—	—	—	—	—
Sphagnam	1		—		1		—		3		1		1	—	—	1	—	1
Rosaceae	—		—		1		1		—		—		—	—	—	—	—	—
Polygonaceae	—		—		—		—		1		—		—	—	—	—	—	—
Chenopodiaceae	—		—		—		—		—		—		—	1	—	1	2	—
Total	5		2		6		2		4		1		3	2	2	2	2	1
% NAP of AP	2.7		1		3.7		1.3		2.1		.6							

* All percentages are based on arboreal pollen (AP) totals of at least 150 grains.

East Zorra Township. The site is located 250 feet south of section 341 located on figure 5. The sequence at this site is given below (from surface down).

0-3 feet	mottled yellowish brown to brownish yellow medium outwash sand containing few pebbles.
3-6	yellowish brown (10 YR5/4) slightly stony silt to clayey silt till; inclusions of underlying silt.
6-9	stratified silt and fine to medium sand; silt is pale olive to yellowish brown and sand is yellowish brown to brownish yellow in colour; shell bearing; to east silt is grey with black organic silt laminae; lower contact slopes eastward but is irregular.
9-12½ (to stream)	A contorted dark brown to black compact organic mud; augering through organic mud indicates underlying material to be silt.

The shell bearing silts here are the same unit as the silts in the lower part of section 341 (Appendix A) which were originally interpreted as Erie Interstadial lacustrine sediments.

Radiocarbon assays on the organic material provided by J. Terasmae of Brock University give dates of 33,670 ± 830 years B.P. (B.G.S. 134a) for the upper part of the organic material and 33,230 ± 610 years B.P. (B.G.S. 134b) for the lower part. A further date on the lower part of the material, provided by W. Blake Jr. of the Geological Survey of Canada, gives an infinite date of greater than 43,000 years B.P. (G.S.C. 1884). It thus appears that the material was probably deposited during the Port Talbot or Plum Point Interstadials of Middle Wisconsinan Age (Dreimanis and Karrow 1972) but could be as old as the St. Pierre Interstadial (Early Wisconsinan) or older. Preliminary palynological data (Table 4) provided by J. Terasmae indicate pollen assemblages not unlike those present in the Port Talbot Interstadial beds (J. Terasmae pers. comm. February 19, 1973; Dreimanis et al. 1966) and suggest a predominantly boreal climate at the time of deposition.

Analysis of the organic material by M. Kuc of the Geological Survey of Canada (G.S.C. Bryological Report No. 245, April 9, 1973) suggests that it is a detrital (mossy) sapropel laid down in the bottom of an hypotrophic lake. The sapropel contained fragments of indeterminable vascular plants, rare plankton, and mosses (*Drepanocladus* sp. forma sp. *D. exannulatus—D. fluitans*). Fragmentary insect remains have been recovered from the material by Dr. A. Morgan of the University of Waterloo.

At the time of writing the organic materials have not been tied directly to the till stratigraphy of the area due to the apparent absence of Catfish Creek Till at the site itself. Catfish Creek Till is present at Section W-346 (Appendix A) about one mile to the southwest where it apparently underlies Zorra till and it is also present in a roadcut one quarter mile east of the site. Further work is presently underway to resolve this problem. Meanwhile the overlying fine-grained till is thought to be Port Stanley Till, however the possibility that it is the older Canning Till or some unknown till remains.

A water-well record provided by the Ministry of the Environment indicates the possible presence of additional Port Talbot or Plum Point Interstadial sediments in the Thames basin near Ingersoll. The apparent organic materials may be considerably older than suggested and acceptance of the well record itself is not without doubt. However, it may be worthwhile to drill a second hole for geological purposes.

Water well record, lot 21, concession I, West Oxford Township. (G.R. 098637).

Thickness (Feet)	Well Log	Writer's Interpretation
22	0- 22 sandy hardpan	Zorra till
43	22- 65 blue clay	Port Stanley Till and/or Erie Interstadial lacustrine sediments
65	65-130 stones and hardpan	Catfish Creek Till
17	130-147 black sand and very black muck	Port Talbot or Plum Point Interstadial sediments
12	147-159 Limestone	Bedrock (Detroit River)

Perhaps the oldest organic material reported in the map-area was found by Westgate and Dreimanis (1967) at the Canada Cement quarry where pollen indicates a cool climate during deposition of stratified sediments underlying till in unit "A". They suggested these materials probably represent a cool period near the end of an interglacial. It is not known whether these sediments relate to the latter part of the Sangamon Interglacial or to the St. Pierre Interstadial. DiLabio (1971) found small wood fragments in Canning Till at the Domtar quarry, Beachville. These materials may be related to the St. Pierre Interstadial.

Glaciolacustrine sediments related to events during the Erie Interstadial (ca 15,500 B.P.) have been described in a previous section. The Woodstock area was free of ice from the end of the Port Bruce Stadial. During the following Mackinaw Interstadial (Dreimanis and Karrow 1972) activity within the Woodstock map-area probably consisted of soil development, periglacial activity such as that reported by Morgan (1972), infilling of local ponds, and the initiation of modern fluvial processes.

Eolian Sediments

Much of the area east of Thames River mapped as Zorra till is mantled with a thin, discontinuous layer of uniform fine sand and silty sand of eolian origin. This was previously recorded by Wicklund and Richards (1961) who considered it to be alluvial or eolian origin. The material is up to four feet thick and is very localized in occurrence, none of it being of sufficient dimensions to map as separate units at the map scale. The sediments are quite strongly weathered where they overlie till.

The eolian sediments are believed to have been laid down immediately following deglacierization of the area during a brief period, probably characterized by tundra conditions, prior to aforestation. Wright (1971b) summarized evidence suggesting that during retreat of the Late Wisconsinan ice a narrow belt of tundra existed in New England and northern Minnesota. Undoubtedly such a belt was present in the area under consideration though its width and duration are unknown. Morgan (1972) has recently provided evidence for tundra conditions in the southern Ontario

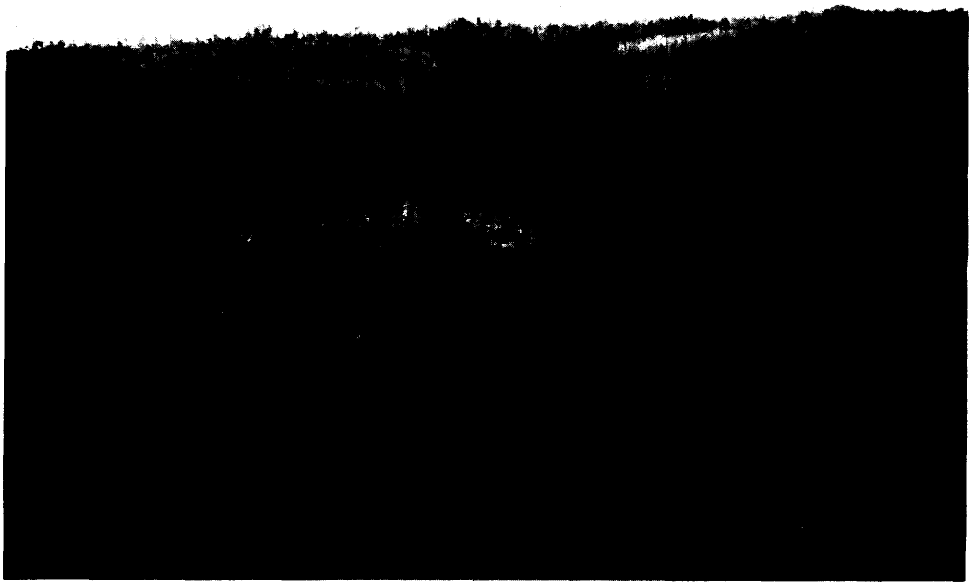

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Photo 10–Buried peat and muck (a). Southwest of Innerkip.

region between about 13,000 and 13,500 years ago. It is probable that such conditions prevailed during the waxing and waning of the various ice lobes.

As the Huron ice lobe retreated sand and silt are thought to have been winnowed from the surface of the Zorra till possibly with the assistance of katabatic winds. The silts then would relate to the Mackinaw Interstadial.

Bog and Swamp Deposits

Small bogs or swamps occur locally throughout the map-area. However, a southwest-northeast trending belt of bog sediments is apparent along the west margin of the Ingersoll Moraine where kettle holes and meltwater channel depressions have filled or are infilling. These largely resulted from stagnant ice conditions and run-off at the time of construction of the Ingersoll Moraine. In general, those bogs occurring in areas underlain by sand and gravel are the result of high water tables and those occurring in areas of till result from perched water tables due to inadequate internal drainage in the fine grained till.

Most of the bog deposits mapped are three to five feet thick however occasional soundings up to eight feet were noted and thicknesses up to 20 feet have been reported. The deposits usually consist of peat and muck which commonly overlie or contain thin bands of shell bearing marl. A six foot auger sample from a typical shallow bog on lot 21, concession IV, East Oxford Township contained the following units:

from the surface down

0-16 inches	—	dark greyish brown muck
16-22	—	partially cemented shell marl
22-40	—	cream coloured fine pure marl
40-58	—	gritty, impure grey marl
58-72	—	interstratified gritty, grey, shell marl and soft brown peat containing only rare wood fragments.

The marl units are usually shell bearing. A collection of molluscs was made from a ditch cut on the south ½ of lot 6, concession 111, Burford Township just east of the map-area. Here three feet of loose spongy peat (sandy in upper six inches) overlay with sharp contact two to three feet of white drying, highly fossiliferous, spongy grey marl which graded down into two feet of well sorted, stone free, greyish brown, fine to medium sand. The mollusc assemblage, identified by Rev. H. B. Herrington of Westbrook, Ontario, and Mrs. M. F. I. Smith of the National Museum of Natural Sciences, is as follows.

Pelecyoda
- *Pisidium variable* Prime
- *P. ventricosum* Prime
- *P. nitidum* Jenyns
- *P. nitidum f. contortum* Prime
- *Sphaerium* (fragments only)

Gastropoda
- *Gyraulus deflectus*
- *Helisoma anceps* Menke
- *Valvata sincera* Say
- *Lymnaea humilis* Say

Other Materials
- ostracoda
- seeds

In addition to the shells occurring within the marl units a number of bogs in the Woodstock-Ingersoll area have yielded partial remains of mastodons (Mastodon americanus). These have been reported by Sternberg (1930; 1963) and Dreimanis (1967) and are briefly listed below. The enclosing bogs are post Port Bruce Stadial age though none have been radiocarbon dated as yet.

Recorded Mastodon Occurrences In Woodstock Area Bogs

Occurrence	*Location*	*Enclosing Material*
A. R. Martin's farm	5 miles east of Woodstock	peat bog

Woodstock Area

G. Grumble's farm (1871)	5 miles east of Woodstock	peat bog
Carter Lake swamp	Oxford County	swamp
Orvil J. Bond farm	West Oxford Twp. 4 miles east of Ingersoll	black muck

Further peat, muck, and marl deposits of insufficient thickness or areal dimensions for mapping at the present scale also occur in areas with high water tables subject to seasonal fluctuation or areas where frequent flooding occurs.

Alluvium

Alluvial gravels, silts, and sands are present along most of the water courses. These deposits are usually less than 10 feet thick in major stream valleys and less than five feet thick in the lesser stream valleys. For the most part the sediments are locally derived and reflect the nature of the surrounding glacial sediments in composition, i.e. in areas of sand plain, as along much of Horner Creek, the alluvium consists mainly of reworked sand, but along the larger Thames River the alluvium may consist of sand or gravel derived from reworked till or gravel. Major floodplains, having a transient channel, generally consist of channel and bar gravels overlain with floodplain silts, sands, and muck.

A number of terrace deposits occurring at elevations above the modern floodplain were mapped as alluvium. These represent fluvial conditions intermediate between those of present day streams and those related to glacial meltwater run-off, possibly in part representing paraglacial effects. These sediments lack the organic remains found in the modern alluvium and are not lithologically distinct from outwash terrace deposits. A walrus tusk was recovered from sediments of this nature on lot 4, concession XIV, East Zorra Township in 1938 by Otto E. Smith.

A sample of mollusc shells was obtained from an alluvial sequence in the Thames River Valley at the Stelco quarry near Beachville. The shells are believed to be of Early Recent age and have the following composition as determined by Rev. H. B. Harrington of Westbrook, Ontario and Mrs. M. F. I. Smith of the National Museum of Natural sciences.

Pelecypoda

Sphaerium?
Sphaerium sp.
S. striatinum (Lamarck)
S. musculium sp.
Pisidium dubium (Say)
P. fallax Sterki
P. casertanum (Poli)
P. adamsi Prime? (or *casertanum*)
P. variabile Prime
P. cruciatum Sterki
P. nitidum f. pauperculum Sterki

Gastropoda

Gyraulus parvus Say
G. deflectus Say
Physa jennessi (probably *P. jennessi skinneri* Taylor)
Helisoma anceps (Menke)
Valvata tricarinata (Say)
Marstonia c.f. gelida F. C. Baker
Amnicola (*amnicola*) *limosa* (Say)
Euconulus
Cionella lubrica (Müller)
Gastrocopta contracta (Say)
Discus cronkhitei (Newcombe)
Retinella
Vertigo
Lymnaea sp.

The shells were obtained from the upper few inches of an eight-foot unit of gravel and sand which was overlain by four to six feet of alluvial silt and fine sand containing interbeds of organic material in the lower two feet and disseminated organic matter in the upper part. The shells were collected from below the lowest occurrence of organic matter in the alluvium.

PLEISTOCENE HISTORY

Early Wisconsinan

No evidence of Pleistocene glaciation prior to the Wisconsinan Stage was found during the present survey; pre-Wisconsinan materials are presumed to have been eroded away or are buried under younger sediments. Following the Sangamonian Stage the first of the Early Wisconsinan ice advances took place in eastern Canada however this did not reach southern Ontario before retreating (McDonald 1971). It was not until the middle part of the Guildwood Stadial about 55,000 B.P. (Dreimanis and Karrow 1972) that Early Wisconsinan ice invaded the Woodstock area from the Erie basin. This resulted in the deposition of one or more tills, primarily the Canning Till, but possibly a second older till (till "A") described by Westgate and Dreimanis (1967) at the Zorra quarry but not observed by the present writer. It is not known how much of the Woodstock map-area was inundated by the Erie lobe at this time but undoubtedly all of the east half and much of the west half were covered.

Activity by the Huron and Georgian Bay lobes at this time is unknown.

Following deposition of the Canning Till in the Woodstock area the Early Wisconsinan ice sheet retreated, probably in an oscillatory manner, northwards to about the Ottawa Valley (McDonald 1971) and the Middle Wisconsinan Substage commenced.

Middle Wisconsinan

The Middle Wisconsinan Substage lasted from about 53,000 to 23,000 years ago and consisted of the Port Talbot Interstadial (53,000—37,000 years B.P. approx), the Cherrytree Stadial (37,000—33,000 years B.P. approx.), and the Plum Point Interstadial about 33,000 years B.P. to 23,000 years B.P. (Dreimanis and Karrow 1972). During much of this time the Woodstock map-area was ice-free and climates were cooler than at present (Dreimanis *et al.* 1966; this report); local mass wasting and fluvial erosion and deposition were the predominant geologic processes. Much of the Thames Basin (South Branch) contained lakes or ponds in which organic sediments were deposited. Near Innerkip these have been dated at 33,670 ± 830 (B.G.S.—134a), 33,230 ± 610 (B.G.S.—134b) and > 43,000 (G.S.C.—1884) years B.P. and probably relate to the Port Talbot Interstadial.

Middle Wisconsinan glacial events in the Woodstock map-area are not well known, however, in the Toronto and Lake Erie area a significant glacial event took place about the middle of this substage to give rise to the Cherrytree Stadial during which the Seminary and Meadowcliffe Tills were deposited in the Toronto area, the Southwold Till in the Lake Erie area south of London, and the Titusville Tills in Pennsylvania (White *et al.* 1969; Dreimanis and Karrow 1972). Westgate and Dreimanis (1967) interpreted tills at the Zorra quarry (tills "C" and "D") to be of Middle Wisconsinan age however these correlations are somewhat speculative. It is possible that glacier ice did enter the Woodstock map-area during the Cherrytree Stadial though the interactions of the various lobes at this time are unknown.

Retreat following the Cherrytree Stadial led to the Plum Point Interstadial during which the Woodstock map-area was ice-free and boreal or subarctic climates prevailed.

