ONTARIO DEPARTMENT OF MINES
AND NORTHERN AFFAIRS

Pleistocene Geology of the Brantford Area Southern Ontario

By

W. R. Cowan

INDUSTRIAL MINERAL REPORT 37

TORONTO

1972

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PLEISTOCENE GEOLOGY OF THE BRANTFORD AREA

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ONTARIO
DEPARTMENT OF MINES
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Cowan, W. R.
1972: Pleistocene geology of the Brantford Area, southern Ontario;
Ontario Dept. Mines and Northern Affairs, IMR 37, 66p.
Accompanied by Maps 2240 and 2241, scale 1 inch to 1 mile.

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ABSTRACT

Sediments representing six glacial advances or fluctuations are present within the area. Early Wisconsinan(?) deposits include the 'lower beds' and the Canning Till whereas Late Wisconsinan deposits comprise the Catfish Creek Till, the Port Stanley Till, the Wentworth Till, and the Halton Till, and associated stratified drift. No deposits of Mid Wisconsinan age have been identified. The Port Stanley, Wentworth, and Halton Tills are the principal tills occurring at the surface.

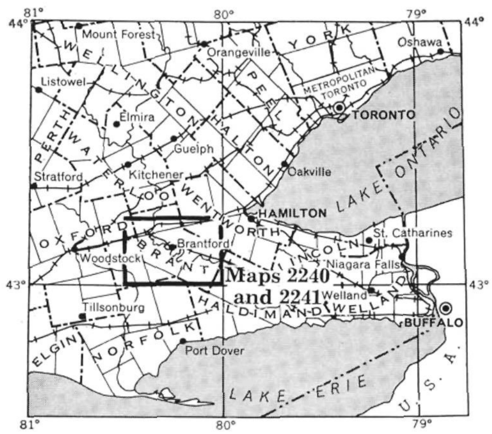

Figure 1—Key map showing location of the Brantford area. Scale, 1 inch to 50 miles.

Large parts of the area are mantled by glaciolacustrine sands, silts, and clays largely laid down in glacial Lakes Whittlesey and Warren. Lake Whittlesey fronted the retreating Wentworth ice-sheet and abandoned shorelines near Paris have elevations of 900 feet. The best developed shoreline of Lake Warren occurs at 870 feet in the Paris-St. George area; this lake was dammed by the Halton ice-sheet.

Widespread glaciofluvial outwash and deltaic gravels associated with the Wentworth ice-sheet comprise an important mineral resource for southern Ontario. Utilization will require sequential land-use planning and necessary environmental controls.

Pleistocene Geology of the Brantford Area Southern Ontario

by

W. R. Cowan[1]

INTRODUCTION

The Brantford area comprises approximately 430 square miles bounded by Latitude 43°00′ to 43°15′ north and Longitude 80°00′ to 80°30′ west. It consists of National Topographic Series Sheet 40P/1 and contains parts of Brant, Haldimand, Norfolk, Oxford, and Wentworth Counties. The principal urban centres within the area are the City of Brantford and the Town of Paris.

Access to the area is available via Highways 2, 5, 24, 24A, 53, 54, 99, and 403 and by the Canadian National, Canadian Pacific, and Toronto, Hamilton and Buffalo railways; in addition a close network of county and township roads is present.

Clay for the manufacture of brick and tile, and sand and gravel have been extracted from deposits within the Brantford area for many years and the large sand and gravel resource located within the area makes up an important part of the mineral resource base of southern Ontario. Mapping of the Pleistocene geology, in which the above deposits occur, is intended to provide information on the distribution, properties, and stratigraphy of these materials for use in planning, engineering, hydrological, geological, and environmental studies.

PRESENT GEOLOGICAL SURVEY

Mapping of the Pleistocene geology of the Brantford area was initiated during the summer of 1968 and completed during the summer of 1969. Field data were obtained from the examination of road-cuts, stream and river banks, excavations, and by test pitting and hand augering where suitable exposures were not available. Additional information was obtained from water-well records and from records made available by various Provincial, Federal, Municipal, and private agencies. Preliminary maps of the work carried out have been published previously (ODM Maps P.516, P.582, Cowan 1969; 1970).

ACKNOWLEDGMENTS

Capable field assistance was provided by R.N. DiLabio in 1968 and by K.K. Chiang, R.N. DiLabio, and D.N. Allen in 1969. Independent mapping was carried out by Mr. Chiang in the southwesternmost part of the area and by Mr. DiLabio in the Town of Paris and northwest of the Village of Burford.

[1] Geologist, Ontario Department of Mines and Northern Affairs. Manuscript accepted for publication by the Chief, Industrial Minerals Section, 9 June 1970.

Mr. C.J. Acton of the Canada Department of Agriculture kindly provided additional information concerning the area and contributed useful discussion. Mr. R. Middleton, City Engineer for Brantford; J.D. Lee Engineering Limited, Paris; Telephone City Gravel Company Limited; Consolidated Sand & Gravel Company Limited; Dufferin Materials and Construction Limited; Flintkote Company of Canada Limited; and several other engineering concerns provided the writer with additional information. Water-well information was provided by the Ontario Water Resources Commission with the assistance of Mr. A.J. Tasker and Mrs. P. Hollett.

Shell samples were identified by Rev. H.B. Herrington of Westbrook, Ontario and by Dr. A.H. Clarke Jr. and Mrs. M.F.I. Smith of the National Museum of Natural Sciences. Dr. J.H. McAndrews of the Royal Ontario Museum contributed field discussion and carried out the pollen analyses reported herein. Professor P.F. Karrow of the University of Waterloo, Professor A. Dreimanis of the University of Western Ontario, and Mr. L.J. Chapman of the Ontario Research Foundation provided discussion on various topics within the area.

Laboratory analyses were carried out by the Laboratory and Research Branch of the Ontario Department of Mines and Northern Affairs.

To all of the above individuals and institutions the writer extends his thanks. Special thanks are extended to the residents of the area who permitted access to their property and who contributed considerable constructive criticism.

PREVIOUS WORK

The Paleozoic rocks underlying the map-area were mapped by Caley (1941) and minor refinements of his rock boundaries have been made in the southwestern part of the area by Sibul (1969) and Yakutchik *et al.* (in preparation); Sanford (1969) has recently produced a new compilation map of the rocks underlying the area. Guillet (1964) presented a considerable quantity of information on the gypsum-bearing rocks of the area whereas additional information on rock lithology and stratigraphy of the Silurian and Devonian rocks is to be found in Bolton (1957) and Hewitt (1960; 1964). The subsurface stratigraphy of Ordovician and Cambrian rocks has been described by Sanford and Quillian (1959), Sanford (1961), and Beards (1967). Other information on the Paleozoic rocks underlying the area is contained in the water-well records maintained by the Ontario Water Resources Commission and in the oil- and gas-well records maintained by the Ontario Department of Energy and Resources Management.[1]

The shape or topography of the bedrock surface beneath the Pleistocene drift cover has been documented by Karrow (1963b) and additional information is available for small parts of the area in Walton (*circa* 1964), Sibul (1969), and Yakutchik *et al.* (in preparation). The thickness of drift overlying the bedrock is obtainable from Karrow's map when used in conjunction with a topographic map (Karrow 1963b).

Information on the ground-water resources of Brant County has been published by the Ontario Water Resources Commission (1964) and additional information is available for small parts of the area in Sibul (1969), Yakutchik *et al.* (in preparation), and Walton (*circa* 1964).

Previous work on Pleistocene features and deposits within the area is also considerable. The early work of Taylor (1913) in defining the terminal moraine systems, and the subsequent physiographic mapping and deglaciation synthesis by Chapman and Putnam (1951; 1966) contributed significantly to the knowledge of the area. Similarly, studies of the prehistoric Great Lakes by Leverett and Taylor (1915), MacLachlan (1938), Leverett (1939), Chapman and Putnam (1951; 1966), Hough (1958; 1963), Karrow (1963a), and Ryder (1963), are important in studying the lake sediments and history. The latter author (Ryder) studied the lake history of Brant County in considerable detail. Dreimanis (1961) has discussed lithologic properties of some glacial tills within the area and Dell (1959) the mineralogy of sands; the latter study resulting in revisions of the glacial history of part of Ontario (Chapman and Dell 1963). Hurst (1962) described the glacial geology of the northeastern part of the map-area and Karrow (1963a) deciphered much of the Pleistocene stratigraphy of the area. The definitive work of the latter author (Karrow), in the Galt area to the north and the included studies from the Brantford area, considers in detail many of the deposits and features to be described herein and should be consulted in conjunction with the present work.

Major sand and gravel operations have been described by Karrow (Hewitt and Karrow 1963) and updated by Cowan (Hewitt and Cowan 1969a), and

[1] Since 1 July 1970, oil- and gas-well records have been maintained by the Petroleum Resources Section of the Ontario Department of Mines and Northern Affairs.

operations of lesser commercial importance by Cowan (Hewitt and Cowan 1969b).

The clay[1] products industry within the area has been described by Guillet (1967).

Agricultural soils were mapped for those parts of the area lying within Norfolk County (*circa* 1928) and Haldimand County (1935a) at a scale of 1 inch to 2 miles by the Ontario Agricultural College and an unpublished map was prepared for Brant County (1935b). Present *et al.* (1965) and Wicklund and Richards (1961) prepared soil maps at a scale of 1 inch to 1 mile for Wentworth and Oxford Counties respectively. A detailed soil survey (4 inches to 1 mile) of Brant County was initiated in 1967 by the Ontario Soil Survey and is continuing under the direction of C.J. Acton of the Department of Agriculture. Publication of these maps should greatly refine the mapping as presented herein.

PHYSIOGRAPHY AND DRAINAGE

Maximum relief within the area is about 350 feet; local relief seldom reaches 200 feet and is most commonly less than 75 feet. The greatest local relief occurs along the Grand River north of Paris where a deeply incised channel fronts the Galt Moraine.

The physiography of the area was mapped by Chapman and Putnam (1951; 1966) at a scale of approximately 1 inch to 4 miles. The principal physiographic features described by them are the Tillsonburg, Paris, and Galt end moraines, which generally have a relief of less than 100 feet, and the gently sloping Norfolk sand plain and Haldimand clay plain. Many of these features will be described within this report.

Excepting a small area adjacent to Copetown and Mineral Springs that drains into the Dundas Valley and thence Lake Ontario, the Brantford area is entirely within the Lake Erie drainage basin. The Erie drainage is via the Grand River system with the exception of the southwesternmost part where a small area west of the Tillsonburg Moraine drains into Big Otter Creek and an area south and west of Burford and Scotland drains into Big Creek[2] and thence into Lake Erie.

The Grand River enters the area north of Paris and is confined to a relatively narrow incised channel until it crosses the Galt Moraine where a rapid decrease in gradient has resulted in considerable deposition of alluvial materials near Brantford. From Brantford to the eastern boundary of the map-area this river has a very low gradient (less than 2 feet per mile) that is in part the result of the low base level at Lake Erie (572 feet) and in part the result of near-surface bedrock; Caley (1941) shows rock outcropping on the south side of the Grand River 1 mile north of Kanyengeh. This was not located in the present survey but rapids at this point indicate the rock is present.

West of the Galt Moraine the principal water courses entering the Grand River are the Nith River and Horner Creek. The Nith River enters the area in the northwesternmost part of the area at an altitude of about 855 feet and flows into the Grand River over bedrock at Paris at an altitude of 735 feet. It is a meandering stream generally deeply entrenched in glacial drift. Horner Creek has its headwaters northwest of the present area at an altitude of about 980 feet. It flows across a sandplain for much of its length until it joins Kenny Creek west of Burford. From here Horner Creek becomes more deeply entrenched and is terraced up to the point where it enters the Grand River at an altitude of about 690 feet. Both of these originated as glacial meltwater channels.

East of Brantford a number of large streams cross the clay plain to enter the Grand River. Fairchild Creek and Big Creek flow from the north; these have well developed dendritic systems cut into the soft and relatively uniform glaciolacustrine sediments. These easily eroded sediments have allowed the streams to achieve their relative grades rapidly and the larger valleys now contain broad flood plains with small meandering streams. To the south, McKenzie Creek and Boston Creek more or less parallel the Grand River until joining it east of the present map-area. The general southward slope of the land plus post-glacial northward uplifting of the land prevented these streams from taking a more direct route to the Grand River in comparison to the streams flowing from the north. The above streams originated during drainage of the glacial Great Lakes.

[1] The term clay, as used herein, refers to grain size rather than mineralogy or engineering properties.

[2] There are two Big Creeks within the Brantford area: the second Big Creek forms a drainage basin between Langford and Copetown and enters the Grand River east of Middleport.

PALEOZOIC GEOLOGY

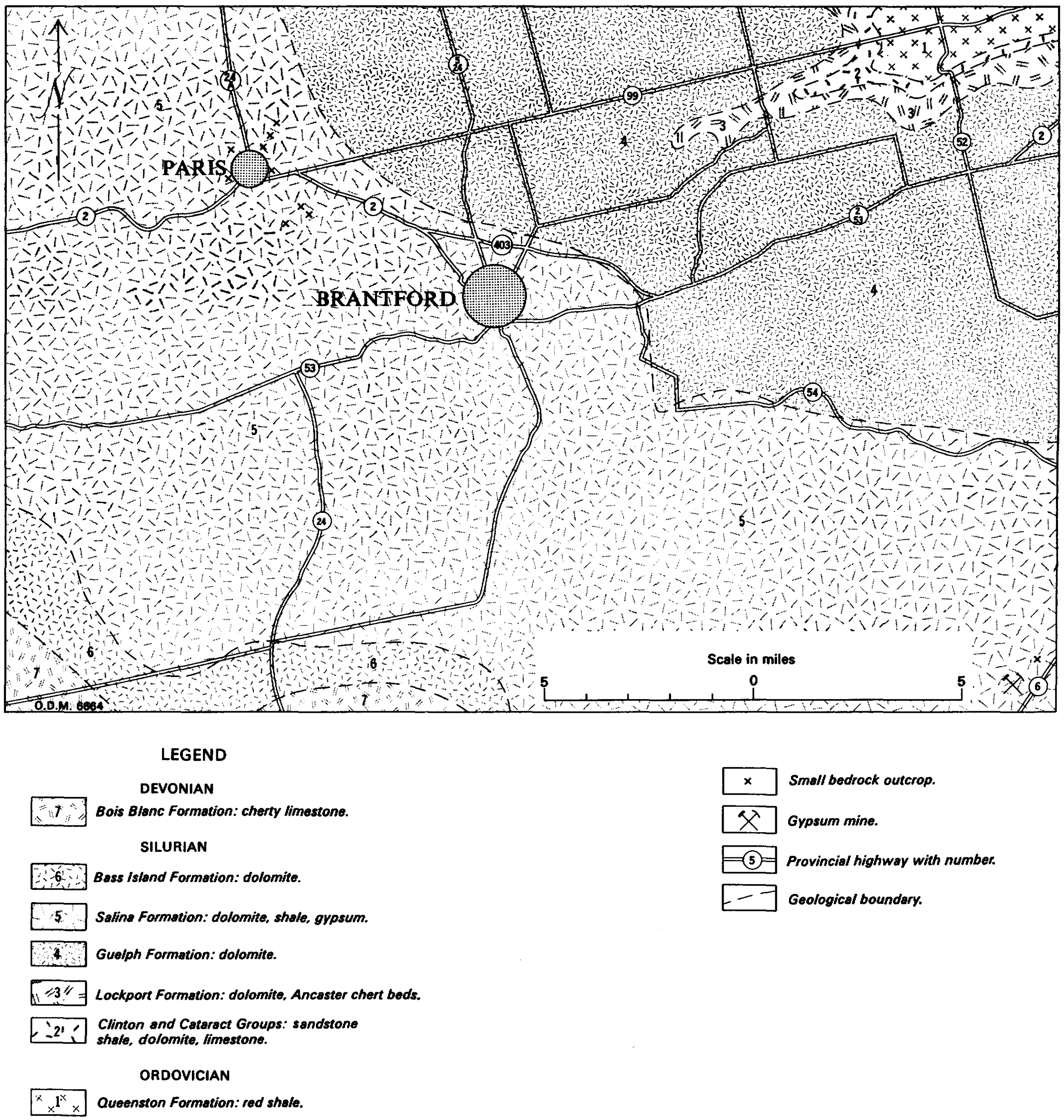

Figure 2—Paleozoic geology of the Brantford area; modified after Caley 1941; Sandford 1969; Sibul and Morrison 1967; Yakatchik and Sibul 1965.

Areal mapping of Paleozoic rocks within the map-area was carried out by Caley (1941). Minor refinements based on oil-, gas-, and water-well data have been made to Caley's map within the southwestern part of the present area by Yakutchik and Sibul (1965) and Sibul and Morrison (1967). More recently, Sanford (1969) produced a compilation map of southwestern Ontario, based on oil- and gas-well data, which alters many of the previously assumed contracts through the utilization of recent bedrock topography maps. Because outcrop density is low, geological maps of the area will be subject to continuous refinement as more drilling records become available.

ORDOVICIAN

Although no outcrops are present, the oldest rocks underlying the area are Ordovician shales of the Queenston Formation. It is found in only a small part of the northeastern part of the map-area (Figure 2). The shale is usually brick-red in colour and consists of thin-bedded, fissile, sandy and argillaceous shale. Seams or bands of green shale occur within the red shale as do green 'eyes' that in some places have centres of calcite geodes or carbonaceous fragments (Guillet 1967, p.57) and seams and concretions of yellowish gypsum (Hewitt 1968, p.4). This formation has a thickness of 400 to 500 feet in this area but it is overlain by drift that in places exceeds 500 feet in thickness. Information on Paleozoic rocks underlying the Queenston Formation is available in Sanford and Quillian (1959), Sanford (1961), and Beards (1967). Abundant Queenston shale fragments occur in Pleistocene sediments close to subcrop areas and more distally when deposited by glaciers from an englacial position.

SILURIAN

The next oldest rocks found in the area are Lower Silurian in age; these rocks are herein called the Clinton and Cataract Groups following Bolton (1957). The Clinton and Cataract Groups occur in only a small area near Mineral Springs and in the walls of the buried Dundas Valley.

The Cataract Group, as described by Bolton (1957) and Hewitt (1968) for the Hamilton-Ancaster area, comprises, in ascending order: the Whirlpool Formation (grey to red sandstone about 12 feet thick); the Manitoulin Formation (11 to 15 feet of blue-grey dolomite with shaly partings); the Cabot Head Formation (fissile grey shale with thin interbeds of calcareous sandstone and limestone, 34 feet thick); and the Grimsby Formation (red shale and interbedded red sandstone 12 feet thick).

The above succession is overlain by the Clinton Group, which in the Hamilton-Ancaster area consists of: the Thorold Formation (greenish grey shale with interbeds of grey sandstone, 13 feet thick); the Reynales Formation (buff dolomite with green shaly partings, about 8 feet thick); the Irondequoit Formation (grey dolomitic limestone with grey shale partings, 6 feet thick); and the Rochester Formation (grey shale and argillaceous dolomite, 5 feet thick).

These two groups, then, have a total thickness of about 100 feet. In the present area these rocks are mantled by a considerable thickness of drift to which they contribute the main identifiable clastic materials.

Overlying the Cataract and Clinton Groups is the buff weathering, fine-grained to crystalline, dolomite of the Lockport Formation. This erosion-resistant dolomite is exposed near Mineral Springs, and elsewhere it forms the cap of the Niagara Escarpment, which is largely buried in the present area. The Goat Island Member of this formation contains chert-bearing beds known as the Ancaster chert beds; some of this chert has been glacially transported and is deleterious in some gravel deposits. The Lockport Dolomite is about 100 feet thick and is generally overlain by more than 25 feet of overburden.

The Guelph Formation overlies the Lockport Dolomite. The Guelph Dolomite, a buff coloured, aphanitic to crystalline dolomite characterized by reefy facies, forms a broad band between North Brantford and Lynden but does not outcrop at the surface. The thickness of the combined Guelph-Lockport beneath the area is of the order of 250 to 350 feet. It is generally overlain by 75 to 150 feet of overburden. These formations provide a large percentage of the rock fragments found in the Pleistocene sediments.

Overlying and conformable with the Guelph Formation is the Salina Formation. This formation forms a broad belt encompassing more than 50 percent of the map-area and, like all the rocks in the area, has a gentle southwesterly dip. Within the map-area the Salina Formation consists of dolomite and shaly dolomite containing lenses of gypsum and has an average thickness of 200 feet, although it may vary from about 70 to 250 feet. Outcrops may be seen on Boston Creek north of the Canadian Gypsum Company Limited Mine and along the Grand River north and south of Paris. Although Caley reported no outcrops exceeding 5 feet in thickness, subsequent fluvial erosion near Paris has revealed outcrops 15 to 20 feet thick; these consist of dolomite strata up to 12 inches thick and shaly dolomite, containing thin seams or lenses of gypsum usually less than 1 inch thick. Guillet (1964) has described these rocks in detail. Overburden in areas underlain by the Salina Formation varies from less than 10 feet to more than 250 feet.

The Salina Formation is overlain conformably by the Bass Island (Bertie-Akron) Formation of Upper Silurian age. Only a narrow band of the southern part of the map-area is underlain by this rock type and no outcrops are present. The rock, mainly a fine crystalline brown dolomite, has a thickness of 35 to 60 feet (Hewitt 1960, p.127) and within the map-area is overlain by 40 to 60 feet of glacial drift.

DEVONIAN

Overlying the Bass Island Formation with erosional unconformity is the Bois Blanc Formation of Lower Middle Devonian age. This highly fossiliferous cherty limestone has a thickness of about 100 feet and occurs in a small area in the southwestern corner of the map-area but it does not outcrop. Chert from this formation is very prominent in the pebble and cobble grades of tills and gravels and is extremely deleterious in the latter.

ECONOMIC GEOLOGY

Although valuable as a source of materials for the manufacture of clay products, the Queenston Formation is not being exploited within the map-area. Guillet (1967) has described the properties and uses of this shale in nearby areas.

Similarly, the Whirlpool Sandstone (building stone, silica), and Clinton Group (crushed stone), the Lockport Dolomite (building stone, crushed stone), the Guelph Dolomite (crushed stone, dolomitic lime), the Bass Island Dolomite (crushed stone), and the Bois Blanc Limestone (crushed stone, portland cement) have been exploited elsewhere but to date none of these have been exploited within the map-area. The properties and uses of many of these have been described by Hewitt (1960; 1964).

Gypsum is being mined from the Salina Formation by the Canadian Gypsum Company Limited of Hagersville. The mine area is located in concessions III and IV, Oneida Township, Haldimand County, west of Highway 6. Leases, obtained from the Six Nations Band of the adjacent Tuscarora Indian Reserve, have expanded potential supply considerably in recent years. Production comes from a 4-foot seam of white, fine-grained gypsum known as the 'Oakfield seam', which is overlain by shaly dolomite; this shaly dolomite needs rock bolting. The seam is located at a depth of 60 to 100 feet; underground mining is thereby required and the pillar-and-room method is used. A full description of the geology and operations of this mine is given by Guillet (1964, p.88-91).

Mining operations are carried out at the rate of 1,400 tons per day with a maximum capacity of 1,600 tons per day; new undeground crushing and conveying systems are expected to increase this rate to 1,800 to 2,000 tons per day in the near future. Milling, calcining, and production of a complete range of gypsum plasters and wallboards are carried out at the property.

Guillet (1964, p.101) described two former gypsum mines within the map-area; these are the Paris Plaster Mine formerly operated on lot 12, concession I, Brantford Township, Brant County and the Torrence Mine on lot 16, concession I, Brantford Township. The latter was never brought into production.

Thicker lenses within the Salina gypsum seams may be expected to result in future mines as required by markets. Some bore holes encountering gypsum within the area are listed by Guillet (1964, appendix).

The Haldimand gas field extends into the map-area from the southeast to Brantford. Natural gas is obtained principally from the Cataract and Clinton Groups at depths in excess of 600 feet.

BEDROCK TOPOGRAPHY

Bedrock topography of the Brantford area has been mapped previously by Karrow (1963b) and additional data are available in Walton (*circa* 1964), Ontario Water Resources Commission Maps 2705-2 and 2706-2 (Sibul and Morrison 1967; Yakutchik and Sibul 1965), in water-well records maintained by the Ontario Water Resources Commission, and in oil- and gas-well records maintained by the Ontario Department of Energy and Resources Management.* The difficulty encountered by drillers in

* Since 1 July 1970, oil- and gas-well records have been maintained by the Petroleum Resources Section of the Ontario Department of Mines and Northern Affairs.

determining the actual bedrock surface in shaly rock, the paucity and uneven distribution of well records, and the occurrence of erroneous records, complicates the preparation of bedrock topography maps, but these maps are useful for groundwater and engineering studies and they can be used to determine drift thickness when used in conjunction with a topographic map.

The bedrock surface in the Brantford area has a maximum relief in excess of 600 feet; this relief is considerably greater than on the present land surface. The lowest points occur in the Dundas Buried Valley east of Copetown (see Karrow 1963b) where elevations are less than 200 feet above sea level and the highest areas occur around Harley in Burford Township, where bedrock elevations exceed 800 feet. Local relief is generally in the order of 10 to 20 feet in subdued areas but may be as much as 300 to 400 feet in buried valleys. The Dundas Buried Valley is the most pronounced feature within the area and probably comprises an ancestral Grand River (Karrow 1963b). Karrow considered the main channel of this valley to extend from Copetown, south of St. George, and through the Blue Lakes area, with an important tributary running from south of Brantford to the main channel south of Lynden. More recent data outlines this southern tributary to a greater degree and Walton's map indicates that he interpreted this feature as being considerably deeper than did Karrow (Walton *circa* 1964). This channel extends from south of Lynden at elevations below 550 feet to a point just west of the junction of the Jerseyville Road and Highway 2 and then through a point just south of Cainsville and along a path towards the Brantford Sanitorium where the channel has elevations less than 540 feet. From here the channel appears to have subdued tributaries from the northwest and southwest. Karrow's (1963b) map showed a deep depression in the southern part of the City of Brantford. Subsequent drilling has shown that the depression is smaller and somewhat south of where Karrow ascribed it to be. Walton's (*circa* 1964) map shows this depression to be a banana-shaped feature south of Brantford with elevations below 500 feet. Recent drilling shows this area to have elevations between 525 and 550 feet (the inferred presence of this depression at lower elevations was based on two or three old drill holes at Brantford that suggest elevations less than 500 feet; no recent borings have suggested elevations of this order).