Late Wisconsinan

At or near the termination of the Plum Point Interstadial the ice front was probably located in the central part of the Lake Ontario basin to the northeast (Dreimanis 1969), though its location in the Huron basin is unknown. Return of more severe glacial conditions led to the strong initial advance of the Late Wisconsinan Substage. This advance during the Nissouri Stadial resulted in the deposition of Catfish Creek Till throughout much of southern Ontario as the ice advanced to its maximum position in Ohio about 16,000-18000 years ago (Goldthwait *et al.* 1965); in Pennsylvania, the Kent, Navarre, and Lavery Tills are apparently the correlatives of Catfish Creek Till. Shifting centres of dispersion at this time produced varied flow directions in the ice sheet and these are recorded in pebble orientations and deformation structures within Catfish Creek Till. Indications are that the initial movement over the Woodstock map-area was predominantly from the northwest then shifting to northerly or northeasterly when the ice sheets coalesced at the time of maximum coverage; as the ice sheet waned a late expansion from the Erie basin to the Dorchester Moraine apparently took place imparting a southeasterly fabric on the uppermost part of Catfish Creek Till. Sand and gravel deposited in conjunction with the Catfish Creek Till are of considerable economic importance in the Woodstock area.

Events of the Nissouri Stadial were followed by glacier retreat in the Erie basin to near the city of Brantford and to an unknown distance to the west and north. This gave rise to the Erie Interstadial during which large proglacial lakes occupied much of the Erie and Huron basins about 15,500 years ago (Dreimanis 1969, Mörner 1970). At this time glaciolacustrine silt, clay, and sand were deposited over much of the Woodstock map-area, particularly in the eastern half.

Glacier reactivation once again took place to initiate what is now known as the Port Bruce Stadial (Dreimanis and Karrow 1972) in southern Ontario. Advance by the Erie lobe into the Woodstock map-area from the southeast overrode the Erie Interstadial sediments resulting in the deposition of the fine-grained Port Stanley Till in Ontario and its counterpart, the Hiram Till, south of Lake Erie. Outer limits of this advance in the Woodstock map-area are somewhat indefinite but it has been suggested in this report that it may have been as far west as Embro. Sediments of Lake Maumee I may have been deposited in low lying areas such as the southern part of the Thames Valley during this advance. Oscillatory retreat of the Erie lobe resulted in the construction of the Ingersoll, St. Thomas, and Norwich Moraines in the Woodstock map-area and the Tillsonburg Moraine in the Brantford and Tillsonburg areas.

At about the same time that the Erie lobe was depositing the Port Stanley Till in the Woodstock area the Huron lobe advanced over much of the western part of the map-area depositing the silty Zorra till. Interpretations made herein, suggest that the outermost part of the Zorra till overlies the outermost part of the Port Stanley Till and that perhaps the two ice sheets may have been nearly confluent at or near the Ingersoll Moraine. A not dissimilar situation exists to the north in the Orangeville area where the probable correlative events resulted in the construction of the Orangeville Interlobate Moraine (Cowan and Sharpe 1973). In this latter area and in the Guelph area the outermost part of the Ontario lobe till sheet overlies the outermost part of the Georgian Bay lobe till sheet (Karrow 1968a; Terasmae *et al.* 1972).

Retreat of the Huron lobe from the Woodstock map-area was accompanied by incision of the Thames River and Mud Creek meltwater channels and the deposition of outwash gravel and sand in terraces. Local ponds and small proglacial lakes developed on the low rolling ground moraine filling depressions with silt, sand, and clay and masking the original glacial topography. Tundra conditions prevailed and eolian silt and fine sand was blown on to the high ground immediately east of the Thames River south of Woodstock. While the glaciers continued to fluctuate to the west, no further direct glacial effects were felt in the western part of the Woodstock area after about 14,000[1] years B.P. though climates remained cool for several thousand years. The infilling of bogs and development of the modern drainage system began shortly after the glaciers retreated and continues today.

On the Erie slope the glacier retreated well into Lake Ontario (Dreimanis 1969) never to return to the Woodstock map-area. This interval of retreat, now

[1]A minimum date of 12,500 ± 180 years B.P. (G.S.C.—1156) has been obtained on basal organic sediment from Maplehurst Lake near Drumbo (R. J. Mott, G.S.C. Pers. Comm. 1972).

known as the Mackinaw Interstadial in Ontario (Dreimanis and Karrow 1972), occurred about 13,500 years ago. Retreat was followed by advance during the Port Huron Stadial during which the Ontario lobe advanced into the Brantford area to the east as far as the Paris Moraine about 13,000 years ago. Advance to and retreat from this position was accompanied by Glacial Lake Whittlesey which left a large sheet of deltaic and near shore sediments over much of the eastern part of the Woodstock map-area. Lesser effects were felt during the lower lake episodes which followed Lake Whittlesey. Following drainage of these lakes, the eastern part of the map-area, has remained free of the direct effects of glaciation for more than 12,000 years allowing non-glacial processes to modify the glacial landscape.

ECONOMIC GEOLOGY

Sand and Gravel

Reported commercial production of sand and gravel within the Woodstock map-area exceeded 670,000 tons valued at about $400,000 in 1970. Production is primarily to meet local needs and comes mainly from five pits: R. S. Clark and Son, Oxford Sand and Gravel Ltd., Shelton Bros., G. B. Thornton (Innes Pit), and the Hart Pit operated by various construction companies. Because of the chert content of the gravels (table 7), only Oxford Sand and Gravel Limited, produces a full range of high-grade products through the use of a heavy media separator which removes most of the chert and other deleterious material. A number of smaller pits also produce material for local use on a part time basis.

Till stratigraphy and ice sheet history control the location, quantity, and quality of Woodstock area granular resources. All major accessible deposits are associated with events related to the deposition of either the Catfish Creek Till or the Zorra till. This is a direct result of the reworking of these comparatively coarse textured stony tills. In contrast, very little usable material occurs in glaciofluvial deposits related to the fine-grained less stony Port Stanley Till. An example of this is the large outwash apron fronting the Ingersoll Moraine west of Drumbo where the outwash consists mainly of slightly stony fine to medium sand with only local pockets of coarse material suitable for extraction.

Three principal areas of present or potential production of granular resources are apparent. The first of these is the Thames River meltwater channel along which considerable amounts of outwash gravel were deposited, especially in the area south and west of Ingersoll. Here much of the material nearest Ingersoll has been removed; though considerable remains these deposits do not exceed future local needs. The gravels generally range from 10 to 25 feet in thickness and chert is deleterious throughout. Frequently the gravel in these terrace deposits is not suitable for crushing as the pebble fraction is too fine.

Terrace remnants along the Mud Creek meltwater channel constitute the second reserves which are important for future local use. A number of small part-time operations are located in these deposits. The terrace remnants are variable in thickness and areal extent; two larger fragments south of Embro are of note as are some remnants near Thamesford. Chert is present throughout these deposits and pebble lithologies are relatively constant (Figure 10).

The third and possibly most important area of granular resources is not well defined but includes much of West Oxford Township between Woodstock and Ingersoll. As previously suggested this area appears to include a buried moraine containing large amounts of glaciofluvial materials. Little is known about these deposits but they are undoubtedly variable in size and quality and overburden may make extraction prohibitive in many instances; chert is deleterious throughout. This area is believed to contain considerable reserves though systematic prospecting will undoubtedly be required to outline the best deposits.

Lesser amounts of gravel and washed sand occur within the Woodstock map-area in kames or small bodies of outwash gravel. Most of these are suitable only for local use.

In summary the Woodstock area does not appear to contain granular resources exceeding future local needs. The townships of Blenheim, North Oxford, West Zorra, and East Nissouri contain sufficient granular resources to satisfy local needs and limited commercial production within the immediate future. The townships of Blandford, East Oxford, and those parts of Burford, North Norwich and Dereham townships lying within the Woodstock map-area have insufficient granular resources to meet future requirements. The Township of West Oxford is considered to be the most promising area for obtaining new resources in the future and for maintenance of the present levels of commercial activity.

PROPERTY DESCRIPTIONS

Some of the more active gravel or sand pit operations are briefly described below though, as stated, production is mainly from five of these. Brief data on numerous other pits is given in Appendix C though much of the information is estimated due to very poor exposures. The more important properties have been described previously by Hewitt and Karrow (1963) and more recently by Hewitt and Cowan (1969a and 1969b).

R. S. Clark & Son Ltd. (10)[1]

Outwash terrace gravels of the Thames Valley meltwater channel make up the Clark deposit. Extraction is from a pit on lot 22, concession I, West Oxford Township, Oxford County. The processing plant is located in a now depleted pit located on Lot 22, broken front, West Oxford Township. The deposit and operations were described previously by Hewitt and Karrow (1963) and by Hewitt and Cowan (1969b).

[1]Numbers in brackets refer to properties located on Map 2282 (back pocket).

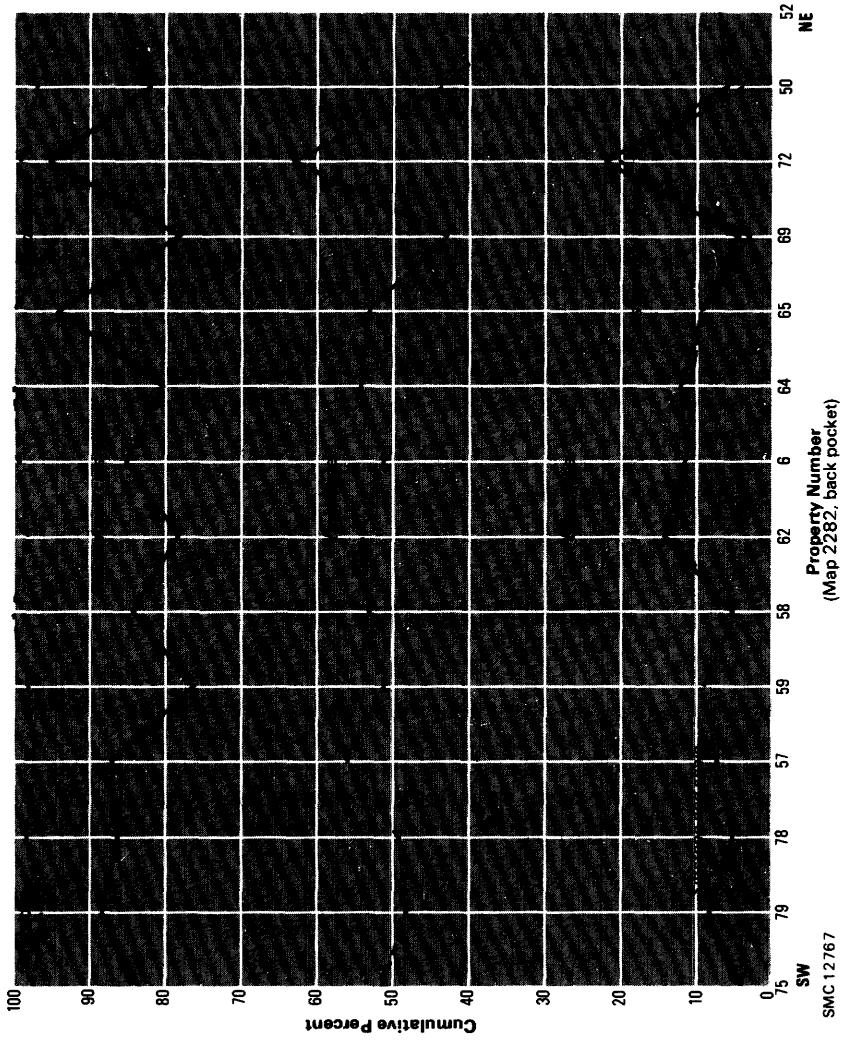


Figure 10—Pebble lithology variations in outwash gravels along the Mud Creek meltwater channel. Property 52 is located near Hickson and Property 75 near Thamesford.

Overburden consists of two to three feet of weathered sand and gravel. The water table occurs at the base of the pit, about 25 feet below the surface.

The material consists of stratified sand and gravel with crossbedding predominantly southerly. Cut and fill structures also trend southerly. The material contains about 30 to 50 percent gravel of which 15 percent exceeds four inches in diameter. Precambrian erratics up to three feet in diameter have been removed.

Pebbles are sub-rounded to well rounded, two pebble counts are given in table 7. Mineralogy and grain size analysis of a sand sample obtained from this pit are given in tables 5 and 6.

Crushing of gravel is done by contract and a screening and washing plant is located on the property. Concrete sand and crushed stone are the primary products.

Culver Pit (11)

The Culver pit is located near the southern limits of the city of Woodstock. Extraction is on an occasional basis and the pit is operated by local construction concerns.

The gravel in this pit is 30-35 feet thick and reserves extend to the west. Overburden consists of 0-8 feet of weathered sand and gravel over much of the pit, however on the east or northeast side of the pit overburden consists of brown, sandy silt till 3 feet thick which is believed to be Zorra till.

The 35-foot west face has a 12-foot lower unit of coarse, poorly sorted, cobble gravel containing lenses of medium to fine sand. This material is estimated to contain 60-70 percent gravel and about 5 percent fines; 40 percent of the gravel exceeds 1 inch in diameter, 10 percent exceeds 4 inches in diameter, and the maximum observed boulder was 1 foot in diameter. This is overlain by 15 feet of poorly sorted, stratified fine gravel and coarse sand containing 80 percent sand and 20 percent gravel which is largely less than 1 inch in diameter. The uppermost 8 feet consists of unsorted medium to coarse cobble gravel and stratified fine sands and silts.

A pebble count from this pit is given in table 7.

Dunseith Bros. (14)

Intermittent operations produce pit run gravel from this pit located on lot 5, concession XIV, East Zorra Township, Oxford County. The gravels are located in a former outwash terrace since overridden and mantled with a thin veneer of Zorra till. Consequently reserves are unknown but are probably not large.

The 12-foot north face has an upper 4-foot unit of finely crossbedded gravelly sand containing less than 10 percent gravel which is mainly in the 1-inch size range. This overlies 8 feet of stratified gravel containing 30 to 40 percent stone and dipping slightly to the west. Fifteen percent of the gravel exceeds 1 inch in diameter, less than 5 percent exceeds 4 inches, and the largest boulder observed was 2½ feet in diameter. A pebble count from this pit is given in table 7.

Table 5

SIEVE ANALYSIS OF SAND FROM THE WOODSTOCK AREA.
Analyses by Mineral Research Branch, Ontario Division of Mines.
Measurements are given in weight percent.

Property number (Map 2282, back pocket)	Standard Tyler Mesh							
	+4	—4 +8	—8 +14	—14 +28	—28 +48	—48 +100	—100 +200	—200
10	3.8	3.7	7.4	19.1	37.2	25.4	1.7	1.7
22	0.6	2.7	7.4	16.6	42.6	28.5	1.0	0.6
27	—	0.7	1.9	8.8	42.7	44.4	0.9	0.6
42	1.0	7.3	20.9	26.0	31.6	12.9	0.2	0.1
48	0.9	4.3	17.1	33.9	30.1	10.4	1.4	1.9
52	1.4	4.9	16.1	47.0	25.4	3.2	0.6	1.4
54	2.5	5.2	11.5	25.1	31.6	21.4	1.7	1.0
80	3.4	7.5	16.2	21.8	34.7	12.3	2.4	1.7
69	3.5	5.0	15.8	50.0	24.4	0.6	0.1	0.6
71	13.5	18.9	24.7	19.4	15.0	5.4	0.7	2.4

Hart Pit (22)

The pit (Photo 11) is located on lot 9, concession XI, East Zorra Township, Oxford County. The property has been described previously by Hewitt and Karrow (1963) and by Hewitt and Cowan (1969b). Reserves are unknown but are probably large extending southward.

The gravels and sands are of glaciofluvial origin and probably represent an overridden kame. Crossbedding observed in 1970 primarily indicated easterly flow directions though directions reported in 1963 and 1969 were southerly. Overburden varies from weathered gravel to five or six feet of sandy silt till (Zorra till) on the east side of the pit. Minor cementation is present.

The pit was being operated from several levels in 1970. The lower level on the west side of the pit exposes 30 feet of material which varies from crossbedded poorly sorted gravel to crosslaminated fine sand containing small faults. Boulders up to 15 inches in diameter are present. One large cobble occurring about eight feet above the base of the pit consisted of sandy Catfish Creek Till.

The largest face exposed occurs on the south end of the pit where 50 feet of material is worked. About 6 feet of till has been stripped from this area. The uppermost 10 feet of the working face consists of loose sandy gravel. This is underlain by 15 feet of interbedded compact medium sand and lenses of crossbedded gravel, 10 feet of stratified medium and coarse sand, 5 feet of crossbedded gravel with six inch layers of medium sand, and the lowermost 10 feet is slump covered.

ODM 8940

Photo 11–Thick glaciofluvial sediments at the Hart pit.

The overall composition of the material is variable, however the pit averages about 60 percent sand and less than 40 percent gravel.

Pebbles and cobbles are largely sub-rounded to rounded, two pebble counts from this pit are given in table 7. Sieve analysis and mineralogy of a sand sample obtained at this pit are given in tables 5 and 6.

The pit is operated by local construction companies and no permanent crushing or screening equipment is located at the pit.

C. S. Keyes (27)

This pit operated on a part time basis by contractors, is located on lot 16, concession II, East Oxford Township, Oxford County. A previous description has been given by Cowan (Hewitt and Cowan 1969b).

The southwest part of the pit has a 20 to 25-foot face. The upper 8 feet of this consists of clean stratified sand and fine pebble gravel. This is underlain by 8 feet of stratified medium gravel containing thin interbeds of fine sand and silt. The gravel is generally better sorted upwards. Estimated composition of this unit is 70 percent gravel and 30 percent sand. Twenty percent of the gravel exceeds one inch in diameter, 5 percent exceeds four inches in diameter, and the maximum cobble size

Table 6 MINERALOGICAL COMPOSITION OF THE −28 +48 MESH FRACTION OF SAND IN THE WOODSTOCK AREA. Mineralogy by Mineral Research Branch, Ontario Division of Mines (all percentages taken to nearest ½ percent).

Property number Map 2282 (back pocket)	10	22	27	42	48	52	54	80
Property Name	R. S. Clark	Hart Pit	C. S. Keyes	Oxford S & G	Shelton Bros.	G. B. Thornton	A. Tree	H. Wight
Quartz	33.5	34.5	36.0	33.0	25.0	29.0	38.5	40.5
Feldspar	11.5	10.5	9.0	8.5	10.0	10.0	11.0	12.5
Paleozoic limestone	41.5	32.0	38.0	42.5	52.0	37.5	34.0	33.0
Grey shale and siltstone	7.5	8.0	11.0	6.5	3.0	9.0	6.0	4.0
Red shale and siltstone	—	—	—	—	—	0.5	1.0	—
Black shale and siltstone	2.5	2.5	1.0	—	2.5	1.0	2.5	4.0
Garnet	0.5	—	0.5	0.5	1.0	—	0.5	—
Hornblende	—	3.0	1.5	1.0	—	1.5	1.5	—
Mica	0.5	—	—	—	—	—	—	1.0
Pyroxene	—	—	—	—	—	—	—	0.5
Limonite/Hematite	0.5	—	0.5	—	1.0	—	0.5	—
Precambrian 1/s	—	—	—	—	—	—	—	—
Magnetite	0.5	—	—	—	—	—	—	0.5
Sandstone	—	2.0	—	2.5	0.5	2.0	0.5	—
Acid igneous rocks	1.0	1.0	—	—	1.0	1.5	—	0.5
Basic igneous rocks	—	2.0	0.5	1.0	1.5	3.0	1.5	—
Scapolite	—	—	—	—	—	—	—	—
Epidote	—	—	—	—	—	—	—	—
Chert	—	0.5	1.0	1.5	—	—	0.5	1.0
Tourmaline	—	—	—	—	—	—	—	—
Cemented aggregates	—	—	—	—	—	—	—	—
Dolomite	0.5	4.0	1.0	3.0	2.5	5.0	2.0	2.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

is eight inches. The lowermost 6 to 8 feet of this face consists of medium to coarse stratified sand.

The northwest face of the pit consists of 12 to 18 feet of well stratified gravelly sand and fine gravel containing interbeds of fine sand up to three feet thick. Cross laminations and crossbeddings suggest a southerly to southwesterly current direction. Ten to 15 percent of this material is gravel which is mainly less than one inch in diameter.

Total thickness of the granular materials at this pit exceeds 40 feet. The owner reports that the material extends below the water table which occurs near the base of the pit and that it also extends horizontally towards the west and northwest. Estimations of reserves are limited by the thick nature of the overburden in areas peripheral to the pit.

The gravel is thought to consist of outwash or ice-contact stratified drift related to the Catfish Creek Till as this till is interstratified with gravels silts and clays in the northern part of the pit. Analysis of a till sample from the pit is given in Appendix B—sample 389 (the sample was obtained from the north-east corner of the pit). Port Stanley Till overlies the gravels adjacent to Highway 401.

Two pebble counts from this pit are given in table 7, and a sieve analysis and the mineralogy of a sand sample are given in tables 5 and 6.

Oxford County (41)

This pit is located on lot 7, concession IV, West Zorra Township, Oxford County. The deposit is located in outwash gravels and large reserves extend towards the southwest and northwards. Operations are on an intermittent basis and portable crushing and screening equipment is brought to the pit as required. The products are primarily used for road gravel.

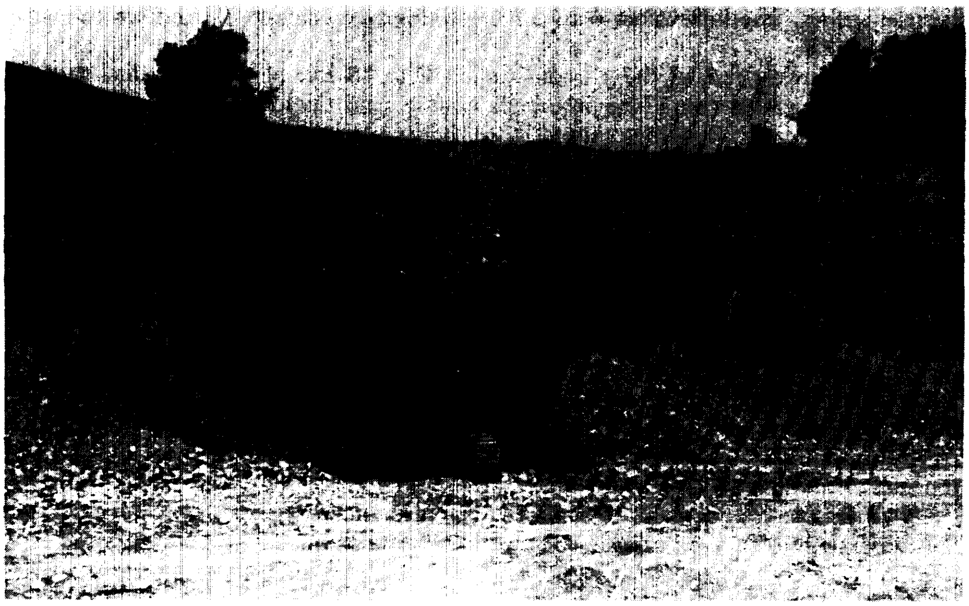
The 20-foot west face of the pit has an upper unit consisting of 10 feet of coarse cobble to boulder gravel which is poorly sorted. Gravel comprises 50 to 60 percent of the material. Of this up to 70 percent of the gravel exceeds four inches in diameter with a maximum size of two feet. The gravel is generally well rounded. Poorly defined crossbedding indicates southwesterly currents during deposition.

Underlying the above unit is five feet of crossbedded coarse sand and pebbly coarse sand which is moderately sorted to well sorted. Gravel comprises less than 10 percent of this unit. Crossbeddings again indicate southwesterly flow. The remainder of the face was slump covered.

A pebble count from this pit is given in table 7.

Oxford Sand and Gravel Limited (42)

This large pit (Photo 12) is located on lot 4, concession V, West Oxford Township, Oxford County, 1½ miles west of Curries. The material is trucked from this location to the plant located on Highway 59 on lot 18, concession III, East Oxford Township. Here are full range of washed and crushed products are produced by a heavy media separator which removes chert and other deleterious materials. The



ODM 8941

Photo 12–Outwash gravels at the pit of Oxford Sand and Gravel Limited.

operations of this pit and plant have been described previously by Hewitt and Karrow (1963) and by Hewitt and Cowan (1969a).

The gravels are primarily of glaciofluvial outwash origin though their history is probably complex. They may form part of a buried moraine. The reserves are probably large and extend westward beneath four to six feet of sandy silt till (Zorra till). The water table is at the base of the pit.

Up to 80 feet of gravel and sand is being worked at three levels. The lower lift consists of 12 feet of laminated to finely stratified medium to coarse sand containing less than five percent fine gravel and rare cobbles. Cross laminations suggest a southerly to southwesterly flow. Cowan (Hewitt and Cowan 1969a) previously reported contortions and dragfolds near the base of this unit which suggested over-riding or pressure from the west. The top of the unit contains scour and fill features. Sand from this lift is occasionally screened through a portable screen to provide concrete sand.

The middle lift has an 18 to 25 foot working west face consisting of poorly stratified medium to coarse cobble gravel containing lenses of well-sorted pebble gravel and thin beds of fine sand. This material averages 60 percent gravel of which 50 percent exceeds one inch in diameter and 5 percent exceeds four inches. Rare boulders up to two feet in diameter are present. Two pebble counts from this lift are given in table 7. In addition, the cobble grade contains chert, red sandstone,

Table 7 PEBBLE LITHOLOGY FOR GRAVEL PITS IN WOODSTOCK AREA

Property number (Map 2282, back pocket)	Lithology in percent								
	Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Precambrian Felsic rocks	Precambrian Mafic rocks	Precambrian Metamorphics
10	39	40	6	—	—	—	5	7	3
10	37	27	8	4	1	—	6	13	4
11	33	43	12	—	2	—	5	4	1
14	10	78	7	—	—	—	3	—	2
22	47	27	11	3	—	—	6	4	2
22	32	28	23	2	3	—	5	7	—
27	19	63	10	—	—	—	4	1	3
27	24	53	12	2	—	—	3	2	4
41	40	34	11	1	—	—	3	9	2
42m	22	40	15	—	2	—	10	10	1
42m	36	40	10	—	—	—	2	8	4
42u	36	43	7	6	—	—	—	6	1
35	27	50	9	2	1	2	3	1	5
36	12	79	5	—	—	—	3	1	—
48	40	41	8	—	—	—	2	3	6
48	30	31	23	1	—	—	1	9	5
52	34	44	10	2	—	—	3	7	—
52	24	38	16	5	2	—	7	6	2
51	30	47	7	3	—	—	4	7	2
54	24	50	2	—	—	5	4	5	9
80	20	56	9	1	1	1	8	3	1
81	40	38	9	1	4	—	3	4	1

Precambrian rocks, buff dolomite, and brown carbonate rocks. Armoured till balls were observed at this lift during a previous visit.

The upper lift exposes 25 feet of poorly sorted medium gravel containing lenses of coarse sand and thin beds of fine sand. The gravel content varies from 30 to 50 percent. Of this 25 percent exceeds one inch in diameter and 5 percent exceeds four inches in diameter. The pebbles and cobbles are rounded to well rounded. A pebble count from this lift is given in table 7. Cobbles and boulders include chert, tillite, and granite. Minor cementation occurs in this pit.

A sieve analysis of a sand sample collected at this pit is given in table 5 and the mineralogy of the minus 28 to plus 48 mesh material is given in table 6.

North Norwich Township (35)

No operations were in progress at the time of visiting this pit in 1970. The pit is located on lot 25, concession II, North Norwich Township, Oxford County. The sand and gravel is of glaciofluvial origin and appears to be as much as 40 feet thick. Most of the material is below the water table which occurs 10 to 15 feet below the surface. Excavation is by dragline.

A shallow 8-foot face consisted of gravel containing 70 percent sand. Sixty percent of the gravel exceeds 1 inch in diameter and 10 percent exceeds 4 inches with a maximum observed size of 8 inches. Cross-bedding dips southerly to southwesterly. Chert is common in the pebble grade. A pebble count from this pit is given in table 7.

North Norwich Township (Alexander Pit) (36)

This pit is located on lots 1 and 2, concession III, North Norwich Township, Oxford County. The gravels are of glaciofluvial origin related to the Catfish Creek Till. Overburden varies from 3 to 15 feet and consists of till and stratified material (see section W-348, Appendix A).

The water table occurs at a depth of 20 feet and present day excavation is from below the water table with a dragline. Excavation is of a part time nature to produce road gravel. The gravel observed was mainly slump covered but appears to be rounded medium gravel. Reported thickness is 60 feet. Minor cementation is present. A pebble count is given in table 7.

Shelton Bros. (48)

This pit is located on lot 6 and 7, concession I, Dereham Township, Oxford County. The property was described previously by Hewitt and Karrow (1963) and by Hewitt and Cowan (1969b).

The gravel appears to consist of outwash or outwash fan sediments with cross-beddings and scour and fill structures which suggest southerly to southeasterly flow directions. However, the writer reported collapse structures and an enclosed sequence of varved clay in 1969 that indicate a somewhat more complex history. A mastodon tusk was recovered from the northeast wall of this pit in 1972.

The east wall of the pit in 1970 exposed 20 feet of gravel and gravelly sand. The uppermost 12 feet consists of weakly stratified medium to coarse gravel containing lenses of well sorted fine to medium pebble gravel. About 70 percent of this unit was gravel of which 30 percent exceeds one inch in diameter, and five percent exceeds four inches; the largest cobble observed was 10 inches in diameter. The underlying eight feet consists of gravelly sand containing lenses of silt with rare thin clay bands.

Two pebble counts from this pit are given in table 7; a sieve analysis and mineralogy of a sand sample obtained at this pit are given in tables 5 and 6.

Overburden on the east side of the pit consists of zero to 12 feet of silt and sand but on the north and northwest side of the pit up to seven feet of sandy silt till (Zorra till) comprises the overburden.

A portable screening and crushing unit, described previously, is located at the pit for the production of sand, crusher run gravel, crushed stone.

G. B. Thornton (51)

This pit is used on a part time basis when transportation is more convenient than from the above pit. The pit is located on lot 1, concession III, West Oxford Township, Oxford County.

The material is believed to be outwash or deltaic in origin and varies in thickness from 25-30 feet at the north end to 10 or 12 feet at the south end of the pit. Overburden consists of 2-3 feet of silt and fine sand and the water table occurs near the base of the pit. Reserves are not estimated to be large.

The poorly exposed material consists of medium gravel containing up to 10 percent fines. Gravel comprises about 40 percent of the material, largely in the 1 to 3 inch size range. Pebbles, cobbles, and boulders are sub-rounded to rounded with a maximum size of 16 inches. Interbeds of fine sand up to 1 foot thick occur and these appear to dip southerly to southwesterly.

A pebble count from this pit is given in table 7.

G. B. Thornton (Innes Pit) (52)

This gravel pit is located on gore lot, concession I, West Oxford Township, Oxford County. The pit has been described previously by Hewitt and Karrow (1963) and Hewitt and Cowan (1969b). The material is believed to be outwash though it is of possible ice-contact origin. Reserves are large and the deposit may continue westward beneath overburden as far as the Thames River. Overburden consists of zero to five feet of silt and fine sand.

Operations are now concentrated in the upper part of the deposit where a face up to 40 feet high is exposed. The material varies from stratified medium to coarse sand to dirty cobble gravel containing up to 10 percent fines. The material is largely poorly sorted; stratification is well developed in the sand and fine gravels and is missing in the coarse gravels. Estimated overall composition of the deposits in the pit is 40 percent gravel and 60 percent sand. Fifty percent of the gravel exceeds one inch in diameter and 10 percent exceeds four inches. Boulders up to one foot in diameter are scattered throughout most of the gravel.

Cementation poses excavation problems in portions of the pit.

Pebbles and cobbles are rounded to well rounded. Two pebble counts are given in table 7; jasper conglomerate of Huron lobe affinity was noted at the pit. Sieve analysis and the mineralogy of a sand sample collected at this pit are given in tables 5 and 6.

A portable crushing and screening unit is brought to the pit as required. Products include pit run gravel and sand, various sizes of crusher run gravel, and various sizes of screened round or crushed stone.

Tree Sand and Gravel (54)

This pit is located on lot 8, concession XII, East Zorra Township, Oxford County. The deposit is in outwash gravels and reserves are nearly depleted, 40 feet of pea gravel is reported to lie beneath the pit. The pit was described previously by Karrow (Hewitt and Karrow 1963, p.130) and by Hewitt and Cowan (1969b).

Four feet of overburden overlies the gravel and the water table occurs at the base of the present pit. The 25-foot northeast face consists of cross-bedded sands and gravels, the material is coarser towards the top of the face and grades downward into fine to medium sands at the base. A few thin layers of well sorted pebble gravel occur. Cross-bedding is varied but overall southerly to southwesterly trend is indicated. Estimated composition of this face is 75 percent sand and 25 percent gravel. Fifty percent of the gravel exceeds 1 inch in diameter, 5 percent exceeds 4 inches, and the maximum size is 8 inches.

The southwest face of the pit consists entirely of crossbedded fine to medium sand.

Sieve analysis and mineralogical analysis of a sand sample from this pit are given in tables 4 and 5.

Pebbles and cobbles are rounded to well rounded at this pit. Pebble lithology is given in table 7; in addition, sandstone, gypsum, marble, jasper conglomerate, and tillite were noted in the oversize rock.

Pit run gravel is the principal product. Equipment consists of front-end loader, a truck, and a screen for removing 1½ inch oversize stone.