With the exception of these entrenched features and a few lesser features, much of the bedrock surface east of Brantford occurs between 575 feet and 650 feet and west of Brantford it occurs largely at elevations between 625 and 750 feet with a few higher areas in the extreme northwest and in the extreme southwest. The buried Onondaga Escarpment crosses the southwestern part of the area.

Considerably more data are required to refine the present picture of the bedrock topography; unfortunately water-well data is not presently or will not be available for some important areas either because of municipal water supplies or because of readily available water supplies situated above the bedrock surface.

PLEISTOCENE GEOLOGY

A remarkable sequence of sediments representing the effects of continental glaciation are to be found within the Brantford area (see Table 1). These deposits, as far as is known, resulted from ice moving out of the Ontario-Erie Basin during the last ice age, the Wisconsinan Glacial Stage. Early Wisconsinan deposits, approximately 70,000 to 53,000 years B.P.[1] (Dreimanis 1970), are found in the deepest river valleys and are relatively limited in extent. Most of the deposits represent a series of glacial fluctuations during Late Wisconsinan time, approximately 22,000 to 10,000 B.P. (Dreimanis 1970), and to the present no organic materials representing Mid Wisconsinan, approximately 53,000 to 22,000 years B.P. (Dreimanis 1970), interstadial events have been found.

[1] B.P.—Radiocarbon years before present; 'present' refers to the year 1950.

Table 1 PLEISTOCENE FORMATIONS AND EVENTS IN THE BRANTFORD AREA.

STAGE		LITHOLOGY	MORPHOLOGIC EXPRESSION
Recent	modern alluvium	sand, silt, gravel, clay	flood plains, valley bottoms
	bog deposits	muck, peat, marl	filled depressions
	older alluvium	gravel, sand	terrace remnants
Late Wisconsinan	later lakes	gravel, sand, silt, clay	clay plains, sand plains, deltas, abandoned shorelines
	Lake Warren	gravel, sand, silt, clay	clay plains, sand plains, deltas, raised shorelines
	Halton Till	silt till	dissected ground moraine
	Lake Whittlesey	gravel, sand, silt, clay	clay plains, sand plains, deltas, raised shorelines
	Outwash	gravel, sand	outwash plains, terraces
	Wentworth Till	stony, silty sand till	end moraine, ground moraine, drumlinoid ridges
	Ice contact stratified drift, outwash	gravel, sand	mainly buried
	Port Stanley Till	clayey silt or silt till	end moraine, ground moraine
	Outwash, ice-contact stratified drift, lacustrine sediments	gravel, sand, silt, clay	mainly buried
	Catfish Creek Till	stoney silt-sand till	mainly buried
	Outwash	sand, gravel	mainly buried
Early? Wisconsinan	Canning Till	clayey silt, silt-clay till	mainly buried
	'lower beds'	silt-clay till, silt, sand, gravel	mainly buried

Table 2 SUMMARY OF TILL ANALYSES; R — RANGE, M — MEAN, VALUES IN PERCENT; GRAIN SIZE AND CARBONATE ANALYSES BY THE LABORATORY AND RESEARCH BRANCH OF THE ONTARIO DEPARTMENT OF MINES AND NORTHERN AFFAIRS.

Grain Size Analyses

	No. of Samples	Clay R	Clay M	Silt R	Silt M	Sand R	Sand M	Medium Diameter R
Halton Till	4	11–22	15	64–77	70	9–22	14	0.008 –0.020
Wentworth Till	20	5–24	12	23–65	39	21–70	49	0.010 –0.297
Wentworth Till, southeastern facies	9	16–36	22	43–59	49	17–37	28	0.004 –0.024
Wentworth Till? fine-grained facies	10	29–57	43	39–68	50	3–12	7	0.0015–0.0059
Port Stanley Till	22	9–51	28	38–71	56	3–42	16	0.0018–0.042
Catfish Creek Till	7	11–21	16	16–50	36	30–73	48	0.027 –0.160
Canning Till	2	29–42	36	48–52	50	10–19	14	0.003 –0.0079
Lower beds	1	33		46		21		0.005

Pebble Lithology

	No. of Samples	Limestone R	Limestone M	Dolostone R	Dolostone M	Chert R	Chert M	Clastics R	Clastics M	Precambrian Crystalline R	Precambrian Crystalline M
Halton Till	1		...	28			...	71		1	
Wentworth Till	18	0–33	11	42–97	81	0–25	2	0–15	3	0–7	3
Wentworth Till, southeastern facies	6	0–7	2	79–100	93	0–2	1	0–8	1	0–10	3
Wentworth Till? fine-grained facies	4	4–12	7	58–94	84	0–1	0	0–4	1	1–26	8
Port Stanley Till	16	2–39	19	47–96	70	0–30	3	0–10	3	0–10	4
Catfish Creek Till	5	10–66	25	30–81	69	0		0–3	0	2–9	5
Canning Till	...	...		...		...		...		...	
Lower beds	...	...		...		...		...		...	

Carbonate Analyses

Percent of minus 200 mesh

	No. of Samples	Total Carbonate R	Total Carbonate M	Ratio, Calcite to Dolomite R	Ratio, Calcite to Dolomite M
Halton Till	3	16.4–18.0	17.0	2.2–4.4	3.1
Wentworth Till	19	32.2–59.9	39.7	0.2–1.1	0.6
Wentworth Till, southeastern facies	7	35.3–52.0	46.8	0.1–0.5	0.3
Wentworth Till? fine-grained facies	10	25.6–37.7	34.6	0.4–2.0	1.0
Port Stanley Till	22	19.9–37.2	30.6	0.8–5.4	1.6
Catfish Creek Till	7	30.4–46.1	38.0	0.7–1.1	0.9
Canning Till	2	31.6–35.8	34	0.9–1.2	1.0
Lower beds	1	34.3		1.3	

DRIFT THICKNESS

The thickness of glacial drift overlying the bedrock of the area varies from zero where rock outcrops to more than 500 feet in the Dundas Buried Valley; most of the following information is from water-well records.

At Brantford the drift varies from 30 to 80 feet in the river valley and has a thickness of 58 feet at the new City Hall. South of Brantford the drift thickens to about 250 feet 2 miles south of the Sanitorium and then thins to about 135 feet at Mount Pleasant. North of Brantford the drift ranges between 50 and 75 feet at Wyndham Hills and 92 feet at Osborne Corners.

Along the Tillsonburg Moraine the drift ranges from 70 feet at Harley to 130 feet west of Northfield Centre and 200 feet north of the Nith River. The Paris Moraine has drift thicknesses ranging from 160 feet south of Paris to 175 feet north of Mount Vernon and 150 feet at Scotland. Drift in the Galt Moraine has thicknesses exceeding 220 feet north of Blue Lakes and 210 feet on Highway No. 5 a half mile east of the junction with Highway 2; south of the Grand River, drift in the Galt Moraine exceeds 200 feet in thickness 1 mile southeast of Brantford Airport and drops off to 180 feet 1 mile west of Maple Grove and 150 feet near Oakland.

Between the Tillsonburg and Paris Moraines the drift varies from more than 130 feet in thickness at Burford to 20 feet 1 mile southeast of Harley. Between the Paris Moraine and Galt Moraine the drift thins from 175 feet near the Brantford Airport to 140 feet 1 mile northwest of Oakland and 60 feet 1 mile southeast of Scotland. In the clay plain area drift thickness near Burtch is about 100 feet, 60 feet near Ohsweken and 25 feet near Six Nations Corner. North of the Grand River the drift varies from 50 feet near the river to 140 feet at Jerseyville and 100 feet near Duffs Corners. In all instances greater thicknesses may be expected in areas adjacent to bedrock lows as depicted by Karrow (1963b).

More detailed information may be obtained from the water-well records maintained by the Ontario Water Resources Commission or from using Karrow's bedrock topography map in conjunction with a surface topographic map.

GLACIAL DEPOSITS AND FEATURES

Glacial Till

Glacial till is a non-sorted, usually non-stratified, sediment carried, deposited, or deformed by a glacier; grain sizes of this material may vary from clay size to boulder size, mixed in any proportion. The area under consideration contains a number of tills representing successive episodes of glacial deposition. The succession was established by Karrow (1963a) through stratigraphic studies in the Galt area to the north and in the Nith River Valley of the present map-area. Though comparable exposures are rare, no evidence has been found to contradict his basic conclusions. Karrow identified tills representing six probable glacial advances including the Halton, Wentworth, Port Stanley, Catfish Creek, and Canning Tills, plus till(s) associated with sediments underlying the Canning Till. Of these, the Halton, Wentworth, and Port Stanley Tills outcrop over considerable areas at the surface whereas the others are found only in stream or river cuts or, exceptionally, adjacent to rivers where fluvial erosion has stripped off the younger cover. A summary of the properties of these tills is found in Table 2 with complete data in Appendix B.

LOWER BEDS

The oldest Pleistocene deposits observed within the map-area comprise the 'lower beds' of Karrow (1963a) who described stratified sediments and a till unit stratigraphically below the Canning Till. These sediments are known to occur only along the Nith River valley and have not been identified elsewhere in the Brantford area.

The till unit is a massive, extremely stiff[1], calcareous, gritty, clayey silt to silt till containing very few pebbles; these pebbles have a maximum size of 2 inches. It is a dark grey colour (10YR 4/1)[2] when fresh and light grey (10YR 6.5/1.5) when dry. As noted by Karrow (1963a, p.35), one phase of this till unit contains a considerable amount of varicoloured material in the grit- and granule-size par-

[1] Unconfined compressive strength for clays after Terzaghi and Peck (1948, p.31) is as follows: very soft (less than 0.25 tons per square foot), soft (0.25-0.5), medium (0.5-1.0), stiff (1.0-2.0), very stiff (2.0-4.0), extremely stiff (greater than 4.0 tons per square foot).

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

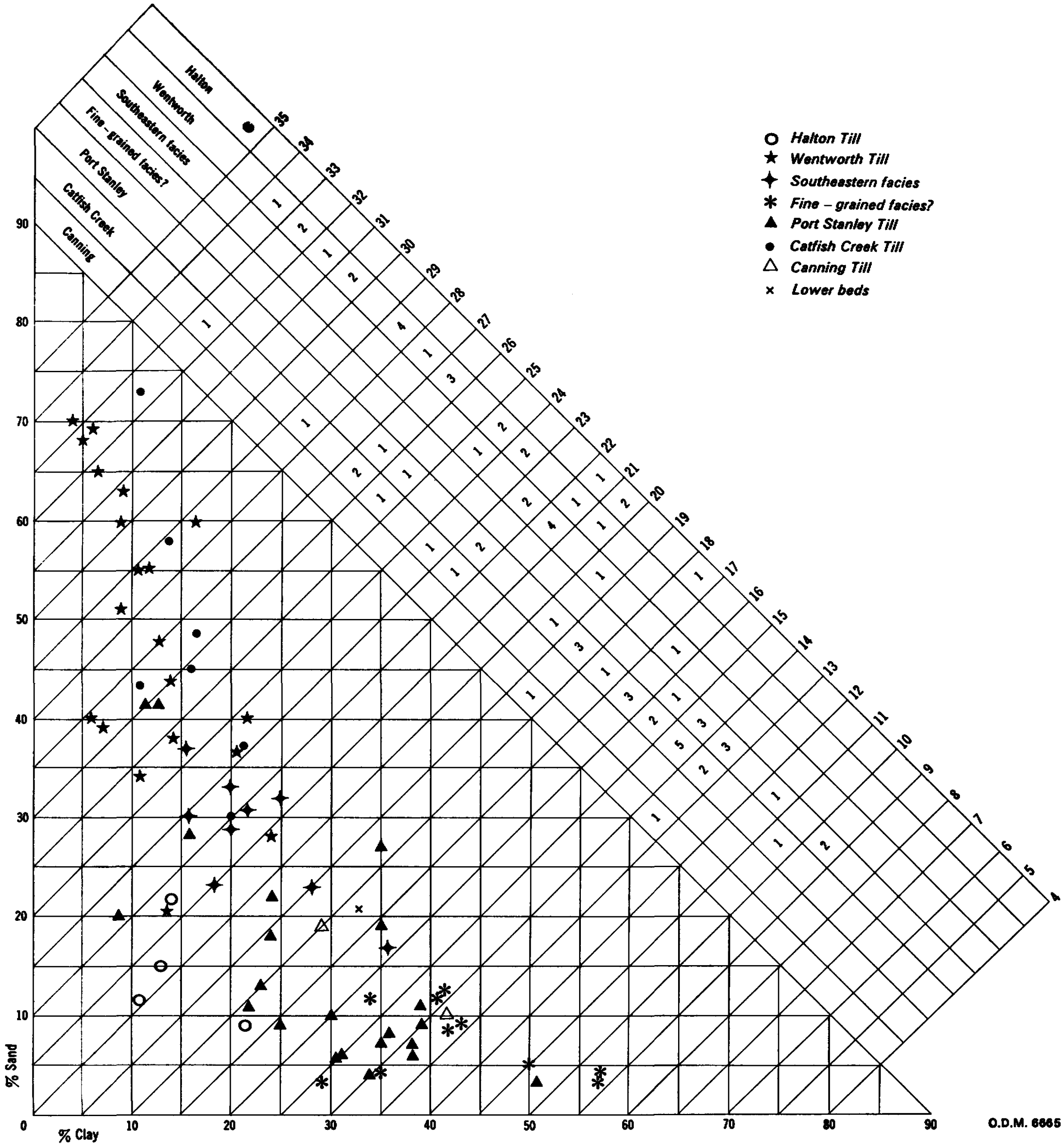

Figure 3–Grain size analyses of tills of the Brantford area; analyses by the Laboratory and Research Branch of the Ontario Department of Mines and Northern Affairs.

ticles. Observed thickness of this till is usually less than 10 feet but maximum thickness is unknown due to its occurrence at the base of river sections.