H. Wight (80)

This deposit, which is almost depleted, is located on lot 13, concession II, Blenheim Township, Oxford County. It has been described previously by Karrow (Hewitt and Karrow 1963, p.128) and by Cowan (Hewitt and Cowan 1969b). The gravels are usually less than 10 feet thick, overlie Port Stanley Till, and are related to a meltwater channel occurring between the Ingersoll and Norwich Moraines.

An eight-foot face consists of one foot of weathered gravel overburden, three feet of fine to medium gravel, a six-inch pebble-cobble layer, and two feet of substratified poorly sorted fine gravel. The remainder of the face was slumped over. Estimated composition of the gravel was 60 percent sand and 40 percent gravel. Twenty percent of the gravel exceeds 1 inch in diameter and less than 5 percent exceeds 4 inches in diameter. The maximum cobble size observed was 6 inches.

Sieve analysis and mineralogical analysis of a sand sample obtained from this pit are given in tables 5 and 6; pebble lithology is given in table 7.

Pit run and crusher run gravel are the principal products of this pit. A portable crusher is brought to the pit when required for stockpiling. A truck-mounted P & H shovel is used for excavation and haulage is by truck.

Gordon Wiseman (81)

This pit is located on lot 4, concession V, West Oxford Township, Oxford County adjacent to the Oxford Sand and Gravel Ltd. pit. The pit is used for pit run and crusher run gravel. Overburden is generally less than three feet thick. The gravels are believed to be outwash related to the Zorra till which overlies the gravel on the west side of the Oxford Sand and Gravel Ltd. pit. Reserves are not considered to be large.

Two lifts are being used. The lower lift consists of 10-18 feet of weakly stratified, sorted pebble and cobble gravel containing 70 percent gravel; of this 35 percent exceeds 1 inch in diameter and 5 to 10 percent exceeds 4 inches. The largest boulder observed was 16 inches in diameter. Cross beds trend southerly to slightly east of south. Numerous chert cobbles are present. A pebble count from this lift is given in table 7.

The southwest face of the upper lift is about 30 feet high. The top 16 feet of this lift consists of horizontally stratified, poorly sorted gravel and sand containing about 50 percent gravel. Of this about 40 percent is found in the 1 to 3 inch size range, 5 percent exceeds 4 inches in diameter, and the largest observed cobble was 8 inches in diameter. The above unit was underlain by sorted fine gravel with southeasterly dipping forsets. This gravel consists of interbeds of granule, coarse sand, and fine pebble layers. Most pebbles are ¼ to 1 inch in diameter. The lower 12 feet of this lift was covered with slumped materials.

Sand mineralogy for this pit may be considered to be similar to that of Oxford Sand and Gravel Ltd. (table 6).

Clay

Only one clay pit was observed in operation during the present survey, that of Norwich Brick and Tile Limited located on lot 11, concession III, North Norwich Township about two miles northwest of Norwich. This operation was described fully by Guillet (1967, p.181-183) at which time production was about 1,300,000 tiles per year. The deposit appears to be the result of a local ponding during the retreat of the ice sheet which laid down the Port Stanley Till. Eight to 10 feet of laminated silt and clay is exposed overlying a slightly pebbly, grey, clayey silt till (Port Stanley Till). Chemical, mineralogical, and ceramic data for this pit are reproduced here in table 8 from Guillet (1967, p.182).

A number of other pits formerly operated in the area; Baker (1906) reported clay pits at Ingersoll and Woodstock.

Clay reserves within the map-area are limited to local pond deposits such as the one described above or to buried glaciolacustrine sediments of the Erie Interstadial. The Port Stanley Till might also be thought of as a clay reserve but pebbles and grits would have to be removed. Clay used in the manufacture of portland cement by the Canada Cement Company Limited at Zorra Station is washed from the overburden at the quarry; this overburden consists mainly of till.

Peat and Marl

No commercial extraction of either peat or marl is presently taking place within the Woodstock area. However, a number of the larger bogs contain up to six feet of muck, marl, and peat. These comprise a sizeable resource of materials suitable for horticultural purposes as soil conditioners and for top dressing lawns. The few bogs which exceed these thicknesses are usually of small areal extent and do not represent better economic prospects.

Soils

Soils within the Woodstock area are entirely developed upon Pleistocene sediments of Late Wisconsinan age and most soil development has taken place within postglacial time (the area has been free of the direct effects of glaciation for about 13,000 years however glacial-climatic effects persisted for several thousand years following deglacierization of the area). Wicklund and Richards (1961) provided a soil map of Oxford County, which encompasses most of the Woodstock map-area, and much of the adjoining area is presently being remapped. Soil associations of southern Ontario have been described by Hoffman *et al.* (1964). Table 9 relates the soil series used in southern Ontario to the glacial sediments described in this report though correspondence is not without exception. The soils developed on the non-organic sediments fall within the grey-brown podzolic and humic gleysol great groups depending on drainage.

Table 8 CHEMICAL MINERALOGICAL, AND CERAMIC PROPERTIES OF A 10½ FOOT VERTICAL CHANNEL SECTION FROM NORWICH BRICK AND TILE LTD. PIT (from Guillet 1967, p.182), North Norwich Township.

Partial Chemical Analysis:
Norwich Brick & Tile Limited

Sample	1
Height above floor (*feet*)	0.0–10.5
	(*percent*)
Fe_2O_3	5.00
CaO	15.8
Loss on ignition	17.52
Soluble salts	0.83

Mineral Analysis: Norwich Brick & Tile Limited
(B=moderate; C=minor)

Sample		1
Height above floor (*feet*)		0.0–10.5
		(*percent*)
Non-clay minerals	— Quartz	22
	Calcite	21
	Dolomite	7
	Soda-lime feldspar	3
	Potash feldspar	1
	Amphibole	<1
Clay minerals	— Illite	B
	Chlorite	B
	Expanding minerals	C

Ceramic Tests: Norwich Brick & Tile Limited

SAMPLE 1 : 0.0′–10.5′

Water of plasticity (*percent*)	24
Lineal drying shrinkage (*percent*)	5.2
Pyrometric cone equivalent	3

	Cones		
	010 (1660°F)	06 (1840°F)	03 (1980°F)
Lineal firing shrinkage (*percent*)	1.7	1.8	2.3
Colour	tan	cream-tan	cream-buff
Hardness	soft	soft	almost hard
24-hour absorption (*percent*)	18.7	18.4	17.6
5-hour boil absorption (*percent*)	19.8	19.4	19.6
Specific gravity	1.74	1.74	1.75

Table 9 SOIL SERIES MOST COMMONLY DEVELOPED ON PLEISTOCENE SEDIMENTS OF THE WOODSTOCK AREA

SEDIMENT	SOIL SERIES DRAINAGE		
	Good	Imperfect	Poor
Till			
Zorra till	Guelph	London	Parkhill
Zorra till with silt veneer	Honeywood	Embro	
Port Stanley Till	Huron	Perth	Brookston
Glaciofluvial Sediments			
Gravel	Burford		
Sand	Fox	Brady	Granby
Glaciolacustrine Sediments			
Sand	Fox	Brady	Granby
Recent Alluvium			
Sand, silt, gravel	bottomland — variable drainage		
Organic Sediments			
Muck, Peat	muck — very poor drainage		

APPENDIX A

Descriptions of measured sections located on Figure 5. (footage measured from surface down, is approximate due to variation in thickness of individual units).

W-341

0–8	brown (10YR 5/3.5) gritty clayey silt till, sand lens near base (sample 341 C).
8–12	compact, dark grey (10YR 4/1) silty clay till, nearly stone free, sand stringers (sample 341B).
12–15	(to stream edge) olive grey (5Y 5/2) calcareous laminated silt and fine sand; small blebs or lenses of non-calcareous black silt and brown organic material; few shells.
15+	(below water level) shell bearing silt containing, numerous angular rock fragments.

W-346

0–7	brown (10YR 5/3.5) clayey silt till, blocky structure when dry, red shale fragments, fabric 338° (sample 346B).
7–15	rounded medium to coarse outwash gravel, lower contact dips to east.
15–19	stony to bouldery light yellowish brown (10YR 6.5/3) silt till, surface material crumbles when dry, fabric 153° (sample 346A).

W-348

0–4	slightly stony, brown (10YR 5/3) silt till, fabric 153° (sample 348C).
4–7	stratified brown silt and clay, few pebbles, red shale.
7–9½	laminated, yellowish brown silty fine sand; includes one inch band of clean white sand.
9½–10	reddish brown (5YR 5/4), compact substratified, clayey silt till (?) contains silt balls; discontinuously cemented at base, (sample 348B).
10–14	extremely compact, stony-bouldery, brown (10YR 5/4), sandy silt till, fabric 135°, (sample 348A).
14–20+	(water table) brown fine to medium gravel, pebble content: limestone 12%; dolostone 79%, chert 5% Precambrian 4%.

W-380

0–14	brown (10YR 5/3) silt till, blocky when dry, clay films on peds (sample 380A).
14–32	stratified, uniform, medium to fine sand; sharp undisturbed upper contact; southerly to westerly flow indicated.
32–34	weathered medium gravel; pebble content; limestone 29%; dolostone 67%; Precambrian 4%.
34–34½	gritty, clayey silt with high concentration of red shale fragments.
34½–37	stony, greyish brown (10YR 5/2), silt till (sample 380D) stream level.
37+	to west this till is underlain below water level by compact, grey (10YR 5/1), slightly pebbly silt till (?) (sample 380E).

W-387

0–3	brown (10YR 4.5/3), silt till (sample 387A).
3–5	yellowish brown (10YR 5/3.5), stony to bouldery, silt till (sample 387B).

W-403

0–8	sand, gravel, organic matter, shell layers, tree trunks, and lumber; part alluvium-part fill.
8–11½	boulder gravel.
11½–17½	greyish brown (10YR 5/1.5), very compact, stony, sandy silt till (CC), tillite boulders; few inches of discontinuous clayey silt till (?) at or near top of unit.
17½–20	stratified sand and coarse gravel.
20–22	(rock) slump covered.

W-404

0–10	slump covered till similar to underlying unit.
10–32	brown (10YR 5/3), stony, sandy silt till (sample 404), gravelly at base, very compact and fissile upwards.
32–40	sand and gravel, grades upward into overlying unit, springline at base.

W-409 (see Fig. 6)

0–6	weathered brown and yellow silt; few pebbles.
6–10	very hard, slightly fissile, yellowish brown (10YR 5/4) silt till (sample 409A).
10–25	fine to medium sand; few clay bands and silt layers.
25–30	stratified silt, minor clay.
30–40	stony, grey (oxidized brown in upper part), silt till; very sandy in places; substratified and more sandy in upper 3 feet (sample 409B from middle of unit).
40–65	slump covered, mainly bouldery till.

W-411 (see Fig. 6)

0–5	disturbed and weathered material.
5–11	blocky to fissile, brown (10YR 5/3), silt till (sample 411A); sandy to base, contains streaks of silt and inclusions of Catfish Creek Till.
11–15	dark brown, compact, silt till, few pebbles and cobbles, (sample 411B), section moved 20 feet to south.
15–45	complex of waterlaid sediments; lowest 3 feet consists of pebbly fine sand which grades upward into substratified, compact, stony, sandy silt till containing one inch bands of silt and sand; strata dip to northeast; uppermost material is yellowish brown, stony, sandy silt till.
45–47	gravel lens.
47–53	very bouldery (40-50%), olive, sandy silt till; boulders largely striated limestone (sample 411C).
53–65	dark greyish brown (10YR 4/2), gritty silt till (sample 411D); pebbles break cleanly from matrix; to south this till is overlain by fine to bouldery gravel.
65–71	slump to bedrock.

W-423

0–3	brown (10YR 5.5/3) sandy silt till; very friable when dry; lenses of stratified drift (sample 423A).
3–5	interbedded fine sands and thin layers of silt till; grades into overlying unit.
5–10	brown (10YR 4.5/3.5) gritty silt till, blocky structure with few black clay films slightly to west this is underlain with sharp contact by yellowish brown (10YR 5.5/4), sandy silt till, very compact (sample 423C); to east 5–10 foot unit is missing.

W-427

0–7	brown to yellowish brown, clayey silt till, few pebbles, till inclusions (sample 427A).
7–7¼	gravelly coarse sand.
7¼–7½	very pale brown (10YR 7/3) calcareous silt.
7½–8¼	yellowish brown (10YR 5.5/4), sandy silt till, compact, few stones (sample 427B).
8¼–8¾	stratified medium sand.
8¾–9¼	yellowish brown, sandy silt till (sample 427C), pebbles break cleanly from matrix, grit characteristic; black films on fracture surfaces; 3 feet of same material exposed to south (sample 427D).

W-430

0–4	weathered gravel.
4–8	brown (10YR 5/3.5), gritty silt till, few stones, silt streaks, (sample 430).

W-433

0–3	yellowish brown (10YR 5.5/4), stony, sandy silt till; tillite common.
3–4	stratified fine sand and silt.
4–8	yellowish brown (10YR 5.5/4), sandy silt till (sample 433); fabric 133°.

W-435 (west side of road)

0–2	brownish yellow (10YR 6/5), compact clayey silt till, black shale erratics (sample 435A).
2–2¼	very pale brown (10YR 8/3) laminated silt.
2¼–2½	brown (10YR 5/3), silty clay, few grits.
2½–3	light olive brown (2.5Y5/3), stony sandy silt till (sample 435B).

(east side of road)

0–4	weathered reddish brown, pebbly fine sand.
4–6	unoxidized fine to medium sand, till lenses similar to underlying till.
6–8	stony, gritty sandy silt till, becomes finer towards base (Z).

W-439

0–6½	brown (10YR 4.5/3), clayey silt till (sample 439A), boulder pavement at base.
6½–8	stratified sand and silt; minor gravel.
8–9	yellowish brown (10YR 5/3.5), clayey silt till (sample 439B), stratified silt in basal portion.
9–14	angular medium gravel, partially cemented, minor silt and very fine sand; pebble lithology; limestone 31%; dolostone 50%; chert 5%; clastics 2%; Precambrian crystalline 12%.

W-1044

0–5	medium to fine gravel, considerable silt.
5–14	uniform, fine laminated, calcareous fine sand; poorly exposed boulder lag at base.
14–24	brown to yellowish brown, stony, sandy silt till (CC); pebbles and grits well rounded and break cleanly from matrix.
24–30	till as above but containing lenses of clean medium sand.
30–45	(road) medium sand containing thin bands of very fine sand, silt, and clay laminae; grades downward into poorly stratified fine sand and silt, few pebbles, silt balls, and balls of silty till-like material.
—	below road in ditch a dark greyish brown, gritty silt till is exposed (Canning Till).

W-1046

0–6	brown (10YR 4/3) silt till (sample 1046A), blocky structure, variable thickness 2-6 feet.
6–8	laminated silt and fine sand, upper part has beds overturned towards northwest.
8–9	brown (10YR 4/3), compact, fissile, sandy silt till (sample 1046B), red shale fragments.

W-1047

(*approximately same location as W-1 of Karrow 1963a*)

0–16	dark yellowish brown (10YR 4.5/4), gritty to slightly stony, silt till (sample 71047E); inclusions of gravel at 8 feet and silt at 12 feet.
16–17	brownish yellow (10YR 6/5), stony, loose, sandy silt till (sample 71047D-pebbles only); in places one foot of substratified silt till occurs at top of unit.
17–24	dark yellowish brown (10YR 4/5) clayey till-like material consisting mainly of highly distorted glaciolacustrine laminated till and silt; rare pebbles.
24–26½	contorted pale brown fine sand and silt; few inclusions of gritty clay.
26½–36½	extremely stiff, brown (10YR 5/3.5), stony, sandy silt till, few sand stringers, northeast fabric (sample 71047C).
36½–54½	finely laminated, light grey to very pale brown, fine sand; numerous small fragments of red shale.
54½–56	compact, massive brown silt, slump to river, section transferred 150 feet to south.
54–62	grey to very pale brown fine sand and silt, few pebbles in silt layers.
62–66	fine sand, oxidized to reddish yellow, few clay streaks.
66–70	very compact, slightly contorted, laminated fine sand.
70–82	grey, compact, laminated fine sand with few clay laminae; locally gravelly near base.
82–94	greyish brown (10YR 5/1.5), stony to bouldery, sandy silt till (sample 71047B), very compact, pebbles and cobbles well rounded, fabric 270°.
94–96	(river) very dark greyish brown (10YR 3/1.5), blocky clayey silt till (sample 71047A), oxidation along fracture surfaces, fabric northeasterly, ranges up to 7 feet in thickness.