Texture analysis of one sample from the Canning section showed this till to contain 33 percent[1] clay, 46 percent silt, and 21 percent sand. This is considerably finer than is demonstrated by Karrow's analyses; his anlyses (1963a, p.36), showed this till to have the following percentage ranges: clay (18 to 39), silt (23 to 58), sand (38 to 53). This variability may reflect, to a differing degree, the incorporation of associated sediments. Differences also occur in the carbonate content of the minus 200-mesh fraction. The sample analyzed here indicates a total carbonate content of 34.30 percent with a calcite to dolomite ratio of 1.32; this latter figure is considerably higher than the range of 0.56 to 0.8 presented by Karrow (1963a, p.36).

1 Clay-silt boundary 0.002 mm. Silt-sand boundary 0.062 mm.

Karrow (1963a, p.37) tentatively identified the 'lower beds' as Early Wisconinan in age and these beds, based on stratigraphic position and carbonate and heavy mineral composition, have been suggested as correlative with unit 'A' of the Zorra area by Westgate and Dreimanis (1967, p.1139).

CANNING TILL

The type section for the Canning Till is located near the Village of Canning, in Blenheim Township, within the present map-area, where it was first described by Karrow (1963a). He described it as a reddish to purplish fine-grained till stratigraphically underlying the Catfish Creek Till and having calcite to dolomite ratios in the range 0.9 to 1.5 in the minus 200-mesh fraction of the matrix. Generally total carbonate content averages about 37 percent with a calcite to dolomite ratio of 1.0 (Dreimanis and Karrow 1965).

Within the map-area the till has been found to outcrop at the surface at only one locality; here it forms an erosional terrace on a slip-off slope of the Nith River north of Falkland. Elsewhere it is found in section along the Nith and Grand Rivers, possibly Horner Creek, and in one section in the Tillsonburg Moraine; some of these areas are too small to show at map scale. Where stratigraphic control is lacking this till is difficult to distinguish from other heavy textured tills. Limited data suggests that the thickness of this till ranges from 0 to 30 feet.

When fresh this till is dark grey to dark brown (10YR 4/1 to 10YR 4.5/2) in colour, dries to grey (10YR 6.5/1), and weathers to yellowish brown (10YR 5/6). A reddish tinge is noticed in many samples but this is not prominent when compared closely to a Munsell chart. It is a very stiff, clayey silt till containing few cobbles and pebbles, which break cleanly from the till matrix; minor grit is present and the largest cobble noted was 4 inches in diameter. Textural and carbonate properties examined do not differ appreciably from those given by Karrow (1963a, p.36).

This till is considered to be an Ontario-Erie lobe till of Early Wisconsinan age (Karrow 1963a; Goldthwait *et al.* 1965) that has been correlated with the Bradtville Drift of the Lake Erie area (Dreimanis and Karrow 1965) and with unit 'B' at Zorra, Ontario (Westgate and Dreimanis 1967). Usually it appears to represent remnant ground moraine within the present map-area.

CATFISH CREEK TILL

Overlying the Canning Till, in many sections, is a distinct stony, silty sand to sandy silt till that Karrow (1963a) correlated with the Catfish Creek Drift of Dreimanis (de Vries and Dreimanis 1960) having its type area near Lake Erie. It represents a major advance of ice moving across the Brantford area in a generally southerly direction, although most fabrics reported to date are variable. In many places directly overlying the Canning Till, the Catfish Creek Till may be separated from it by gravel or stratified silts. In some localities only gravel is seen underlying this till. Outcrops, ranging from 2 to 30 feet thick, are largely confined to valley-wall sections along the Nith and Grand Rivers and Horner Creek; near Canning however, fluvial erosion has removed younger sediments to expose this till at the surface.

The till itself is usually an extremely stiff, stony, silty sand till that is greyish brown (10YR 5/2) to dark grey (10YR 3.5/1) when fresh, dark brown (10YR 4/3) to yellowish brown (10YR 5.5/4) when oxidized, and light grey (10YR 7/1), very pale brown (10YR 7/3), or pale yellow (2.5YR 7/3) when dried. When exposed at the surface the till becomes loose but otherwise it is extremely stiff and impermeable to perculating groundwaters; this commonly results in the formation of a springline near the upper surface of the till. The hardpan of many drillers, this till poses problems if encountered during excavation. Pebbles, cobbles, and in places boulders, to 1 foot or more in diameter, comprise approximately 10 to 15 percent of this till. A weakly defined boulder pavement has been noted at the surface of this till in a few localities. Average lithology of the ½- to 1½-inch pebble-size material (Table 2) is 69 percent dolomite, 25 percent limestone, and 5 percent Precambrian crystalline material. Chert and clastic rocks are rare in the present samples although they are not uncommon elsewhere (Karrow 1963a; Dreimanis and Karrow 1965).

Except for one sample containing 73 percent sand, the textural composition is similar to those reported elsewhere for Catfish Creek Till (Karrow 1963a; Dreimanis 1961; Dreimanis and Karrow 1965), as are the total carbonate contents and calcite to dolomite ratios (Table 2), which average 38.0 and 0.9 respectively. No examples equivalent to Karrow's finer facies (1968a) were identified as such.

Representing early stages of the Late Wisconsinan glaciation, this till has remarkably consistent lithological and textural properties that have made it most useful as a marker horizon throughout much of southern Ontario. It has been correlated with the Navarre and Kent Tills of northeastern Ohio (Goldthwait *et al.* 1965).

Associated with and overlying the Catfish Creek Till in some areas is a sporadic, thin, unit of till-like material interpreted as ablation till. This material, usually 1 or 2 feet thick but ranging to 4 feet, commonly has a striking reddish brown colour (2.5YR 4/4 to 5YR 4/4) when fresh but may be yellowish brown (10YR 5/4). The redness is believed to result from concentration of small fragments of Queenston Shale that do not appear in the pebble counts due to their small size. Concentrations of sandstone (10 to 30 percent), believed to be derived from the Clinton and Cataract Groups of the Escarpment area, and up to 25 percent Precambrian crystalline material (including one piece of marble, Sample 79b, Appendix B) appear to represent deposition of englacial material transported over a long distance. The matrix of this material has a silty to sandy texture with about 29 to 33 percent carbonate minerals in the silt-clay fraction having calcite to dolomite ratios between 1.2 to 2.2, although only a few results are available as yet.

PORT STANLEY TILL

Clayey silt till stratigraphically younger than the Catfish Creek Till was first described in the present map-area by Karrow (1963a) who correlated it with a till comprising part of the widespread Port Stanley Drift of Dreimanis (de Vries and Dreimanis 1960). This till represents a glacial advance from the southeast following the Erie Interstadial (Dreimanis 1958). Stratified-to-varved silts and clays laid down during this interstadial underlie this till in many places and their incorporation partly accounts for the fine-grained nature of the till (Dreimanis 1961). This till is generally correlated with the Hiram Till of northeastern Ohio and New York (Goldthwait *et al.* 1965).

Within the map-area the Port Stanley Till is the oldest till outcropping over a considerable surface area, largely west of a line drawn between Burford and Paris; elsewhere it is found in valley walls where it overlies glaciolacustrine sediments, Catfish Creek Till, or in some places, gravel. In a few places a poorly developed cobble or boulder pavement has been noted at the base of this till. Surface distribution includes a till cap on the Tillsonburg Moraine, the till forming the Norwich Moraine, an area of confluence of the Norwich and Tillsonburg Moraines northwest of Paris, and minor amounts of ground moraine. The area of moraine confluence northwest of Paris resembles an area of gently undulating ground moraine with only a few topographic highs outlining morainal positions.

Proglacial lakes post-dating deposition of the Port Stanley Till resulted in partial reworking of the till surface and(or) the deposition of a thin veneer of silt or fine sand on the till surface. Consequently much of the area mapped as Port Stanley Till has a modified upper surface that grades downwards into unmodified till. Where the silts or sands are thicker contacts with the Port Stanley Till are gradational.

In thickness the Port Stanley Till ranges from 3 to 30 feet and it is usually referred to as brown clay by well drillers. Soils developed on this till are Guelph loam, London loam, Perth silt-loam, and Huron silt-loam in the Oxford County part of the map-area (Wicklund and Richards 1961). These soils are rated as good to fair for most crops required in dairy or mixed farming.

In an unoxidized state this till is dark grey in colour (10YR 4/1) but usually it is oxidized and when fresh is dark brown (10YR 4/3) to dark yellowish brown (10YR 4/4) or yellowish brown (10YR 5.5/4). On drying the till becomes light grey (10YR 7/2) or very pale brown (10YR 7/3). A stiff to very stiff till, the Port Stanley Till contains less than 5 percent gravel-size material and only in a few places are large cobbles or boulders encountered. Lithology of the pebble-grade material strongly reflects the underlying dolomitic terrain (Table 2 and Appendix B). Chert is rare, except adjacent to Bois Blanc subcrop areas, whereas clastics and Precambrian crystalline material generally comprise less than 5 percent of the total respectively. Textural analyses show this till to be primarily a clayey silt till with a few occurrences of a sandy silt phase and rarely a silty clay; this is somewhat coarser than textures of this till described previously (e.g. Dreimanis and Karrow 1965).

The carbonate content of the silt-clay fraction was found to average about 31 percent with a highly variable calcite to dolomite ratio having a mean of 1 to 6 (Table 2 and Appendix B). Generally this ratio is lower than previously reported (Dreimanis and Karrow 1965) but this is not unexpected considering the high dolomite content of the pebble-grade material. Distribution of the carbonate ratios (Figure 4) show that the highest ratios occur in the northwestern part of the area with those along or near the Tillsonburg Moraine generally ranging between 1.0 and 1.5. Comparing these ratios to the limestone to dolomite ratio in the pebble-grade material (Figure 4) it is apparent that the smallest ratios in the silt-clay grade usually occur with the

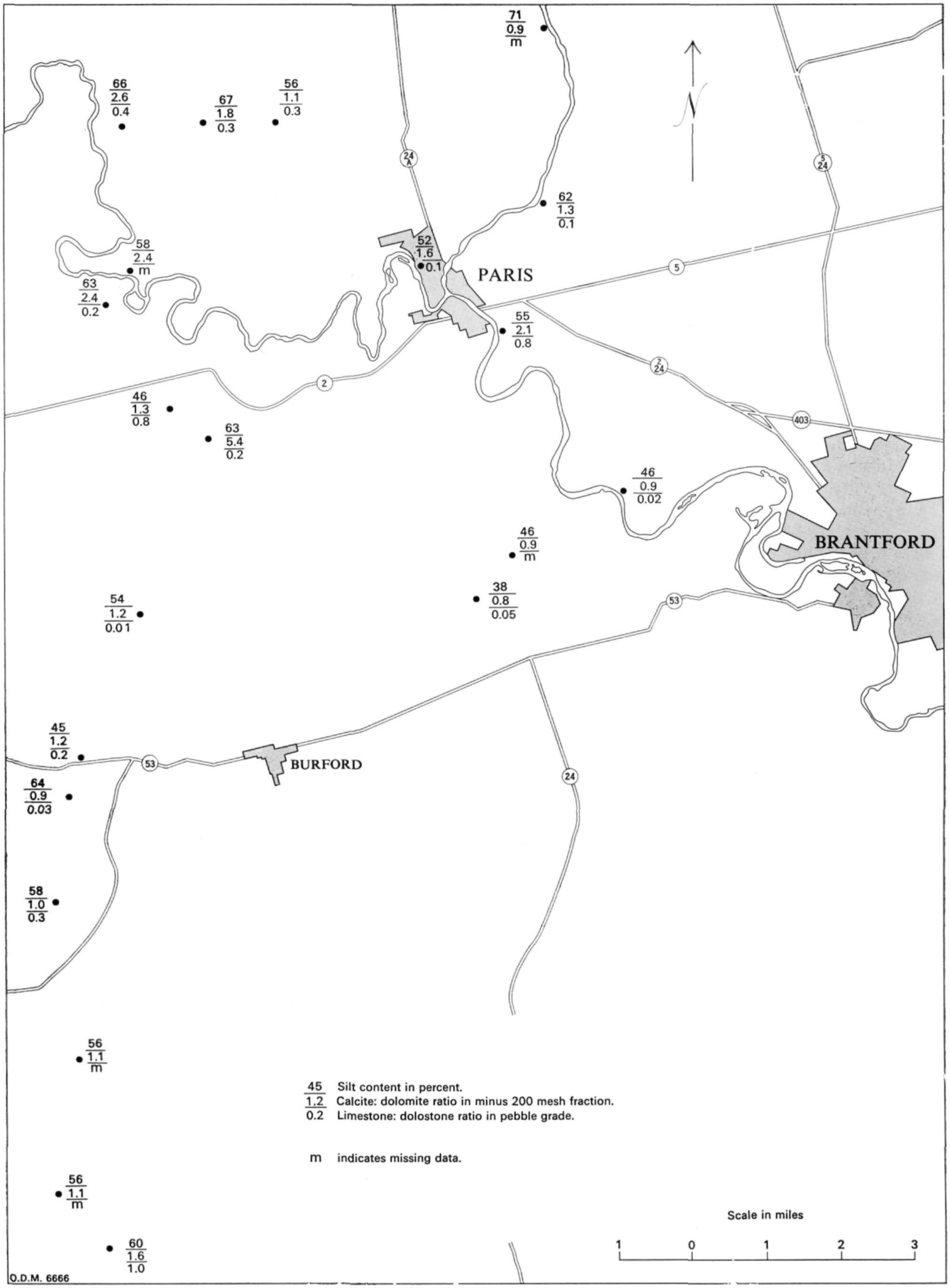

Figure 4—Some properties of the Port Stanley Till in the Brantford area; silt content and calcite dolomite ratio analyses by the Laboratory and Research Branch of the Ontario Department of Mines and Northern Affairs.

smallest ratios in the pebble grade. The highest limestone to dolomite ratios in pebbles largely occur in the northwest as with the ratios in the silt-clay grade. Intermediate pebble ratios seem to be scattered. As ice moving to the northwest was progressing over a dolomitic terrain in much of this area, the higher concentrations of calcareous material in the northwest may represent increased deposition of englacial material derived from limestone areas nearer to Lake Erie.

WENTWORTH TILL

Originally defined by Karrow (1959), this till takes its name from the type area in Wentworth County. Representing a Late Wisconsinan advance (Port Huron) by ice of the Ontario-Erie lobe, this till is confined largely to the Paris, Galt, and Moffat Moraines, and associated ground moraine. As it encompasses a broad area and a number of landforms developed under differing depositional conditions, this till is variable (Karrow 1961; 1963a; 1968a). Generally it has been found to average about 50 percent sand, 35 percent silt, and 15 percent clay in texture with an average total carbonate content in the silt-clay fraction of 38 percent and an average calcite to dolomite ratio of 0.8 (Dreimanis and Karrow 1965), which is similar to the present findings (Table 2); pebble lithologies are variable.

Harris (1967) attempted to subdivide the Wentworth Till within the Galt map-area; his techniques have been criticized by Straw (1968) and certainly his uppermost non-calcareous till has properties inconsistent with those of unweathered materials derived in part from dolomites of the Niagara Escarpment area (Hewitt 1960, p.127, Table 3). Regardless of other investigations the till considered here is stratigraphically and lithologically consistent with that described by Karrow as Wentworth Till.

The Wentworth Till, within the present area, is largely confined to the Paris, Galt, and Moffat Moraines from west to east. As the ice depositing this till was fronted by proglacial lakes, much of the till was partly reworked and veneered by near-shore lacustrine sands as the ice retreated. Consequently, except for the very highest ground, the areas mantled by the Wentworth Till are modified and in the southernmost part of the map-area this approaches a near-gravel facies; these modified materials grade downwards into unmodified till in most places. This till varies from 5 feet to more than 80 feet in thickness and supports the development of the Guelph and Dumfries soil series for the most part.

Commonly a stony, silty, sand till, which may be bouldery, the Wentworth Till, in general, is more sandy in morainal areas and finer in low-lying terrain and river sections. The usually coarse nature of this till (partly from the incorporation of gravelly deposits) plus the large quantities of meltwater, which were apparently available at that time, resulted in the deposition of advance and recessional outwash gravels, generally with the Wentworth Till sandwiched between (Photo 1). Brown (10YR 4.5/3.5) to yellowish brown (10YR 5/4-5/5) or dark yellowish brown (10YR 4/4) when fresh (usually oxidized), this till dries to pale or very pale brown (10YR 6/3-8/3) or light yellowish brown (10YR 6/4). Although stoniness makes compactness difficult to measure this till is usually loose at the surface and stiff to very stiff at depth. Size analyses of the till matrix (Table 2 and Appendix B) is variable as reported by Karrow (1963a) and the carbonate content of the silt-clay fraction conforms closely to values reported previously (Karrow 1963a; Dreimanis and Karrow 1965). In places, pebbles, cobbles, and boulders comprise up to 50 percent of this till but 10 to 20 percent is most common. Pebble lithology is primarily dolomitic with lesser amounts of limestone, clastic, or Precambrian crystalline material; chert may be locally prominent near the Bois Blanc subcrop area.

The Wentworth Till has been traced along the Paris Moraine to at least Windham Centre in the Simcoe map-area. Here properties of the till are consistent with those of the Brantford area except in pebble lithology where changes in bedrock geology are reflected (Samples S1, S2, S3, Appendix B).

In addition to the Wentworth Till described above, two texturally different tills are present in the eastern part of the map-area that have lithologic properties somewhat similar to the Wentworth Till. These are tentatively described as possible facies of the Wentworth Till because there is no stratigraphic evidence to suggest that they are older or younger than the glacial episode to which the Wentworth Till is related.

The first of these is referred to here as the southeastern facies that outcrops in the southeasternmost part of the map-area, commonly in the form of drumlinoid ridges protruding through a mantle of younger lacustrine sediments; in addition to the mapped parts, inliers too small for mapping at the present scale may be expected.

Mainly loam to silt-loam in texture this till contains about 10 percent pebbles with boulders, in a few places, up to 2 or 3 feet in diameter. It is usually very stiff but is in a few places extremely stiff. In colour this till varies from brown (10YR 4/3, 7.5YR 5/4), to dark yellowish brown (10YR 4/4) or

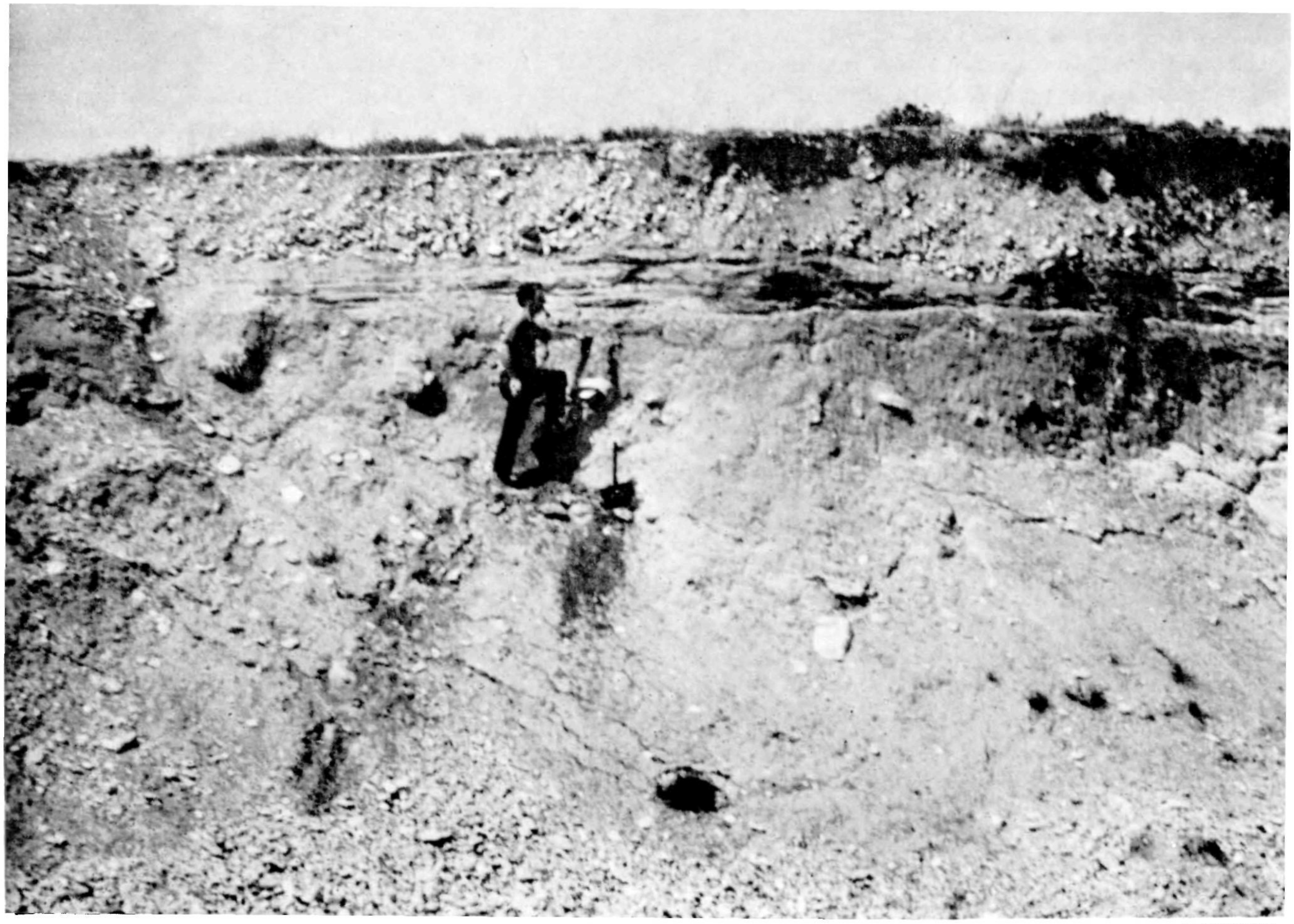

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Photo 1—Wentworth Till sandwiched between outwash gravels; east side of Galt Moraine, north of Oakland.

yellowish brown (10YR 5/4) when fresh and dries to pale brown or very pale brown (10YR 6/3 to 10YR 7/4).

The mainly sub-angular pebbles, as in the Wentworth Till, are predominantly dolomitic as is the silt-clay fraction of the matrix, which averages 47 percent carbonates with calcite to dolomite ratios less than 0.5 (Table 2 and Appendix B).

Although correlation with the Wentworth Till is only tentative the lithologic similarities plus its stratigraphic position as surface, and therefore uppermost, till suggest that this correlation is correct.

The second till considered here as a possible facies of Wentworth Till is more conjectural than the till described above. It occurs in the south Brantford-Burtch-Victoria Mills area, predominantly as scattered occurrences in stream or river cuts where younger lacustrine sediments have been eroded away (these remnants are too small to show at map scale). Occurring between the southeastern loam-till facies and the Moffat and Galt Moraines it has not been observed underlying other tills and is therefore thought to be the uppermost till in the outcrop area; it appears to be older than the glaciolactustrine sediments east of the Galt Moraine.

A clayey silt or silty clay till, which is generally very stiff, this till is dark grey or grey (10YR 4/1-5/1) to dark brown or brown (10YR 4/3-5/3) in colour when fresh and it dries to light grey (10YR 7/1-2), very pale brown (10YR 7/3), light brownish grey (10YR 6/2) or light yellowish brown (10YR 6/3.5). Boulders as large as 3 or 4 feet in diameter occur in a few places and stoniness is variable from nearly stone free to 10 percent. Its fine texture excepted (Table 2 and Appendix B), this till has properties not unlike those of the Wentworth Till; the pebble counts are very similar whereas the silt-clay fraction has only a slightly lower total carbonate content and slightly higher calcite to dolomite ratios. Fine-grained facies of the Wentworth Till or its equivalent have previously been reported (Dreimanis 1961; P.F. Karrow 1969, personal communication); these occurrences were attributed to the incorporation of fine-grained glaciolacustrine sediments.

If its apparent position of youngest till in the area of outcrop is correct, then this till may tentatively be correlated with the Wentworth Till with which it has some properties in common. However, if it is older than this, the possibility of correlating it with the heavier textured Port Stanley or Canning Tills must be considered; of these, field appearance and carbonate properties are more suggestive of Canning Till.

HALTON TILL

The Halton Till, after Halton County in which it is widespread and in which the type section is located, was first named by Karrow (1959). It represents the last incursion of a Late Wisconsinan glacier moving westward out of the Lake Ontario basin into the map-area where this till is largely confined to the Dundas Valley and environs. As noted by Karrow (1963a) and White and Karrow (1968) the ice depositing this till apparently had a fluctuating margin resulting in stratified sediments being sandwiched between one or more till units (e.g. Section B2, Appendix A). Closely associated with proglacial lakes, this till may be seen overlying glaciolacustrine fine sands at many localities, especially in the westernmost parts of its outcrop area where the till thins to less than 6 feet. Elsewhere, water-laid till facies have been reported, and south of Copetown an abandoned shoreline fragment approximates the western boundary of the till as does an ice-contact deltaic-outwash fan. As no transverse elements representing possible end moraines are present in that part of the map-area mantled by Halton Till, the ice-contact feature mentioned above may correspond to the outermost Waterdown Moraine of Karrow (1963a).