W-1228

(*approximately same location as P4 of Karrow 1963a*)

0–3	(varies to 6 feet in thickness) brown (10YR 5/3.5), slightly pebbly silt till, silt balls, red shale fragments (sample 71228A), lower 6 inches consists of stratified pebbly silt and clay.
3–4½	rounded pebble gravel, 1 inch layer of clay at base, inclusions of underlying till.
4½–12	yellowish brown (10YR 5.5/4) loam till (sample 71228B), stringers of sand and fine

	gravel, blocky fracture, pebbles break cleanly from matrix, similar to 16-17 foot unit at section 1047.
12–16	stratified gravel and sand, conglomeratic silt band near middle of unit.
16–33	yellowish brown (10YR 5.5/5) oxidized, hard, stony loam till, (sample 71228C), oxidized to 9 feet-unoxidized color (2.5Y5.5/2).
33–35	dark greyish brown (10YR 4/2) clayey silt till, (sample 71228D), no distinct break with overlying unit.
35–43	slump to river.
	W-1435
0–4	weathered, yellowish brown (10YR 5/4), nearly stone free, silt till (sample 71435).
4–5	stratified silt and clay.
5–15	greyish brown (10YR 5/2) silty clay till, few stones, dries to blocky structure (sample 71435A).
15+	(road) yellowish brown (10YR 5.5/3.5), compact, stony, sandy silt till, loose on outer surface (sample 71435B); some sand at upper contact.
	W-1733 (cut plus augering)
0–2½	weathered yellowish brown sand.
2½–5½	brown, gritty, sandy silt till (Zt).
5½–6½	dark brown, gritty, clayey silt till (PST), missing in places.
6½–8	laminated clayey silt with fine sand partings.
	W-1850
0–4	yellowish brown (10YR 5.5/3.5), clayey silt till, nearly stone free.
4–4¼	reddish brown (5YR 4.5/3), gritty silty sand (till-like).
4¼–7	pebbly sand grading downward into stony, sandy silt till (CC).
	W-2309
0–15	fine to medium outwash gravel and gravelly sand, springline at base.
15–33	very compact, bouldery, sandy silt till (CC); greyish brown in lower portion, upper 5-6 feet oxidized to yellowish brown.
	W-2438
0–2	gravel and reworked till.
2–8	compact, stony, gritty, silt till, fissile structure.
8–9	gritty brown clay which grades downward into laminated clay, silt, and very fine sand.
	W-7089
0–5	brown (10YR 5/3.5), fissile, stony, sandy silt till.
5–6	stratified medium to fine sand, rare pebbles, lenses of underlying till.
6–8	brown (10YR 4/3) compact, blocky silt till.
	W-7169
0–1½	organic rich stony sand.
1½–8	greyish brown (10YR 5/2) to brown (10YR 4.5/3) oxidized, stony, sandy silt till, sand lens at 7 feet.
8–8½	compact, grey, medium sand.
8½–10	dark grey (10YR 4/1), compact, gritty, clayey silt till.
	W-7171
0–2	stony, gritty, sandy silt till.
2–2½	slightly pebbly, stratified medium to coarse sand.
2½–9	brown (10YR 5/3), gritty sandy silt till, compact, blocky, becomes finer downward, unoxidized colour (10YR 5/2), fabric 060°, (CC).
	W-7249
0–1	weathered dark brown sandy topsoil.
1–1¾	brown, fissile, stony, sandy silt till.
1¾–3	blocky, dark brown, silty clay till (probably equivalent to sample 7249), sharp irregular upper contact.
3–4	oxidized, stony medium sand.
4–6	light olive brown (2.5Y5/4), stony, sandy silt till, boulder striae ESE-WNW, (sample 7249A).

W-7267

0–1½	stratified, brown, silt and clay; few pebbles; blocky in upper part.
1½–4	substratified till and coarse sand; few silt and clay layers in upper one foot; till is very stony, light olive brown (2.5Y5/4), sandy silt till (sample 7267).

W-7277

0–5½	compact, fissile, sandy silt till, partially leached to 3 feet, black shale erratics, base of unit not seen.
5½–10½	slump covered.
10½–12	light olive brown (2.5Y5/4), stony, silt till, blocky structure, clay films on joints, (sample 7277).

W-7286

0–5½	brown (10YR 4/3), fissile compact, sandy silt till.
5½–8	very compact, dark yellowish brown (10YR 3.5/4), clayey silt till.
8–10	yellowish brown, fissile silt till (sample 7286).

W-7303

0–14	compact, stony, poorly exposed, sandy silt till.
14–18	grey (10YR 4.5/1) to oxidized brown (10YR 5/3), compact, silt till; contains clay balls, silt laminations, red shale (sample 7303).

W-7333

0–3	compact, brown (10YR 4/3), clayey silt till.
3–6	very compact, brown (10YR 4.5/3), stony, sandy silt till, fabric 143°.

W-7514

0–5	dark brown (10YR 3.5/3), fissile, stony, sandy silt till; black shale erratics.
5–5½	stratified yellow silt and brown silt till.
5½–7	brown (10YR 4.5/5), blocky to fissile, gritty clayey silt till (sample 7514).
7–12½	stratified silt and sand, section shifted 30 feet to south.
12½–17	crossbedded, medium to coarse sand, NNE flow indicated.

W-7584

0–11	light olive brown (2.5Y5/4), fissile, stony, loam till (sample 7584A).
11–12	poorly sorted, gravelly coarse sand.
12–14	yellowish brown (10YR 5/4), compact, stony, sandy silt till; irregular blocky joints have clay films on surfaces, (sample 7584B).
14–20	slump to ditch.

W-7596

0–2	yellowish brown (10YR 5/4), stony, sandy silt till; 3 inch sand lens (Z).
2–4½	brown (10YR 4/3), stiff, gritty, clayey silt till; greenish-grey clay films on fracture surfaces (PS?).

W-7628

0–3	brownish yellow, fissile, weathered, sandy silt till; substratified at base and interfingers with underlying unit (Z).
3–6	stratified medium sand.
6–8	light olive brown (2.5Y5/4), hard, stony, sandy silt till (sample 7628).

W-7630

0–7	slightly stony, compact, sandy silt till; sand lenses in lower 2 feet.
7–8	poorly sorted gravel.
8–12	light olive brown (2.5Y5/4), very hard, stony, sandy silt till (sample 7630); blocky structure, dark brown films (manganese?), on fracture surfaces.

W-7661

0–5	brown (10YR 5/3), slightly stony, sandy silt till (Z), basal contamination.
5–6½	brown (10YR 5/3), gritty, clayey silt till, few stones; upper 3 inches is yellow silt.
6½–7½	stratified pebbly sandy silt till and brown gritty silt till; related to overlying unit.
7½–9½	light olive brown (2.5Y5/4), compact sandy silt till (sample 7661); gravel in upper few inches.
9½–20	slump to ditch.

W-7679

0–10	yellowish brown (10YR 5.5/4), fissile, sandy silt till.
10–14	gravel and sand.
14–15	light olive brown (2.5Y5/4), hard, stony, gritty, sandy silt till (CC), sand lenses.

W-7719

0–3	stiff, weathered, sandy silt till (Z).
3–4	slightly pebbly, silty sand.
4–5	very hard, stony, silt till.
5–8	slightly stony, reddish grey, (5YR 4.5/1.5), clayey silt till; clay laminae.

W-7733

0–5	light yellowish brown (2.5Y5.5/4), fissile, stony, sandy silt till; silt and fine sand stringers, (sample 7733A).
5–7	stratified fine sand and silt.
7–10	light olive brown (2.5Y4.5/4), stony, sandy silt till, very compact, blocky; manganese films on fracture surfaces (sample 7733B).

W-7748

0–8	brown (10YR 5/3.5), fissile silt till (sample 7748A).
8–9	compact stony sand, weakly stratified.
9–12	light olive brown (2.5Y5/4), hard blocky silt till (sample 7748B).

APPENDIX B

Till analyses (sample locations are plotted on Map 2281, back pocket)

Notes

1) Except for pebble counts, analyses were carried out by the Mineral Research Branch of the Ontario Division of Mines.
2) Sand-silt boundary 0.062 mm.; silt—clay boundary 0.002 mm.; Md. is median diameter in millimetres.
3) Pebble counts on pebbles ½-1½ inches in diameter.
4) Carbonate analysis on minus 200 mesh (0.074 mm.) fraction using Chittick apparatus.
5) Heavy mineral separations on—60 + 140 mesh fraction. Media—tetrabromethane (S.G. 2.95).
6) Till identification: C—Canning Till; CC—Catfish Creek Till; PS—Port Stanley Till; Z—Zorra Till; ABL—Ablation Till; ENGL—Englacial Till.

Sample No.	N.T.S. Grid Ref.	Till	Texture				Pebble Lithology %								Carbonates %				Heavy Minerals %		Color Fresh	Remarks
			Clay %	Silt %	Sand %	Md. mm	Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Precambrian	Ratio Ls/Dol	Calcite	Dolomite	Total	Ratio Cal/Do	Total	Magnetics		
91	152605	PS	28	44	28	0.016	46	42	4	1	—	P	7	1.09	20.8	15.4	36.1	1.35	5.4	8.7	10YR5.5/4	
92	266681	PS	43	44	13	0.0056	—	—	—	—	—	—	—	—	20.2	10.5	30.6	1.92	2.6	8.4	10YR5/4	
93	234781	Z	12	45	43	0.043	23	71	2	2	—	—	2	0.31	16.1	17.6	33.7	0.92	5.2	8.0	10YR4/3	
94	348866	PS	23	48	29	0.017	5	91	—	1	—	—	3	0.06	20.2	14.0	34.1	1.44	4.4	6.9	10YR5/4	fabric vector 040°
304	374832	PS	24	56	20	0.0079	36	60	—	3	—	P	1	0.60	22.8	10.5	33.3	2.17	5.3	7.8	10YR4/4	
323	217828	Z	11	46	43	0.043	—	—	—	—	—	—	—	—	18.2	23.0	41.2	0.79	6.1*	10.2	10YR5.5/4	
331	255861	Z	15	43	42	0.050	21	63	3	2	—	—	3	0.46	15.6	17.2	32.8	0.91	5.8*	9.6	10YR4/4	
338	254804	PS	34	51	15	0.005	—	—	—	—	—	—	—	—	17.6	18.4	35.9	0.95	5.6*	8.3	10YR4.5/3	
341C	232802	Z?	31	42	27	0.016	40	48	5	—	—	—	7	0.83	15.1	21.7	36.7	0.69	5.5*	5.2	10YR5/3.5	
341B	"	PS	46	39	15	0.006	47	51	—	—	—	—	2	0.94	15.4	14.8	30.2	1.04	5.1*	4.6	10YR4/1	
346B	220788	Z	25	43	32	0.022	38	53	5	1	—	P	4	0.72	12.7	20.7	33.4	0.61	5.8*	7.1	10YR5/3.5	fabric mean vector 338°
346A	"	CC	14	56	30	0.024	28	59	—	—	—	—	13	0.47	14.1	35.5	49.6	0.40	3.6*	17.4	10YR6.5/3	fabric mean vector 153°
348C	355610	PS	34	57	09	0.0040	32	56	3	—	—	—	9	0.62	24.7	11.6	36.3	2.13	3.6*	10.4	10YR5/3	fabric vector 153°
348B	"	engl	30	47	23	0.0077	32	63	—	—	—	1	4	0.75	19.4	25.0	44.4	0.78	4.3*	47.2	5YR5/4	
348A	"	CC	19	42	39	0.028	32	57	7	—	—	—	2	0.68	20.9	28.1	49.0	0.74	4.3*	10.3	10YR5/4	fabric vector 135°
349B	354637	abl	11	54	35	0.037	43	32	23	—	—	—	3	1.50	18.0	19.9	37.9	0.91	2.5*	6.0	10YR5.5/4	overlies 349A
349A	"	PS	35	61	04	0.0037	—	—	—	—	—	—	—	—	24.8	11.4	36.2	2.17	2.3*	9.5	10YR5/3	
354	268793	PS	24	53	23	0.0086	32	64	—	—	—	—	4	0.50	22.9	13.2	36.0	1.73	5.2*	11.7	10YR4/3	
362	273788	PS	25	53	22	0.0082	33	61	—	—	—	P	6	0.54	22.3	12.2	34.5	1.83	4.8	11.6	10YR4/3	fabric vector 155°
370	223770	Z	22	46	32	0.015	22	75	—	—	—	P	3	0.29	16.8	19.4	36.2	0.87	5.0	10.5	10YR5/3	
373	195870	Z	28	45	27	0.0090	39	50	6	—	—	—	5	0.78	23.2	15.4	38.7	1.51	5.6	14.0	10YR5.5/3	
374	250759	PS	32	48	20	0.0063	10	85	—	—	—	3	2	0.13	22.1	12.9	34.9	1.71	5.0	9.0	10YR5/4	fabric vector 121°

379A	369795	PS	27	48	25	0.0081	49	48	—	—	—	—	3	1.02	17.9	17.2	35.1	1.04	5.5	10.3	10YR5/3	5 feet below surface
379B	"	PS	43	50	07	0.0028	—	—	—	—	—	—	—	—	23.8	7.7	31.4	3.08	5.6	10.2	10YR4/2	15 feet below surface
380A	355803	PS	28	65	07	0.0038	49	47	—	—	—	—	4	1.05	22.1	10.8	33.0	2.03	4.2	8.4	10YR5/3	
380D	"	CC	07	39	54	0.080	43	54	—	—	—	—	3	0.80	14.5	22.8	37.3	0.63	6.9	14.3	10YR5/2	
380E	"	C?	24	68	08	0.0056	—	—	—	—	—	—	—	—	22.2	14.9	37.2	1.49	5.5	9.7	10YR5/1	
387A	375665	PS	32	61	07	0.0058	—	—	—	—	—	—	—	—	21.2	15.3	36.5	1.38	2.9	10.3	10YR4.5/3	
387B	"	CC	12	53	35	0.028	27	72	—	—	—	—	1	0.38	17.5	21.3	38.8	0.82	4.0	8.3	10YR5/3.5	
388	318633	PS	22	54	24	0.012	47	46	3	—	—	—	4	1.09	21.5	12.1	33.6	1.78	4.8	8.0	10YR5/4	
389	227738	CC?	18	44	38	0.028	41	52	—	—	—	—	7	1.27	19.6	17.5	37.1	1.12	6.1	11.6	10YR5/5	
395	289743	PS	19	56	25	0.015	18	80	—	—	—	1	1	0.22	18.8	15.9	34.7	1.18	4.6	6.3	10YR3/3	
396	293724	PS	31	53	16	0.0052	17	79	—	1	—	—	3	0.22	20.7	14.3	35.0	1.44	4.9	7.6	10YR4/3	fabric vector 141°
397	295716	PS	15	58	27	0.020	23	67	1	2	—	—	7	0.34	17.4	17.6	35.0	0.99	4.4	8.2	10YR5/4	oxidized to 14 feet
398	335714	PS	33	52	15	0.0054	—	—	—	—	—	—	—	—	19.6	15.6	35.2	1.26	4.1	8.2	10YR4.5/3.5	
399	294684	PS	28	63	09	0.0059	—	—	—	—	—	—	—	—	23.6	17.5	41.1	1.35	2.5	6.7	10YR5/3.5	
400	273666	PS	27	54	19	0.0077	21	70	5	—	—	—	4	0.30	21.6	16.0	37.5	1.35	3.5	6.9	10YR5/3.5	fabric vector 031°
401	256723	PS	29 .	49	22	0.0063	19	78	—	—	—	—	3	0.24	20.1	15.6	35.7	1.29	4.2	8.4	10YR5/3.5	
404	114682	?	07	45	48	0.052	38	48	5	1	—	—	8	0.79	19.9	31.4	51.4	0.63	3.6	9.4	10YR5/3	
409A	118691	Z	12	56	32	0.024	44	40	3	—	—	—	13	1.10	15.1	25.9	41.0	0.58	4.4	8.4	10YR5/4	
409B	"	CC	09	56	35	0.030	—	—	—	—	—	—	—	—	18.3	33.8	52.2	0.54	3.1	8.0	grey	upper part brown
411A	117689	Z	24	57	19	0.007	57	26	3	—	—	—	14	2.19	22.2	18.8	41.0	1.18	4.8	6.7	10YR5/3	
411B	"	PS	36	60	04	0.0042	—	—	—	—	—	—	—	—	23.7	16.6	40.3	1.43	2.5	8.0	dk. brown	
411C	"	CC	08	56	36	0.022	57	35	—	—	—	—	8	1.61	16.7	36.3	53.0	0.46	4.4	9.5		olive-grey
411D	"	C	24	51	25	0.010	30	60	2	1	—	—	7	0.50	20.9	20.8	41.8	1.01	4.4	8.2	10YR4/2	fabric vector 131°
414A	117687	C	23	54	23	0.0092	—	—	—	—	—	—	—	—	20.0	18.3	38.3	1.09	3.8	10.2	10YR4/2	
419	177731	Z?	11	35	54	0.087	24	56	10	2	—	—	8	0.43	20.5	23.7	44.2	0.87	4.8	7.9	10YR5/3	
420	152824	Z	12	43	45	0.045	39	51	8	—	—	—	2	0.78	20.4	25.1	45.4	0.81	4.4	9.0	10YR5.5/4	
422	124822	Z	21	46	33	0.017	30	52	12	—	—	—	6	0.58	21.0	16.6	37.6	1.27	5.6	9.5	10YR5.5/4	
423A	139829	Z	09	46	45	0.048	35	51	7	1	—	—	6	0.69	12.5	23.8	36.3	0.53	5.3	10.3	10YR5.5/3	
423C	"	CC	08	43	49	0.054	44	39	11	3	—	—	3	1.13	14.3	30.5	44.8	0.47	4.6	10.2	10YR5.5/4	