Originally an area of ground moraine, the initial surface of the Halton Till was modified considerably by running water derived from the Halton ice as it retreated downslope into the Dundas Valley; consequently, this area now presents a very rolling topography (Photo 2) subject to continuing fluvial erosion.

The till, part of Karrow's (1963a, p.45) Dundas facies (a fine-grained grey till), is a calcareous, silt till having a maximum thickness of 40 feet, although it is usually less than 20 feet and in many places less than 10 feet. When fresh, this till is grey or greyish brown (10YR 5/1), oxidizes to yellowish brown (10YR 5/4), and when dry it ranges from pale yellow (2.5YR 7/3) to very pale brown (10YR 7/4). The content and degree of abrasion of included stones is variable but flaggy material showing only minor abrasion is common. Escarpment-type lithologies are dominant and fragments of Queenston Shale are encountered in many places. On dried exposures the till may exhibit a blocky structure and, where it is not loose near the surface, it has an unconfined compressive strength in the very stiff to extremely stiff range.

The texture of this till (Table 2) is more silty than previously reported by Karrow (1963a). Total carbonate content for the silt-clay fraction is much lower in this till than any of the others and the calcite to dolomite ratios are high; the values given here (Table 2) are similar to the average values presented by Dreimanis and Karrow (1965).

The Ancaster silt-loam is the principle soil developed on this till (Presant *et al.* 1965).

End Moraines

End moraines consist of linear accumulations of glacial drift representing former ice frontal positions. Within the Brantford area several such moraines or parts thereof exist. Whereas each of these apparently represents a stage of deglaciation, some are complex and may contain multiple tills or at least be in part cored by glaciofluvial or glaciolacustrine sediments; such moraines are usually referred to as 'palimpsest', e.g. Karrow (1969), Totten (1969), after White (1962). As deglaciation proceeded from west to east the oldest moraines occur in the west and the youngest in the east.

The Norwich Moraine is the oldest end moraine within the area crossing it at the extreme northwestern corner. As Chapman and Putnam stated (1966, p.62) the moraine is fragmentary in this area as it is cut through by several meltwater channels and, in addition, much of it has been buried by glaciolacustrine sand. Although it is partly made up of kame gravels and sands to the immediate west, within the map-area this moraine is made up of Port Stanley Till and consists of small knolls within a surrounding area of ground moraine. The knolls generally are not more than 25 feet above the surrounding terrain.

The apparent next oldest moraine is the Tillsonburg Moraine named by Taylor (1913, p.14). From west of Northfield Centre through Harley to Highway 53 the moraine is a well-developed ridge rising

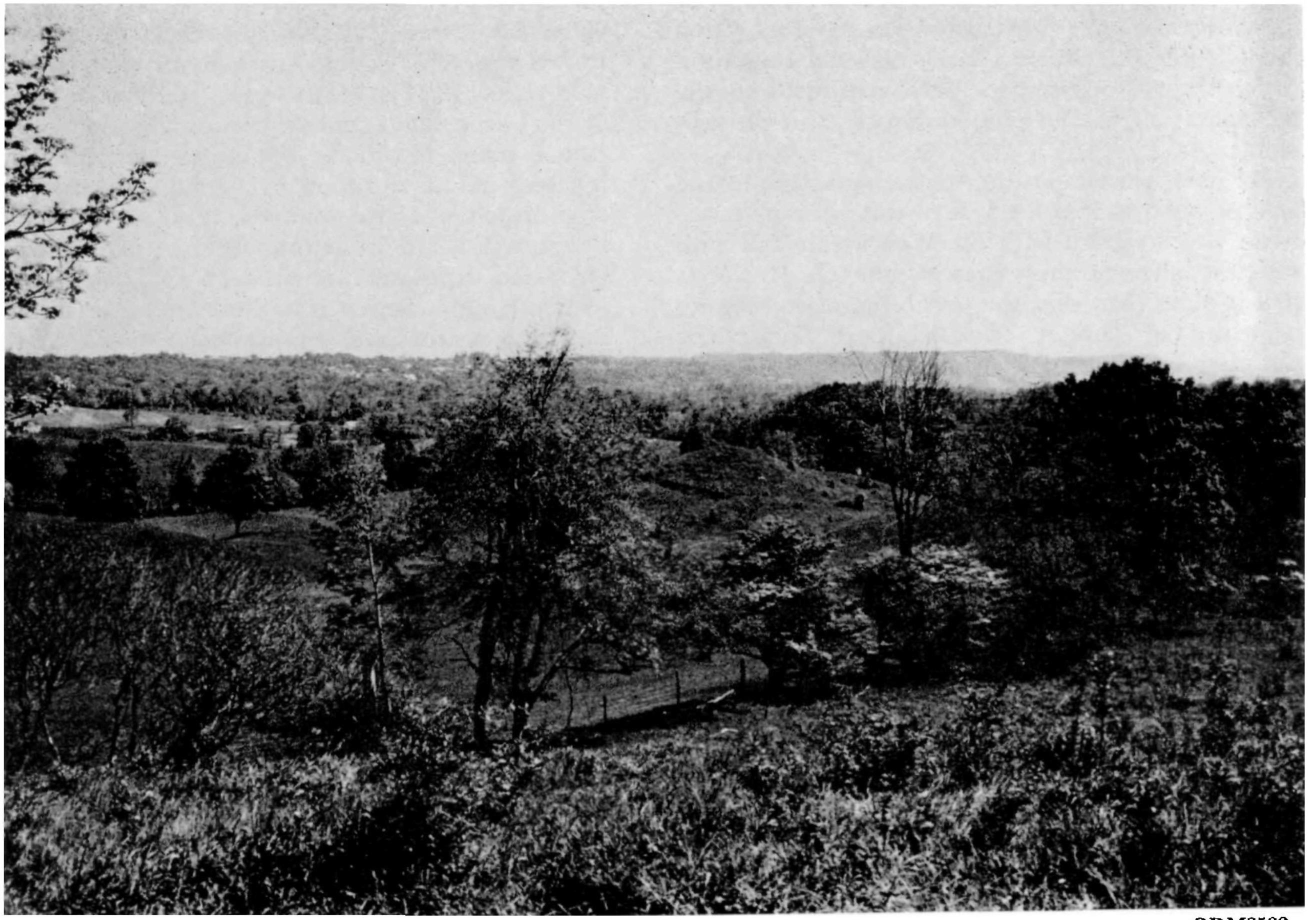

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Photo 2—Dissected ground moraine north of Mineral Springs; Niagara Escarpment in background.

from 25 to 75 feet above the surrounding sand plains. North of this it is fragmentary until it merges, north of the Nith River, with an area of ground moraine above which the end moraine appears as low knolls.

Meagre evidence suggests that the Tillsonburg Moraine, which is capped with Port Stanley Till, may be considerably older than this surface till. A roadcut in this moraine (Section B70) Appendix A, suggests that Catfish Creek Till and possibly Canning Till may core parts of this moraine. Elsewhere, the Port Stanley Till may be seen overlying glaciofluvial sand or glaciolacustrine sand; along the main ridge south of Highway 53 water-well records suggest that the till, usually thin or missing, generally overlies considerable thicknesses of fine sand and silt. The true age of this moraine is suspect and requiries drilling to determine the stratigraphic sequence more accurately.

The waters of glacial Lake Whittlesey have modified the flanks of much of this moraine and in a few places shoreline features were developed.

The Paris Moraine represents the outer part of the Port Huron Moraine System in this area (Chapman and Putnam 1966) and generally the outermost extent of the Wentworth Till; marble boulders representing englacial deposition were found north of Scotland on the moraine ridge (not shown on Map 2240, back pocket). Taylor (1913; 1939) described this moraine briefly in 1913 and his paper in 1939 described it in considerable detail. South of the Town of Paris the moraine is readily traceable as it forms a continuous ridge; north of Paris this is not the case and different authors give the moraine different locations. Taylor (1939, p. 380) interpreted the moraine as crossing to the eastern side of the Grand River at Paris to merge with and form the outermost ridge of the massive Galt Moraine. Chapman's and Putnam's (1951) map shows the moraine to remain on the western side of the river within the Brantford map-area; no till was mapped in the present survey in much of the area north of Paris

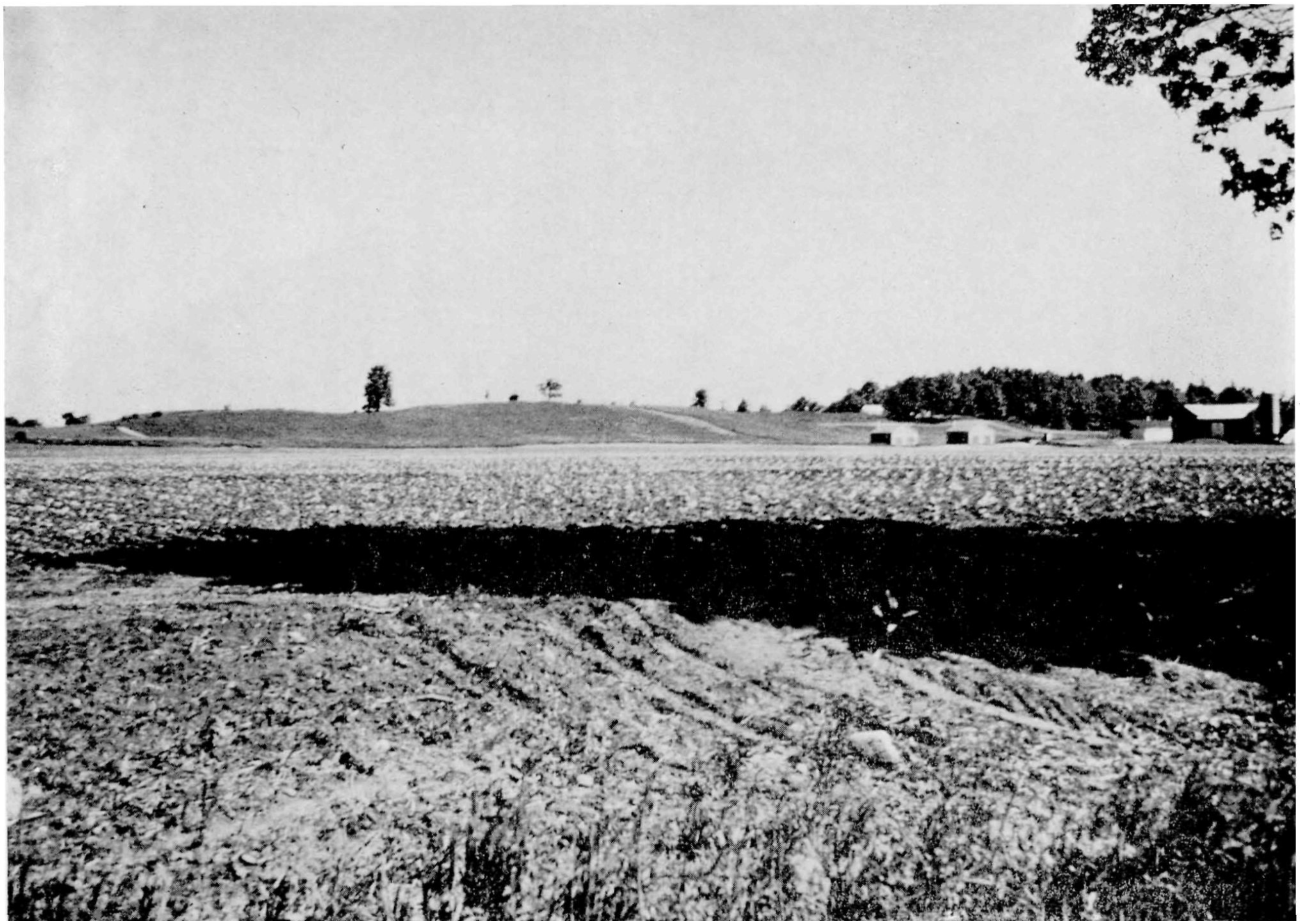

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Photo 3–Tillsonburg Moraine northwest of Burford.

designated as till moraine on their map. Karrow's (1963a) work in the Galt map-area located the moraine on the western side of the Grand River, although it is somewhat fragmentary in the area in question. The moraine is interpreted here as being on the western side of the river with a large gap north of Paris.

Between Paris and Mount Vernon, the Paris Moraine is largely a gently rolling area mantled by Wentworth Till; kame gravel may be found underlying the till at Horner Creek and at Scotland and numerous cuts and drill holes indicate the presence of glaciofluvial gravels and sands beneath a thin cover of till (Photo 4). Much of the moraine has been modified on the surface by the waters of glacial lakes Whittlesey and Warren. Between Mount Vernon and Scotland the moraine consists of a narrow till-capped ridge (Figure 5) fronted on the west by an apron of dirty, coarse flaggy proximal facies outwash; farther west the distal facies of this outwash becomes better sorted and considerably thinner where it may be found overlying fine sand.