Sample No.	N.T.S. Grid Ref.	Till	Texture				Pebble Lithology %								Carbonates %				Heavy Minerals %		Color Fresh	Remarks
			Clay %	Silt %	Sand %	Md. mm	Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Precambrian	Ratio Ls/Dol	Calcite	Dolomite	Total	Ratio Cal/Do	Total	Magnetics		
424	093710	Z	18	47	35	0.022	65	21	3	1	—	4	5	3.10	20.4	16.3	36.7	1.25	6.0	12.1	10YR5/4	
425	111778	Z	16	51	33	0.023	36	50	8	1	—	—	5	0.72	15.5	31.2	46.7	0.50	3.0	7.9	10YR5.5/4	
427A	113814	?	37	44	19	0.0040	46	39	10	—	—	—	5	1.17	20.7	19.2	39.9	1.08	4.9	8.2	10YR4/3	
427B	"	?	17	50	33	0.023	45	35	5	5	—	—	9	1.28	18.5	23.6	42.1	0.78	5.4	9.6	10YR5.5/4	
427C	"	CC	21	42	37	0.025	49	40	1	—	—	—	10	1.23	19.8	16.1	35.9	1.23	5.3	8.7	10YR5/4	
427D	"	CC	21	41	38	0.025	32	61	3	—	—	—	4	0.52	23.1	12.6	35.7	1.83	5.4	7.5	10YR5/4	
428	078804	Z	21	54	25	0.012	64	20	2	1	—	—	13	3.20	20.8	17.0	37.8	1.22	5.5	11.5	10YR5/4	
430	078785	?	30	59	11	0.0053	55	27	4	2	—	3	10	2.04	21.4	15.7	37.1	1.36	5.6	13.3	10YR5/3.5	
431	085765	Z	22	48	30	0.014	57	31	2	1	—	—	9	1.84	18.7	16.4	35.1	1.14	5.4	9.7	10YR5/3.5	
433	075752	CC?	18	49	33	0.019	52	36	1	—	—	—	11	1.44	13.7	23.8	37.5	0.58	3.1	8.7	10YR5.5/4	fabric vector 333°
435A	051737	Z	23	44	33	0.016	52	33	4	—	—	1	9	1.57	19.8	20.1	39.9	0.98	4.5	11.6	10YR6/5	
435B	"	CC	10	43	47	0.048	48	38	5	3	—	—	6	1.26	18.2	21.4	39.6	0.84	5.4	12.4	2.5Y5/3	
437	230674	Z	12	44	44	0.051	41	44	4	1	—	—	10	0.93	16.2	17.1	33.3	0.95	5.1	11.5	10YR5/5	
438	258677	Z	19	39	42	0.033	42	46	9	—	—	—	4	0.95	19.0	16.5	35.4	1.15	4.6	10.9	10YR5/5	
439A	263664	PS	35	45	20	0.005	25	61	5	1	3	—	5	0.41	21.0	12.0	33.0	1.75	4.8	7.3	10YR4.5/3	
439B	"	CC	25	48	27	0.012	35	41	21	2	—	—	1	0.85	20.2	16.6	36.8	1.21	5.8	10.5	10YR5/3.5	
441	285669	PS?	19	46	35	0.023	37	49	11	1	—	—	2	0.76	19.1	16.2	35.3	1.18	6.5	10.0	10YR5/5	
442	299643	PS	29	47	24	0.0088	40	43	13	1	—	—	3	0.93	19.8	16.4	36.2	1.21	4.9	6.3	10YR5/2.5	
1044A	372746	PS	32	62	06	0.0040	—	—	—	—	—	—	—	—	25.2	10.7	35.9	2.36	1.9	6.8	10YR4/3	
1046A	282764	PS	26	59	15	0.0062	—	—	—	—	—	—	—	—	22.6	11.8	34.4	1.92	4.1	8.7	10YR4/3	
1046B	"	CC	16	42	42	0.034	—	—	—	—	—	—	—	—	18.5	18.3	36.8	1.01	5.9	11.2	10YR4/3	
2163	282599	?	09	43	48	0.052	35	24	9	22	—	—	10	1.46	19.0	16.3	35.3	1.17	4.1	2.9		Tillsonburg area

2286B	227718	PS?	13	42	45	0.047	42	48	5	—	—	—	5	0.87	17.1	17.1	34.2	0.99	5.9	13.0		
2289	217726	Z	15	49	36	0.028	42	43	6	1	—	—	8	0.98	14.7	15.4	30.1	0.95	5.3	9.6		
7001	066865	Z?	10	22	68	0.200	53	38	4	2	—	—	3	1.45	20.7	21.8	42.5	0.95	8.1	12.9	10YR5/3	Ice-contact area
7002	012846	Z	11	44	45	0.050	49	34	4	4	—	—	9	1.43	17.0	18.4	35.4	0.92	5.8	9.5	10YR5/4	
7003	033785	Z	18	47	35	0.022	61	20	2	—	—	9	8	3.03	17.2	21.3	38.5	0.81	5.6	11.3	10YR5.5/4	fabric vector 120°
7004	033818	Z	18	55	27	0.019	59	28	4	2	—	2	5	2.10	14.7	23.3	38.0	0.63	4.3	8.4	10YR5/4	
7005	000873	Z?	36	47	17	0.0049	82	13	—	1	—	—	4	6.30	29.8	22.8	52.6	1.31	3.4	6.8	10YR5/3	
7006	071833	?	34	42	24	0.0055	71	16	6	—	—	2	5	4.45	23.8	13.4	37.2	1.78	5.3	11.9	10YR5/3	
7007	108849	Z?	34	48	18	0.0054	44	32	16	—	—	1	7	1.38	22.4	12.9	35.3	1.74	4.9	9.8	10YR4/3	fabric vector 117°
7008	014710	Z	14	46	40	0.032	57	30	6	—	—	—	7	1.90	15.8	28.3	44.1	0.56	3.9	7.4	10YR6/3	
7009	008674	Z	19	49	32	0.017	56	33	4	—	—	—	7	1.70	18.8	19.2	38.0	0.98	1.1	12.5	10YR4/3	
7010	132715	Z	19	48	33	0.020	35	46	14	2	—	—	3	0.76	17.4	18.1	35.4	0.96	4.5	8.8	10YR4/3	
7011	128757	Z	10	33	57	0.100	55	36	4	1	—	1	3	1.53	17.4	19.9	37.3	0.87	5.5	8.9	10YR5/4	
7012	043643	Z	20	32	48	0.023	56	28	8	—	—	—	8	2.00	17.0	20.3	37.3	0.84	4.7	10.6	10YR5/4	
7013	203648	Z	20	38	42	0.039	41	48	7	—	—	—	4	0.85	16.7	19.6	36.3	0.85	5.3	10.2	10YR5/4	
7014	186671	Z	15	41	44	0.041	46	39	9	1	—	—	5	1.18	17.8	22.4	40.2	0.80	5.6	10.4	10YR5/4	
7015	147635	Z	10	36	54	0.075	29	57	7	—	—	—	7	0.51	13.7	21.7	35.4	0.63	6.1	9.9	10YR4.5/4	
7016	182726	Z	16	33	51	0.067	35	38	21	—	—	—	6	0.92	22.3	29.2	51.5	0.76	3.7	10.5	10YR5/4	
7022	192757	Z	14	46	40	0.036	37	42	4	2	—	1	14	0.88	18.8	31.8	50.5	0.59	3.6	15.7	—	
7100	049823	Z	10	60	30	0.027	—	—	—	—	—	—	—	—	15.7	36.8	52.5	0.43	2.6	8.6		
7210	045756	Z	10	57	33	0.025	46	21	6	2	1	4	20	2.19	17.4	27.7	45.1	0.63	4.1	9.3	10YR5/3	
7227	072767	Z	12	59	29	0.014	68	17	1	1	2	4	7	4.00	21.2	23.5	44.7	0.90	4.5	8.4	—	fabric vector 048°
7248	084783	?	48	43	09	0.0022	55	20	7	2	1	—	15	2.75	19.5	17.8	37.2	1.10	3.5	7.8	10YR4/3	
7249	"	CC	6	50	44	0.048	47	34	3	5	2	—	9	1.38	11.5	36.4	47.9	0.32	4.3	8.2	10YR5/4	fabric vector 125°
7267	086773	CC?	10	41	49	0.054	44	37	4	2	—	—	13	1.19	19.8	32.6	52.4	0.61	2.3	8.6	2.5Y5/4	
7277	114784	?	8	55	37	0.030	53	26	6	4	—	—	11	2.04	18.8	30.8	47.7	0.61	3.7	7.6	10YR5/3	
7286	126815	CC?	13	52	35	0.030	44	46	2	—	—	—	8	0.96	15.6	24.7	40.3	0.63	2.5	8.1	10YR5/4	
7295	079805	?	49	38	13	0.0021	51	28	5	—	1	1	14	1.82	26.9	15.9	42.9	1.69	5.0	10.1	10YR4.5/3	
7303	076783	PS?	31	66	03	0.0051	56	24	4	1	4	2	9	2.32	23.9	19.5	43.5	1.23	3.8	7.6	10YR5/1	Section 303

Sample No.	N.T.S. Grid Ref.	Till	Texture				Pebble Lithology %								Carbonates %				Heavy Minerals %		Color Fresh	Remarks
			Clay %	Silt %	Sand %	Md. mm	Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Precambrian	Ratio Ls/Dol	Calcite	Dolomite	Total	Ratio Cal/Do	Total	Magnetics		
7326	053732	PS?	14	67	19	0.013	43	25	9	3	—	—	19	1.76	24.8	22.5	47.4	1.10	3.0	10.5	10YR5/3	
7344	073759	CC	13	54	33	0.020	64	31	2	—	—	—	3	2.06	21.8	25.6	47.3	0.85	2.2	18.2	2.5Y4/4	
7514	045836	?	38	44	18	0.0036	56	32	—	—	—	2	10	1.75	25.9	12.4	38.3	2.09	2.6	14.0	10YR4.5/3	
7531	007842	Z	12	53	35	0.036	64	17	4	—	—	4	10	3.76	18.0	27.5	45.9	0.65	2.5	10.8	10YR5/3.5	
7584A	160737	Z	16	32	52	0.073	50	34	6	1	—	—	9	1.47	24.8	26.6	51.4	0.93	6.0	11.8	2.5Y5/4	
7584B	"	CC	18	50	32	0.022	42	38	2	2	—	1	15	1.11	21.8	31.8	53.6	0.69	2.7	5.3	10YR5/4	
7628	151828	CC	06	38	56	0.075	45	33	5	6	—	4	7	1.36	16.0	33.4	49.5	0.48	2.8	9.6	2.5Y5.4	Waterlaid?
7630	153821	CC	15	47	38	0.029	31	42	11	—	2	—	14	0.74	20.9	24.4	45.3	0.86	3.6	10.6	2.5Y5/4	
7661	177745	CC	14	49	37	0.025	46	30	7	—	—	—	17	1.53	21.6	28.9	50.5	0.75	3.2	10.6	2.5Y5/4	
7714	156869	CC	11	49	35	0.027	41	40	6	2	2	—	9	1.03	21.0	27.6	48.7	0.76	4.0	7.5	10YR4.5/2	
7718	177812	Z?	15	44	41	0.035	56	31	3	—	1	2	7	1.80	22.0	21.9	43.9	1.01	3.2	10.2	10YR5/3.5	
7733A	016677	Z?	06	49	45	0.048	47	40	3	1	—	—	8	1.17	19.9	27.2	47.1	0.73	1.9	9.8	2.5Y5.5/4	
7733B	"	CC	10	53	37	0.033	51	25	5	6	3	—	10	2.04	20.8	25.4	46.2	0.82	3.9	9.1	2.5Y4.5/4	
7746	001692	Z	22	51	27	0.012	42	32	7	3	—	1	14	1.31	19.4	20.3	39.7	0.96	3.4	10.4	10YR5/5	
7748A		Z	12	51	37	0.032	50	33	3	—	—	—	14	1.51	17.5	23.0	40.4	0.76	2.3	10.7	10YR5/3.5	Lucan Sheet
7748B		CC	05	55	40	0.045	52	35	4	—	—	—	9	1.49	21.0	24.7	45.7	0.85	4.8	10.5	2.5Y5/4	
71047E	387873	PS	24	54	22	0.0089	48	42	2	2	1	1	4	1.14	18.4	19.4	37.8	0.95	3.3	7.2	10YR4.5/4	
71047D	"	?					31	54	2	3	—	—	10	0.57	—	—	—	—	—	—	10YR6/5	
71047C	"	CC	10	43	47	0.054	37	41	2	2	8	—	10	0.90	14.6	23.8	38.4	0.62	2.3	7.9	10YR5/3.5	fabric vector 033°
71047B	"	CC	13	50	37	0.032	23	57	7	—	—	—	13	0.40	14.9	35.9	50.8	0.42	1.5	7.5	10YR5/1.5	fabric vector 270°
71047A	"	C	28	46	26	0.0085	34	38	5	2	2	4	15	0.89	20.5	13.2	33.7	1.55	1.7	5.9	10YR3/1.5	fabric vector 034°
71065	348883	CC	09	38	53	0.070	27	46	7	2	3	—	15	0.59	16.6	24.8	41.4	0.67	4.1	9.0	10YR5/5	

71228A	405875	PS	23.4	15.2	38.6	1.54	1.7*	40.0		10YR5/3.5							37	61	02	0.0036 —	— — — — — — —
71228B	”	?	11	35	54	0.075	48	35	2	2	—	—	13	1.37	15.7	20.3	36.0	0.77	5.9	14.1	10YR5.5/4
71228C	”	CC	10	52	38	0.032	20	60	12	—	—	—	8	0.33	18.0	35.3	53.3	0.51	2.5	8.5	10YR5.5/5
71228D	”	CC?	28	45	27	0.012	—	—	—	—	—	—	—	—	18.3	21.3	39.6	0.86	3.1	7.9	10YR4/2
71257	293855	?	11	47	42	0.038	34	52	7	—	1	1	5	0.65	13.5	27.5	50.0	0.49	3.7	12.6	10YR5/3.5
71286	265849	PS?	27	46	27	0.0077	—	—	—	—	—	P	—	—	17.6	16.4	34.1	1.08	2.7	13.5	7.5YR4.5/3
71382	247882	Z?	08	54	38	0.030	31	54	9	2	—	1	3	0.58	19.2	22.5	41.7	0.85	2.7	11.8	10YR5.5/4
71435	147712	Z	22	54	24	0.012	41	44	5	—	—	—	10	0.93	17.3	22.2	39.5	0.78	5.0	10.6	10YR5/4
71435A	”	PS	43	45	12	0.0030	—	—	—	—	—	—	—	—	18.4	20.4	38.7	0.90	2.2	7.1	10YR5/2
71435B	”	CC	09	44	47	0.054	55	24	8	1	—	—	12	2.30	15.3	26.6	41.9	0.57	2.9	5.1	10YR5.5/3.5
71732	216753	Z	12	35	53	0.075	47	29	12	3	2	—	7	1.62	18.0	26.1	44.1	0.69	5.3	10.1	10YR6.5/3.5 Inclusions of P.S.T.
71838	173626	Z	14	33	53	0.073	—	—	—	—	—	—	—	—	16.1	27.7	43.8	0.58	6.7	13.2	—
72383	071612	Z	12	40	48	0.055	—	—	—	—	—	—	—	—	15.1	33.3	48.4	0.45	5.4	14.5	10YR5.5/4
72396	090643	Z	13	49	38	0.036	—	—	—	—	—	—	—	—	18.9	28.9	47.8	0.65	5.9	11.5	10YR5/3 overlies sand
72456	141709	?	16	49	35	0.029	—	—	—	—	—	—	—	—	16.0	33.9	50.0	0.47	3.4	7.6	10YR5/3
72546	213739	?	12	42	46	0.052	—	—	—	—	—	—	—	—	14.3	31.5	45.8	0.45	5.0	9.3	10YR5.5/4
72558	098625	Z	08	39	53	0.067	—	—	—	—	—	—	—	—	13.3	31.5	44.8	0.42	4.2	8.5	10YR5.5/5 overlies sand
72565U	286620	PS	19	61	20	0.018	—	—	—	—	—	—	—	—	17.4	23.0	40.4	0.75	3.1	6.8	10YR5.5/4
72565L	”	PS	42	53	5	0.0033	—	—	—	—	—	—	—	—	18.2	24.6	42.8	0.74	3.7	9.0	10YR4.5/2
72570	251676	Z?	15	42	43	0.040	—	—	—	—	—	—	—	—	20.2	23.7	43.9	0.85	5.9	10.4	10YR5.5/4
72571	235687	Z?	17	43	42	0.031	—	—	—	—	—	—	—	—	19.4	20.3	39.7	0.96	5.0	8.3	10YR5/3
70W-2572	241704	PS	35	53	12	0.0055	—	—	—	—	—	—	—	—	22.2	17.0	39.2	1.31	4.5	8.0	10YR4/2
T- 2	255582	?	08	41	51	0.065	45	41	9	2	—	—	3	1.10	18.2	23.5	41.7	0.78	2.6	11.4	10YR5/4 Norwich Moraine
T- 3	257567	PS	49	46	05	0.0033	—	—	—	—	—	—	—	—	22.2	11.9	34.1	1.87	4.0	11.3	10YR4.5/3 Norwich Moraine
T- 4	261553	PS	39	54	07	0.0033	—	—	—	—	—	—	—	—	22.7	11.4	34.1	1.99	5.1	11.3	10YR5/1.5
T- 7	273496	PS	27	65	08	0.0066	40	50	7	—	—	—	3	0.80	31.0	12.2	43.2	2.54	2.0	9.6	10YR5/3 Tillsonburg Moraine
T- 8	234406	?	19	62	19	0.0068	—	—	—	—	—	—	—	—	21.2	12.1	33.4	1.76	4.8	12.0	10YR4/3 Paris Moraine
T-10	218374	PS	40	52	08	0.0035	—	—	—	—	—	—	—	—	24.2	11.4	35.6	2.12	3.2	5.3	10YR4/3
T-12	192398	PS	30	61	09	0.0063	—	—	—	—	—	—	—	—	21.4	13.4	34.8	1.60	2.5	8.4	10YR4/3

Appendix C

(back pocket)

Information on sand or gravel pits not described in text. Lot numbers asterisked in North Oxford Township were formerly in North Dorchester Township.