The above situation represents heavily laden meltwaters running from the ice and depositing the debris rapidly into a proglacial lake as was suggested by Taylor (1939, p.383). South of Scotland much of the till-capped part of the moraine has been reworked by glaciolacustrine processes and some of this has been reworked to a near-gravel facies.

The steep east side of the Paris Moraine, between Scotland and Mount Vernon, represents an ice-contact slope modified by wave action (not shown on Map 2240, back pocket); shoreline features are poorly developed and difficult to distinguish accurately.

East of the Paris Moraine the next youngest moraine is the Galt Moraine. South of Oakland the moraine consists of till knolls protruding through a mantle of younger glaciolacustrine fine sands. From 1 mile south of Oakland to 6 or 7 miles north of Oakland this moraine consists largely of outwash gravels with a narrow till ridge in the very highest parts, on the eastern side of the moraine, layers of Wentworth Till may be interstratified with advance and recessional outwash gravel (see Photo 1).

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Photo 4—Wentworth Till overlying outwash gravelly sand in Paris Moraine near Paris.

East of the Brantford Airport the Galt Moraine consists of till-capped ridges, which water-well records suggest may be cored by gravel. A small re-entrant here makes the separation of the Galt and Moffat Moraines somewhat difficult in this area.

North of the Grand River the moraine increases in size and from east of Paris to Blue Lakes it is a broad till ridge of which only the highest parts have not been surficially modified by Lake Warren. North of Blue Lakes the moraine attains its greatest bulk and height with only the lowest parts modified by glacial lakes. Here it consists of two ridges of bouldery Wentworth Till with the interridge area mantled by a thin veneer of silt and sand; it is the outer ridge that Taylor (1939) considered to be the extension of the Paris Moraine north of Paris.

Karrow (1963a, p.17) named two fragmentary moraines, composed of Wentworth Till and lying east of the Galt Moraine, the Moffat Moraines. Fragments of one of these is present in the Brantford map-area. From south of Maple Grove to the re-entrant east of Brantford Airport the moraine consists of a discontinuous, narrow till ridge that is modified and mantled by a veneer of sand. North of the Grand River to Highway 5 the ridge is subdued and partly reworked. This moraine consists of Wentworth Till and is generally below the main water planes of Lake Warren although close to the junction of Highway 2 and Towerline Road an erosional shoreline feature is cut into the moraine at about 825 feet. Exposures were inadequate to determine whether this moraine contains considerable water-laid till although one exposure west of Mount Pleasant suggested weak stratification was present.

No other end moraines are present in the area. The ice-contact delta southeast of Summit Station was believed to correlate with the outermost Waterdown Moraine (Karrow 1963a, p.17) north of Copetown and possibly with the Fort Erie Moraine to the south although Chapman and Putnam (1966, p.72) suggested it may correlate with the Niagara Falls Moraine.

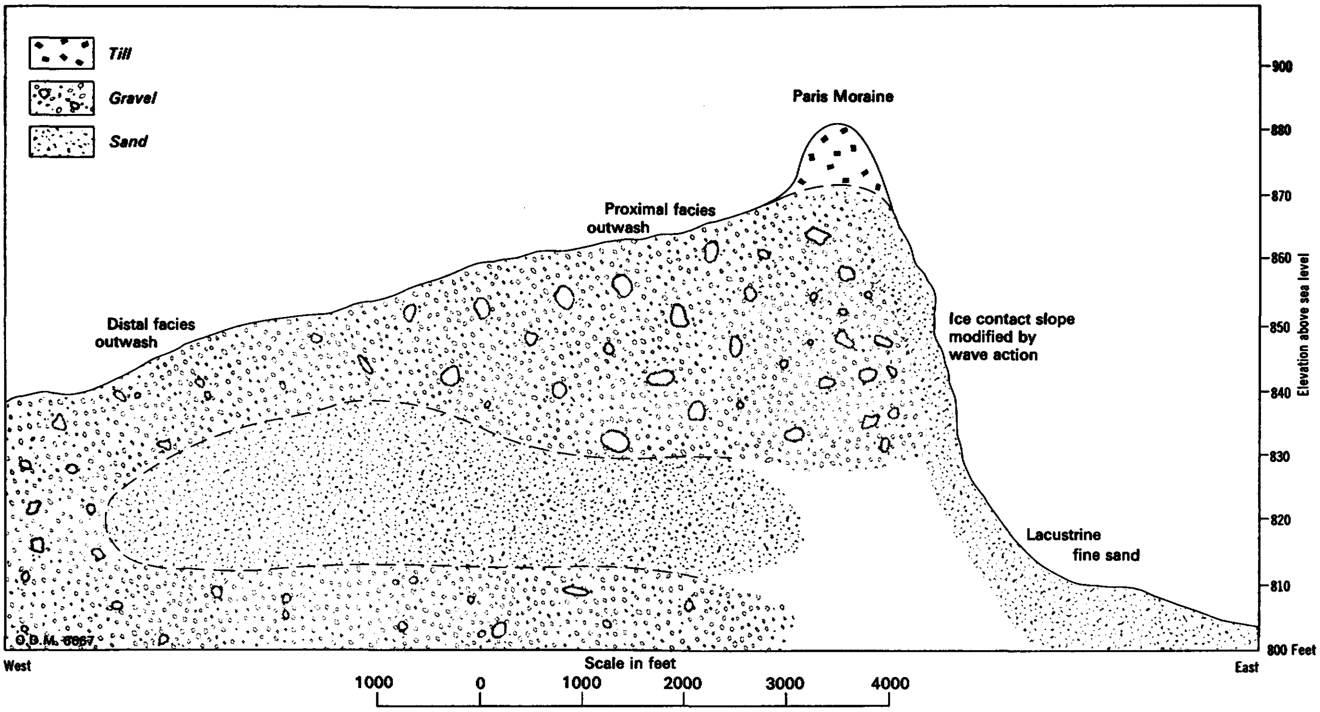

Figure 5—Sketch of the Paris Moraine 2 miles southeast of Burford in the Brantford area.

Ground Moraine

Ground moraine consists of gently undulating morphologic terrain units formed by the deposition of glacial till but within which there are no transverse linear elements; this type of feature is generally referred to as till plain in southern Ontario. Within the Brantford area, ground moraine has a limited extent and occurs within three different till sheets.

The oldest ground moraine appearing at the surface occurs within the area mapped as Port Stanley Till northwest of Paris and east of the Tillsonburg Moraine. This area is flat with accentuated relief where meltwater channels have been cut into it. The relief is probably more subdued than the original surface as much of this area has been reworked by glaciolacustrine waters with some silt and sand being deposited as veneer, particularly in the lower ground.

A small area of ground moraine occurs within the Wentworth Till east of the Galt Moraine and northwest of St. George. Somewhat more rugged than the first area, this ground moraine has relief up to 25 feet and contains a few kettle holes. Here too, the surface has been somewhat modified by glaciolacustrine processes.

The youngest area of ground moraine comprises the area mapped as Halton Till, east of Copetown. This area is very rolling with considerable relief (see Photo 2) and generally has a hummocky appearance. The greater part of this topography is post-deposition of the Halton Till and results from fluvial erosion both by glacial meltwaters and post-glacial drainage. As this area forms part of the headwaters of Sulphur Creek, which drains into Spencer Creek beyond the map-area, and as relief is considerable, erosion on these slopes is continuing.

Drumlins

Drumlins or drumlinoid ridges occur only in Tuscarora Township south of the Grand River; these have been briefly described by Chapman and

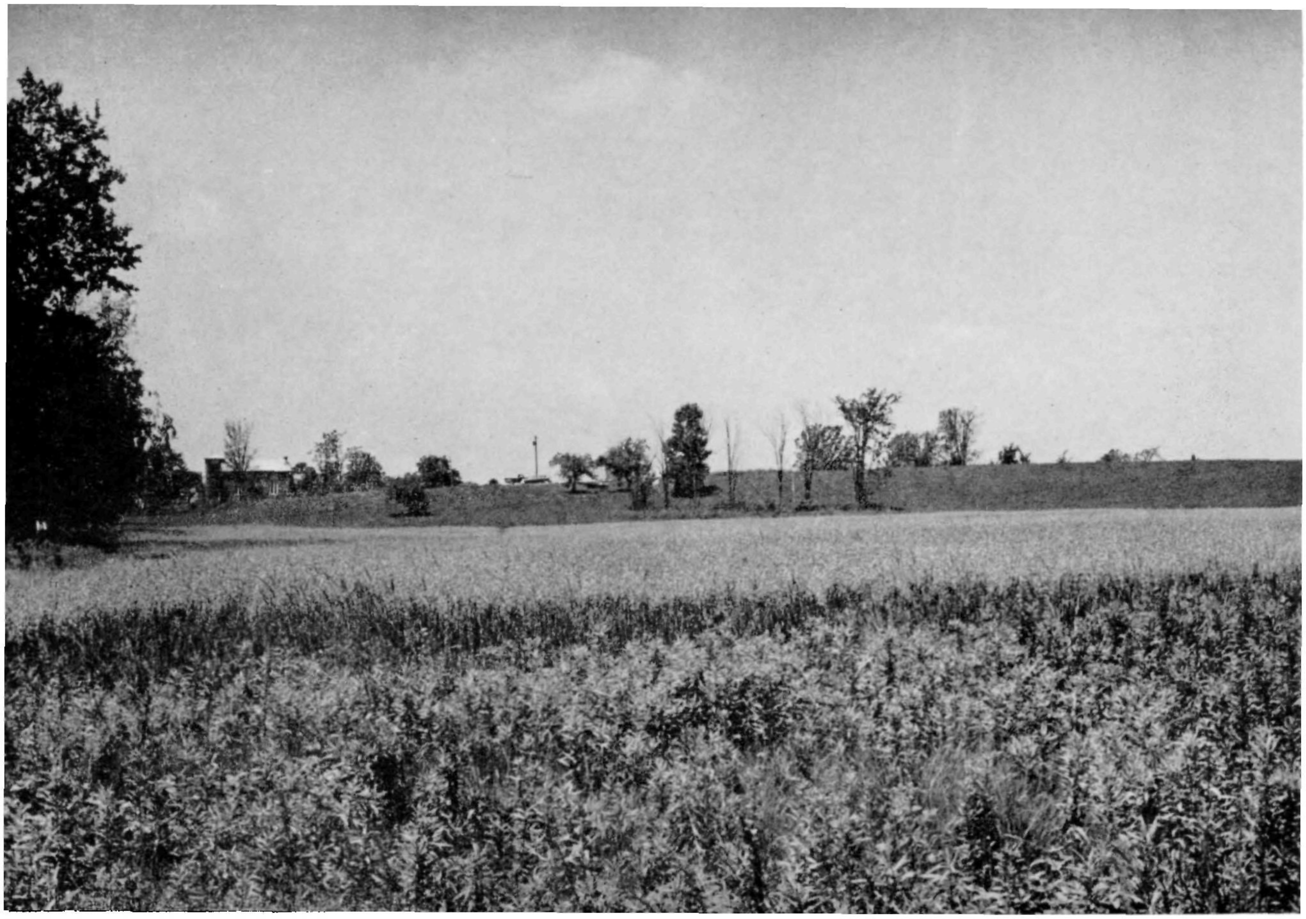

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Photo 5—Drumlinoid ridge at New Credit.

Putnam (1966, p.78). The drumlins occur as islands protruding through a mantle of overlying glaciolacustrine sediments and as a consequence only the upper parts of the drumlins are seen. The visible drumlins probably comprise an area of drumlinized ground moraine and unmapped buried drumlins may occur close to the surface in adjacent areas.

Generally these drumlins form narrow ridges ranging up to 1,000 yards in length and have widths of about 100 to 200 yards. They occur between the elevations of 705 and 730 feet giving them a maximum height of about 25 feet. No well-defined shoreline features were noted on these ridges but some appeared to have steep sides accentuated by the flat-lying onlapping deep-water lacustrine sediments. Because of the general lack of near-shore sediments adjacent to the ridges, any minor shoreline features would probably correlate with drainage phases of the glacial Great Lakes rather than with a well-defined water plane.

The drumlins trend at S50 to 70W and are cored by till described previously as a southeastern facies of the Wentworth Till. The till has a thickness of 40 to 50 feet in several of the drumlins so that any buried ground moraine would probably be thin.

As the principal topographic features in the area of occurrence, these drumlins provide local landmarks and result in names such as Stoneridge Corners. Because of the good drainage on these features in many places they are the site of cemeteries and churches (Photo 5).