METRIC CONVERSION FACTORS

Linear Measure

1 kilometre = 0.6214 mile
1 metre = 39.37 inches
1 centimetre = 0.3937 inch

Square Measure

1 square kilometre = 0.3861 square mile

Gradient

1 metre per kilometre = 5.280 feet per mile

Map Scale (ratio)

1 inch to ¼ mile = 1 : 15,840

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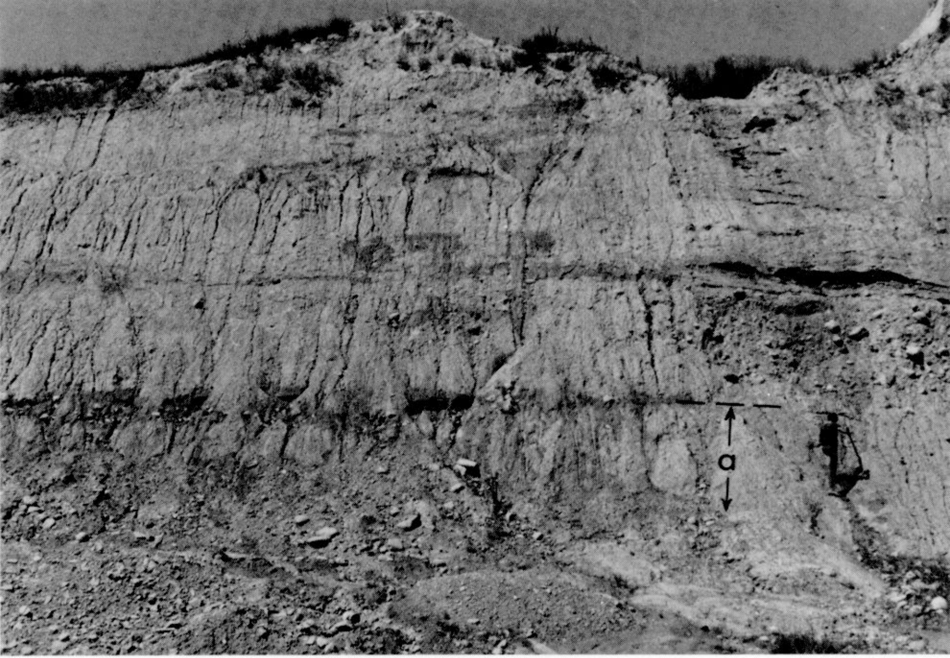
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ODM 804

APPENDIX C

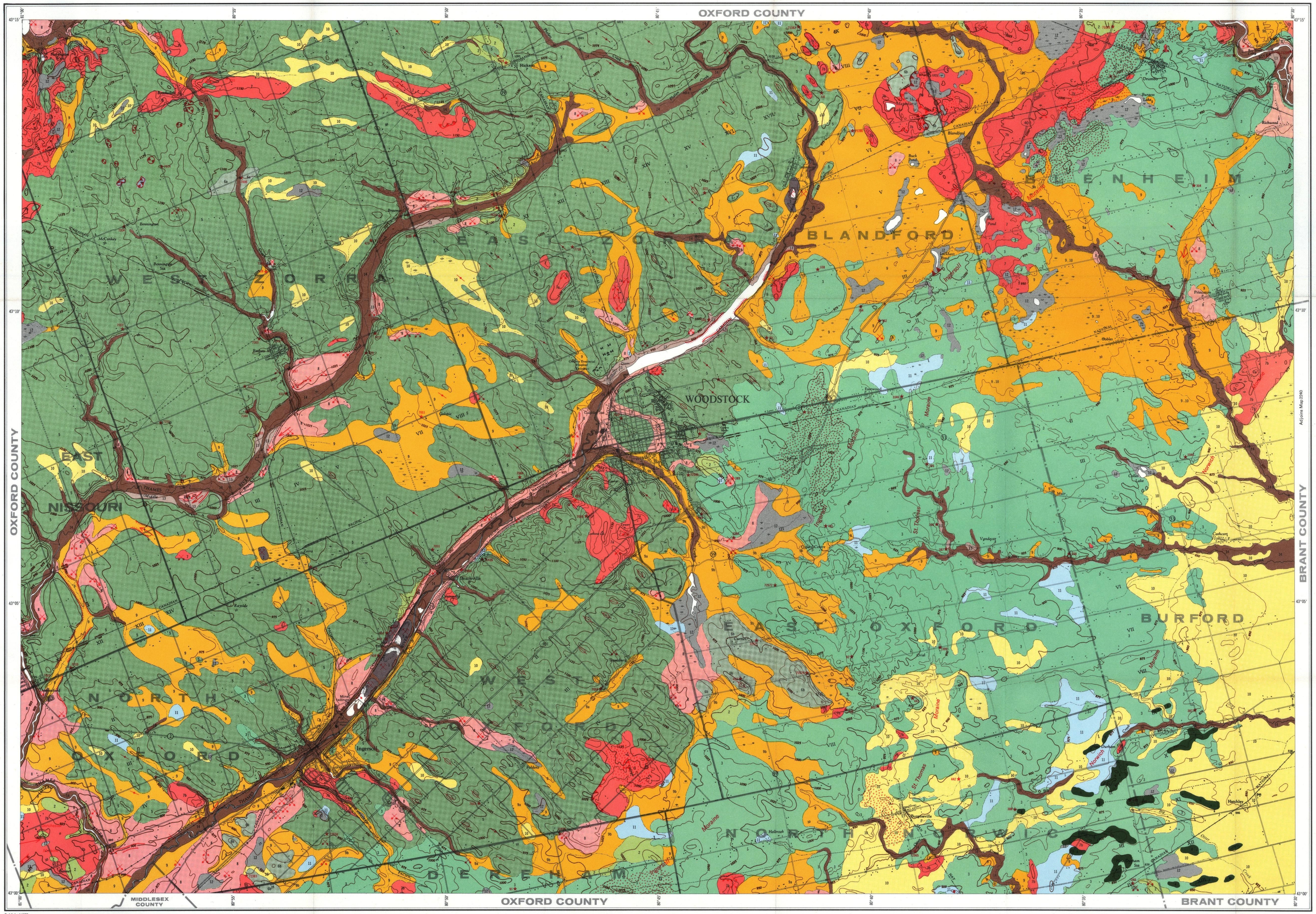
Information on sand or gravel pits not described in text.

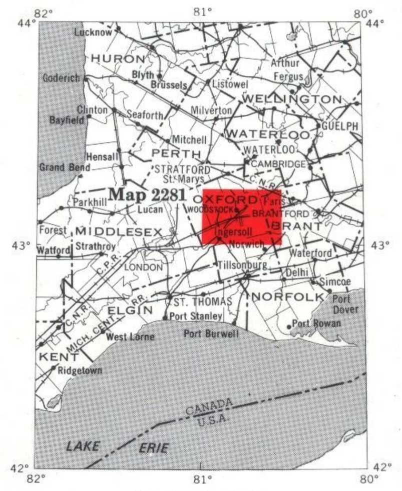
Property Number (See Map 2282, back pocket)	Owner or Operator	Location: Township	Location: Concession	Location: Lot	Thickness of Overburden	Observed Thickness of Deposit	Reported Thickness of Deposit	Estimated Reserves (S–small, L–large, U–unknown)	Composition: % stone (estimated)	Composition: % sand (estimated)	Composition: % stone greater than 1"	Composition: % stone greater than 4"	Composition: maximum boulder	Origin of deposit	Pebble Lithology (percent): Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Precambrian Felsic rocks	Precambrian Mafic rocks	Precambrian Metamorphic rocks
1	Bartondale	North Oxford	IV	23 FND	2	18	—	U	30	70	20	—	—	outwash	—	—	—	—	—	—	—	—	—
2	Bartondale	North Oxford	IV	23 FND	2	12	18	U	25	75	—	—	—	outwash	—	—	—	—	—	—	—	—	—
3	—	Blandford	III	11	2	15	—	S	40	60	—	—	4'	ice-contact	32	52	1	2	2	—	3	5	3
4	—	Blandford	VI	4	0	6	—	S	—	—	—	—	—	outwash	36	41	3	5	8	—	1	4	1
5	—	Blandford	VII	2	3	10	—	S	15	85	—	—	2'	ice-contact	—	—	—	—	—	—	—	—	—
6	—	Blenheim	IV	22	2	15	—	S	very variable				4'	ice-contact	18	68	3	1	2	—	1	6	1
7	—	Blenheim	VI	18	2	15	—	S	very variable				2'	ice-contact	—	—	—	—	—	—	—	—	—
8	—	Blenheim	VII	19	1	10	—	S	35	65	—	10	4'	ice-contact	—	—	—	—	—	—	—	—	—
9	Chittles, L.	Blenheim	VII	8	4	20	—	S	25	75	40	5	3'	outwash	24	70	1	—	—	—	2	—	2
12	Cuthbert, V.	West Oxford	V	4	0–8	25	—	U	30	70	30	—	4"	outwash	—	—	—	—	—	—	—	—	—
13	Denby pit	West Oxford	B.F.	1	15	25	—	L	15	85	—	—	6"	ice-contact	—	—	—	—	—	—	—	—	—
15	—	East Nissouri	XI	3	3	30	—	L	60	4	—	50	3'	outwash	47	32	4	3	—	—	4	6	4
16	—	East Nissouri	XII	6	—	12+	—	U	15	85	—	5	—	outwash	—	—	—	—	—	—	—	—	—
17	—	East Zorra	IX	5	—	18	—	S	70	30	30	5	4'	ice-contact	43	36	10	1	—	—	4	5	1
18	—	East Zorra	IX	15	—	<10	—	S	—	—	—	—	—	outwash	42	38	5	1	1	1	7	1	4
19	—	East Zorra	X	13	—	20	—	S	25	75	—	20	3'	outwash	30	49	7	1	—	1	3	6	3
20	Graham, A. M.	West Zorra	VII	10	—	20	—	S	50	50	—	10	9"	outwash	33	35	20	1	—	—	5	4	2
21	Hamilton, F.	East Zorra	XIII	4	—	30	—	S	60	30	75	15	3'	outwash	17	59	7	1	—	—	11	5	—
23	Hillview Farms	East Oxford	IV	17	1	8	—	S	35	65	20	5	—	outwash	23	67	3	2	—	—	2	—	3
24	Hossack, A.	East Nissouri	XII	4	—	12	—	U	35	65	—	5	1	outwash	47	35	10	1	—	—	2	2	3
25	Hough, H.	East Zorra	X	15	—	9	—	S	25	75	—	5	1	outwash	37	39	4	3	2	—	5	8	2
26	Kalbfleisch, K.	Blandford	VI	2	2	15	—	S	70	30	40	10	2½'	ice-contact	—	—	—	—	—	—	—	—	—
28	Kitmer, T.	West Zorra	I	28	—	40	—	U	very variable				—	ice-contact	40	41	9	1	—	—	1	3	4
29	Little, J.	West Zorra	I	4	—	10	—	S	30	60	—	15	10"	outwash	53	29	7	1	2	—	3	4	1
30	McCall, D.	East Nissouri	XIII	6	—	12	—	U	25	75	—	15	1'	outwash	44	37	5	2	—	—	5	4	3
31	Matheson, S.	West Zorra	V	26	5	20	—	S	30	70	—	5	2½'	ice-contact	43	29	7	5	3	P	3	2	8
32	M. T. C.	West Oxford	II	1	5	9	—	S	50	50	40	—	1'	outwash	45	35	8	—	1	—	2	7	2
33	Mitchell, G.	East Nissouri	XIII	7	2	7	25	U	25	75	—	5	—	outwash	40	40	4	4	2	2	—	3	5
34	Moyer, C.	West Zorra	III	6?	3	20	—	S	30	70	—	—	5'	outwash	42	25	9	2	—	—	4	9	9
37	—	N. Norwich	IV	gore	8	4+	—	U	—	—	—	—	—	ice-contact	27	54	8	—	—	—	2	7	2
38	—	North Oxford	I	24	2	15	—	S	—	—	—	—	—	alluvium	—	—	—	—	—	—	—	—	—
39	—	North Oxford	II	22 FND	2	8	—	S	—	—	—	—	—	outwash	—	—	—	—	—	—	—	—	—
40	—	North Oxford	V	24 FND	4	12	—	U	35	65	60	5	4'	outwash	—	—	—	—	—	—	—	—	—
43	Oxford Sand & Gravel Ltd.	East Oxford	III	17	4	5	—	S	50	50	70	30	2'	outwash	9	72	8	2	—	—	5	2	2
44	Phelps pit	West Oxford	B.F.	4	2	20	—	S	50	50	40	5	1'	outwash	54	27	9	1	—	—	4	5	—
45	Pratt, C.	East Zorra	XIII	17	—	12	—	S	70	30	—	30	4'	outwash	26	53	7	1	—	—	1	7	5
46	Ruckles, V. W.	North Oxford	V	23	2	15	—	U	25	75	75	5	4'	outwash	19	64	9	—	—	—	4	4	—
47	Schmidt, R.	East Zorra	XIV	16	2	8	—	S	65	35	40	10	3'	outwash	—	—	—	—	—	—	—	—	—
49	Steel Co. of Canada Ltd., The	North Oxford	III	14	2	15	—	S	40	60	—	10	1'	outwash	39	38	7	7	1	—	3	2	3
50	Steel Co. of Canada Ltd., The	North Oxford	IV	14	4	8	—	S	60	40	20	—	—	alluvium	29	32	9	8	—	—	6	4	11
53	Totten, G.	West Zorra	IV	7	—	20	—	S	50	50	—	40	41	outwash	40	24	13	2	—	1	4	12	4
55	van Straalen, F.	West Oxford	II	23	6	18	—	S?	—	—	—	—	—	outwash	33	44	13	—	—	—	3	5	2
56	Walmsley Bros. Ltd.	North Oxford	V	24 FND	2	20	—	U	40	60	—	—	—	outwash	—	—	—	—	—	—	—	—	—
57	Walters, G.	Blenheim	VIII	21	4	30	—	S	30	70	30	<5	—	ice-contact	30	61	2	—	—	—	2	4	1
58	Walters, L.	East Zorra	IX	22	—	3–35	30	S	30	70	—	—	—	ice-contact	42	37	14	—	—	—	3	3	1
59	—	West Oxford	B.F.	23	2	15	—	S	15	85	—	—	6"	outwash	—	—	—	—	—	—	—	—	—
60	—	West Oxford	B.F.	28	0	12	—	S	25	75	—	—	—	outwash	—	—	—	—	—	—	—	—	—
61	—	West Oxford	B.F.	gore	6	40	—	L	40	60	40	10	3	ice-contact	—	—	—	—	—	—	—	—	—
62	—	West Oxford	I	23	2	15	—	S	20	80	—	—	6"	outwash	—	—	—	—	—	—	—	—	—
63	—	West Oxford	I	23	2	15	—	S	—	—	—	—	—	outwash	—	—	—	—	—	—	—	—	—
64	—	West Oxford	I	27	2	15	35	U	20	80	—	—	5"	outwash	—	—	—	—	—	—	—	—	—
65	—	West Oxford	II	13	2	12	—	S	—	—	—	—	6"	outwash	46	33	8	—	—	5	1	4	3
66	—	West Zorra	I	27	—	15	—	S	35	65	20	5	8"	ice-contact	—	—	—	—	—	—	—	—	—
67	—	West Zorra	II	6	—	15	—	S	40	60	—	15	2'	outwash	49	31	7	3	—	—	2	6	2
68	—	West Zorra	III	6	—	15	—	S	60	40	—	25	2'	outwash	48	31	5	—	—	—	10	5	1
69	—	West Zorra	III	20	5	30	—	U	30	70	—	25	2'	outwash	35	30	8	4	—	—	8	8	7
70	—	West Zorra	III	29	—	20	—	S	5	95	—	—	4'	ice-contact	—	—	—	—	—	—	—	—	—
71	—	West Zorra	IV	11	4	8	—	S	15	85	—	5	6"	outwash	39	39	7	3	2	—	5	2	3
72	—	West Zorra	V	9	—	25	—	U	40	60	—	10	18"	outwash	42	26	11	—	—	1	5	10	5
73	—	West Zorra	V	10	—	15	—	U	30	70	—	—	4'	outwash	44	41	9	—	—	—	—	5	1
74	—	West Zorra	V	11	—	15	—	U	50	50	—	30	4'	outwash	—	—	15	—	—	—	—	—	—
75	—	West Zorra	V	16	—	8	—	S	—	—	—	—	—	outwash	49	27	5	—	1	2	5	6	5
76	S. Schelther?	West Zorra	VI	10	1	35	—	L?	70	30	—	40	3'	outwash	39	35	3	6	1	—	2	10	4
77	—	West Zorra	VI	11	3	20	—	S	40	60	—	5	10"	ice-contact	47	28	14	1	1	1	—	2	5
78	—	West Zorra	VII	11	—	15	—	U	60	40	—	20	3'	outwash	41	32	20	1	2	—	—	4	—
79	—	West Zorra	VIII	1	—	6	—	S	30	70	—	10	4'	outwash	27	46	12	—	—	—	5	7	3

ONTARIO
DIVISION OF MINES

HONOURABLE LEO BERNIER, *Minister of Natural Resources*
W. Q. MACNEE, *Deputy Minister of Natural Resources*
G. A. Jewett, *Executive Director, Division of Mines* E. G. Pye, *Director, Geological Branch*

Map 2281
Woodstock
Quaternary Geology





Scale 1 inch to 50 miles

LEGEND

CENOZOIC
QUATERNARY
RECENT

14 Modern alluvium, unsubdivided: silt, sand, gravel.

13 Older alluvium: sand or gravel.

12 Bog deposits: peat, muck, marl.

PLEISTOCENE
LATE WISCONSINAN

11 Fine-grained glaciolacustrine or pond deposits: silt and clay.

10 Glaciolacustrine or pond deposits: sand and silty fine sand.

9 Glaciofluvial outwash sand, unsubdivided.
9a Glaciofluvial outwash sand including some gravel.
9b Glaciofluvial outwash sand frequently underlain by gravel.

8 Glaciofluvial outwash gravel and gravelly sand frequently overlain by several feet of sand or silt.

7 Ice-contact stratified drift, unsubdivided: sand and gravel including some till or silt.
7a Ice-contact stratified drift, mainly gravel.
7b Ice-contact stratified drift, mainly sand.

6a Silt till (Port Stanley Till or fine-grained Zorra till, or older till).
6b Sandy silt till (Catfish Creek Till or Zorra till).

5 Zorra till: yellowish brown silt to sand silt till.

4 Stony to bouldery ablation till, usually overlying sand ridges or Port Stanley Till.

3 PORT STANLEY TILL: silt till; may include older drift in valley walls.

2 CATFISH CREEK TILL: stony, sandy silt till; may include older drift in valley walls.

UNCONFORMITY

PALEOZOIC
DEVONIAN

1 Bedrock outcrop: limestone, dolomite, chert.

Deposits on this sheet are mapped where they reach three feet or more in thickness. Thinner deposits are not shown.

SYMBOLS

County boundary.
Township boundary.
Topographic contours.
Drumlin or drumlinoidal ridge.
Glacial fluting.
Glacial meltwater channel with inferred direction of flow.
Hummocky topography.
Esker.
Terrace escarpment.
Ice-contact slope; enclosed area indicates kettle hole.
Geological boundary, position interpreted.
Bedrock outcrop.
Limestone quarry (operating or abandoned).
Clay pit and tile factory.
Sand and gravel pit.
Till sample locality.

For other conventional signs refer to 1:50,000 National Topographic System.

Published 1973

SOURCES OF INFORMATION

Geology by W. R. Cowan and assistants, Geological Branch, 1969, 1970.

Aerial photography: Forest Resources Inventory, Ministry of Natural Resources, Toronto; National Air Photo Library, Department of Energy, Mines and Resources, Ottawa.

Water well records of the Ontario Water Resources Commission, Ministry of the Environment.

Preliminary map, P.701 Pleistocene Geology of the Woodstock Area, scale 1:50,000, issued 1971.

Cartography by P. A. Wisbey and assistants, Surveys and Mapping Branch, 1973.

Topography from map 40P/2 (East and West sheets) of the National Topographic System, with additional information by W. R. Cowan.

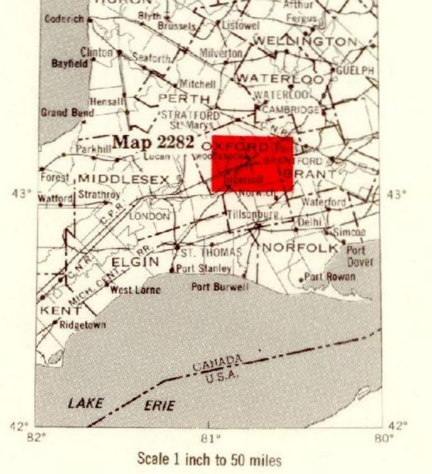
Magnetic declination in the area was approximately 6°35′ West in 1970.

Map 2281
Quaternary Geology
WOODSTOCK
SOUTHERN ONTARIO

Scale 1 : 63,360 or 1 Inch to 1 Mile

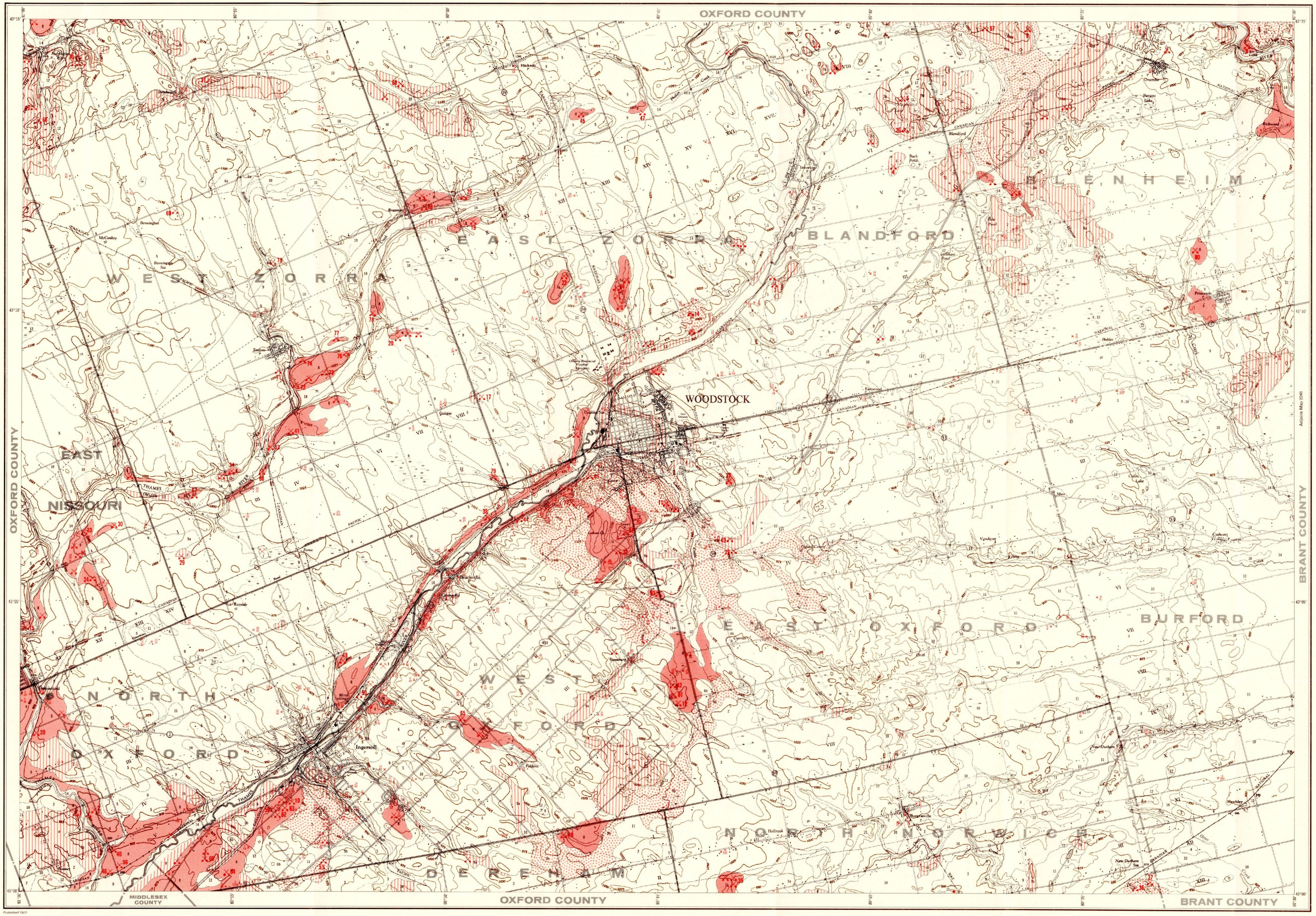
Chains 80 40 0 1 2 3 4 5 Miles
Feet 10,000 0 10,000 20,000 Feet
Metres 1000 0 1 2 3 4 5 6 Kilometres

ONTARIO
DIVISION OF MINES
HONOURABLE LEO BERNIER, Minister of Natural Resources
W. Q. MACNEE, Deputy Minister of Natural Resources
G. A. Jewett, Executive Director, Division of Mines   E. G. Pye, Director, Geological Branch



LIST OF PROPERTIES

1. Bartondale.
2. Bartondale.
   Blandford Township.
3. Concession III, lot 11.
4. Concession VI, lot 4.
5. Concession VII, lot 2.
   Blenheim Township.
6. Concession IV, lot 22.
7. Concession VI, lot 18.
8. Concession VII, lot 19.
9. Chitties, L.
10. Clark, R.S. and Son Ltd.
11. Culver pit.
12. Cuthbert, V.
13. Denby pit.
14. Dunseith Bros.
15. East Nissouri Township, conc. XI, lot 3.
16. East Nissouri Township, conc. XII, lot 6.
   East Zorra Township
17. Concession IX, lot 5.
18. Concession IX, lot 15.
19. Concession X, lot 13.
20. Graham, A. M.
21. Hamilton, F.
22. Hart pit.
23. Hillview Farms.
24. Hossack, A.
25. Hough, H.
26. Kalbfleish, K.
27. Keyes, C. S.
28. Kitmer, T.
29. Little, J.
30. McCall, D.
31. Matheson, S.
32. Ministry of Transportation and Communications.
33. Mitchell, G.
34. Moyer, C.
35. North Norwich Township.
36. North Norwich Township. (Alexander pit)
37. North Norwich Township, conc. IV, gore lot.
   North Oxford Township.
38. Concession I, lot 24.
39. Concession II, lot 22, F. N. D.
40. Concession V, lot 24, F. N. D.
41. Oxford County.
42. Oxford Sand and Gravel Ltd.
43. Oxford Sand and Gravel Ltd.
44. Phelps pit.
45. Pratt, C.
46. Ruckles, V. W.
47. Schmidt, R.
48. Shelton Bros.
49. Steel Company of Canada Ltd., The.
50. Steel Company of Canada Ltd., The.
51. Thornton, G. B.
52. Thornton, G. B. (Innes pit).
53. Totten, G.
54. Tree Sand and Gravel.
55. van Straalen, F.
56. Walmsley Bros. Ltd.
57. Walters, G.
58. Walters, L.
   West Oxford Township.
59. Broken front concession, lot 23.
60. Broken front concession, lot 28.
61. Broken front concession, gore lot.
62. Concession I, lot 23.
63. Concession I, lot 23.
64. Concession I, lot 27.
65. Concession II, lot 13.
   West Zorra Township.
66. Concession I, lot 27.
67. Concession II, lot 6.
68. Concession III, lot 6.
69. Concession III, lot 20.
70. Concession III, lot 29.
71. Concession IV, lot 11.
72. Concession V, lot 9.
73. Concession V, lot 10.
74. Concession V, lot 11.
75. Concession V, lot 16.
76. Concession VI, lot 10.
77. Concession VI, lot 11.
78. Concession VII, lot 11.
79. Concession VIII, lot 1.
80. Wight, H.
81. Wiseman, G.



Map 2282
Granular Resources
WOODSTOCK
SOUTHERN ONTARIO

Scale 1 : 63,360 or 1 Inch to 1 Mile

Chains 80 40 0 1 2 3 4 5 Miles
Feet 10,000 0 10,000 20,000 Feet
Metres 1000 0 1 2 3 4 5 6 Kilometres

SOURCES OF INFORMATION

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Magnetic declination in the area was approximately 6°35' West in 1970.

LEGEND

CENOZOIC
QUATERNARY
RECENT

14	14 Modern alluvium, unsubdivided: silt, sand, gravel.
13	13 Older alluvium: sand or gravel.
12	12 Bog deposits: peat, muck, marl.

PLEISTOCENE
LATE WISCONSINAN

11	11 Fine-grained glaciolacustrine or pond deposits: silt and clay.
10	10 Glaciolacustrine or pond deposits: sand and silty fine sand.
9	9 Glaciofluvial outwash sand, unsubdivided. 9a Glaciofluvial outwash sand including some gravel. 9b Glaciofluvial outwash sand frequently underlain by gravel.
8	8 Glaciofluvial outwash gravel and gravelly sand frequently overlain by several feet of sand or silt.
7	7 Ice-contact stratified drift, unsubdivided: sand and gravel including some till or silt. 7a Ice-contact stratified drift, mainly gravel. 7b Ice-contact stratified drift, mainly sand.
6	6a Silt till (Port Stanley Till or fine-grained Zorra till, or older till). 6b Sandy silt till (Catfish Creek Till or Zorra till).
5	5 Zorra till: yellowish brown silt to sand silt till.
4	4 Stony to bouldery ablation till, usually overlying sand ridges or Port Stanley Till.
3	3 PORT STANLEY TILL: silt till; may include older drift in valley walls.
2	2 CATFISH CREEK TILL: stony, sandy silt till; may include older drift in valley walls.

UNCONFORMITY

PALEOZOIC
DEVONIAN

1	1 Bedrock outcrop: limestone, dolomite, chert.

Deposits on this sheet are mapped where they reach three feet or more in thickness. Thinner deposits are not shown.

SYMBOLS

County boundary.
Township boundary.
Topographic contours.
Geological boundary.
Bedrock outcrop.
Limestone quarry (operating or abandoned).
Clay pit and tile factory.
Sand and gravel pit.
Water well location indicating thickness of overburden overlying reported thickness of granular materials; (s indicates medium to course sand).
37 Location of property; (see report).
Area known to contain useable granular materials; frequently containing active or inactive pits. Probability of locating economic deposits is moderate to high.
Area underlain by stratified drift containing local masses of useable granular materials; quality and quantities uncertain; development and extraction costs may be high. Probability of locating economic deposits is moderate to low.
Area containing buried granular materials; useable materials may be very localized; prospecting and development costs may be high. Probability of locating economic deposits is moderate to low.
Area having low probability for location and production of granular materials.

For other conventional signs refer to 1:50,000 National Topographic System.