GLACIOFLUVIAL DEPOSITS AND FEATURES

Outwash Deposits

Outwash deposits in the form of high-level fluvial terraces, outwash plains, and outwash aprons associated with end moraines are common in the Brantford area. Much of this material, consisting of poorly sorted gravels and sands, was deposited by meltwaters derived from the Wentworth ice, which

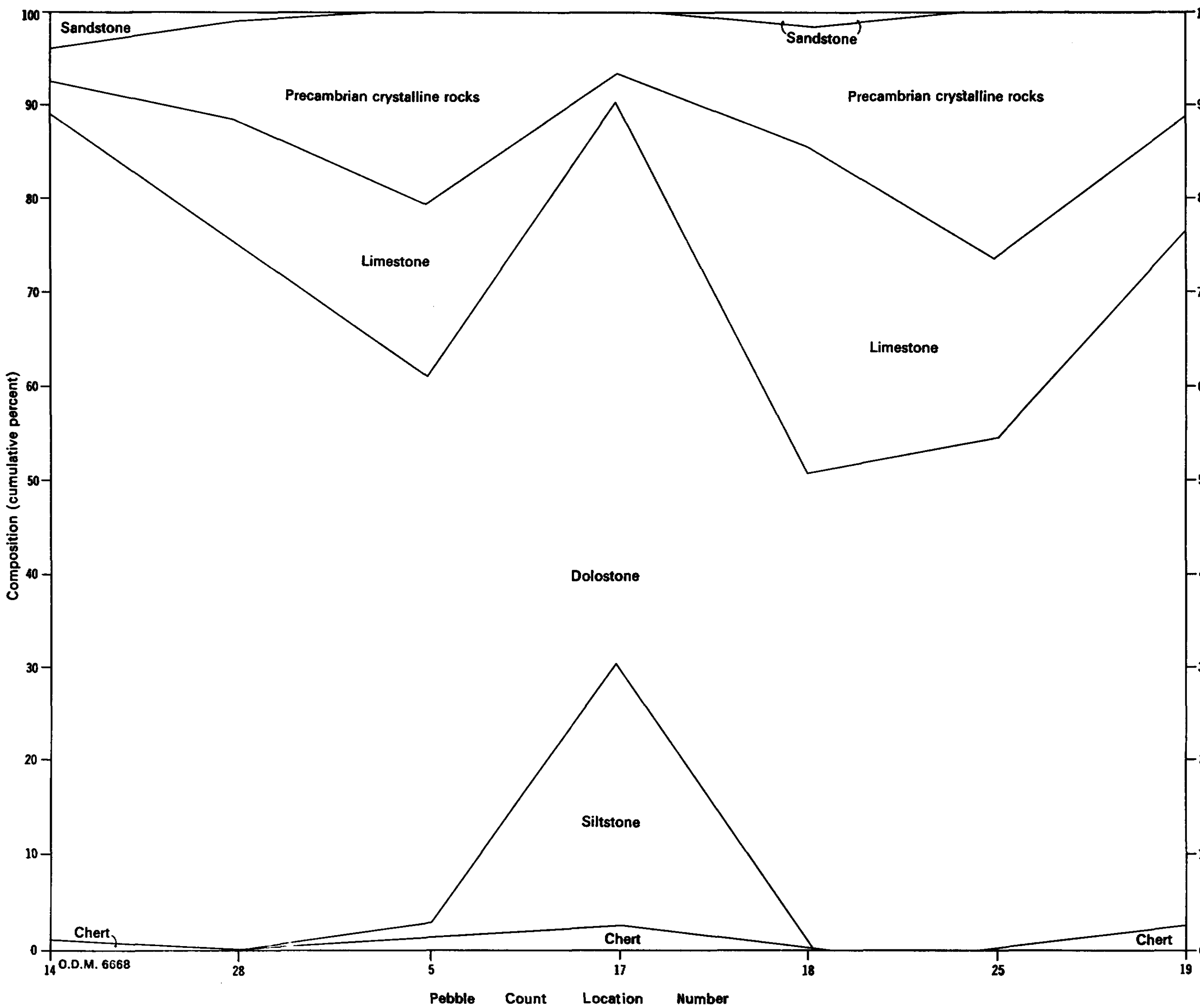

Figure 6—Pebble lithology of gravels in the Paris-Brantford outwash complex; locality trend is from north, on the left, to south, on the right; sample locations as shown on the Granular Deposits Map (Map 2241, back pocket).

also provided considerable quantities of coarse material. As proglacial lakes were usually contemporaneous with glaciofluvial deposition, outwash plains and terraces that cut into them generally coincide with glacial lake levels, making the differentiation difficult in places; deltaic gravels have been included with outwash gravels for mapping purposes.

The most important outwash feature is a complex that can be traced from western Brantford north through Paris and beyond the area; these gravels were briefly described by Logan (1863) under the name 'Artemesia Gravel' and were shown on his map of superficial deposits compiled by R. Bell and published in 1865. Since that time these gravels have received considerable notice as they form part of a huge meltwater channel related to the Paris and Galt Moraines, e.g. Taylor (1939), Chapman and Putnam (1951; 1966).

This feature originated when meltwaters flowing south down the Grand River debouched into a broad area north of Paris depositing gravels up to 60 feet thick; the Paris Moraine is largely missing or eroded from this area.

Interbedded Wentworth Till, south of Paris, indicates deposition during and following advance to the Paris Moraine. Subsequent lowering of water levels resulted in terracing of the outwash plain; several of these terraces, e.g., the one at 870 feet, appear to coincide with glacial lake levels and the feature is deltaic in part.

Lithology of the pebble-grade material, illustrated in Figure 6, consists primarily of Silurian carbonate rocks; the chief anomaly is a high concentration of siltstone in Sample 17. Siltstone concentrations are not uncommon and L.J. Chapman (1970, personal communication) has observed a silt-

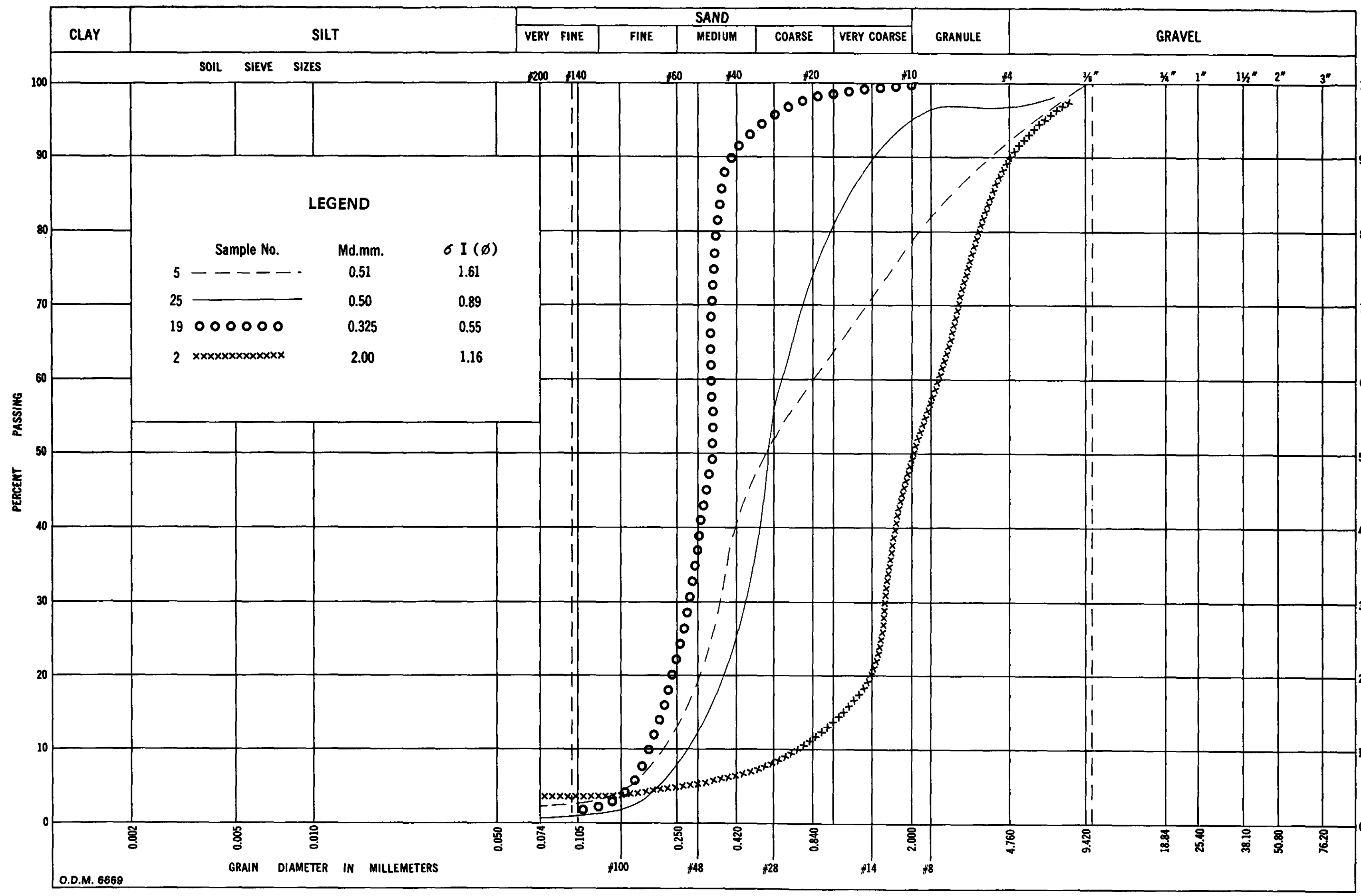

Figure 7–Grain-size distribution curves for some outwash sands in the Burford area; analyses by the Laboratory and Research Branch of the Ontario Department of Mines and Northern Affairs; analyses stopped at 200 mesh. Sample locations are shown on the Granular Deposits Map (Map 2241, back pocket). Median diameter and Inclusive Graphic Standard Deviation (σI, after Folk 1965, p.46) were calculated after replotting data on probability paper.

ODM8592

Photo 6—Cementation in uniform outwash gravels near Paris.

stone-bearing unit near the upper surface of this outwash complex that he has interpreted as resulting from long distance glaciofluvial transport from near the Escarpment area. Alternatively it may represent englacial debris from local Westworth ice although pebble counts (Appendix B) show siltstone to be rare in the Wentworth Till of the Brantford area.

Samples 5, 25, and 19 in Figure 7 illustrate the grain size distribution of sands from the Brantford-Paris complex. The moderately to poorly sorted Samples (25 and 5) are typical of outwash sands whereas the moderately well-sorted Sample 19 is not typical in this area (other samples are to be found in Appendix C); this latter sample was obtained from a 20-foot section of uniform, medium to fine sand layered between gravel units on lot 19, concession III, Brantford Township.

Cementation occurs locally within this complex (Photo 6); the cementing material is usually calcite and dolomite but in a few samples it may be, in part, gypsum derived from the Salina Formation.

Outwash deposits associated with the above complex occur along Horner Creek and in front of the Paris Moraine, southwest of Paris.

The large outwash apron fronting the Paris Moraine between Mount Vernon and Scotland was described previously in conjunction with the Paris Moraine.

Southwest of Burford a large area has been mapped as outwash gravels that extend southwards under overlying glaciolacustrine fine sands. These gravels generally are medium to fine in the north and become finer southwards. They are believed to be deltaic in origin and the present surface is at an elevation of about 830 feet.

Minor amounts of outwash gravel occur along the Galt Moraine southwest of Brantford and at the head of the Dundas Valley; a sample of poorly sorted sand from this latter deposit is illustrated by Sample 2, Figure 7.

Spot samples indicating grain size and mineralogy of sands and pebble lithologies are given for many of these deposits in Appendices C, D, and E.

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Photo 7—Ice-contact gravel near Scotland illustrating wide range of grain size and slump features.

Meltwater Channels

A number of abandoned drainage channels, now containing small underfit streams or drainage lines, are present in the area. These represent the paths followed by the streams that deposited the above-mentioned outwash deposits and the streams that dissected these deposits when water levels dropped.

The Nith River was one of these and it probably had its greatest flow when drainage of the Grand River was blocked by ice standing at, or west of, the Paris Moraine, north of the present map-area. The water flowed southeast to a point northwest of Falkland where it entered glacial Lake Whittlesey. The Wentworth ice then retreated somewhat and allowed drainage through a gap north of Paris and later via the Grand River. Early drainage from these sources flowed west of Paris into Lake Whittlesey and thence south in front of the Paris Moraine; further retreat allowed meltwaters to flow along the Horner Creek meltwater channel and later down the large channel that formed between the Paris and Galt Moraines. Meltwaters running from the Wentworth ice, as it retreated, then formed a deep channel breaching the Galt Moraine at Blue Lakes.

Lowering of water levels and the final drainage of the glacial lakes resulted in terracing along the major stream valleys, breaching of the Galt and Moffat Moraines in several places, and channel cutting in outwash and lacustrine deposits.

That many of these channels were operative during earlier glacial episodes is evidenced by stratified glaciofluvial sediments between successive tills.

ICE-CONTACT DEPOSITS AND FEATURES

Kames

The only depositional features of ice-contact origin within the Brantford area are kames. Most of these have been overridden or modified and can only be identified by internal collapse structures, inclusions of till, or extreme and abrupt grain size changes (Photo 7). Kame gravels core much of the moraine ridge between Scotland and Mount Vernon and are exposed in a gravel pit at Scotland and again at Mount Vernon where no till overlies the gravels on the southern side of Horner Creek. A large feature 1 mile to the southeast of Falkland was interpreted to be kame gravel largely from water-well records and from remnant topography; the gravels are poorly exposed in this feature as it is capped by a thin veneer (variable between 0 to 8 feet) of stratified, silt, clay, gravelly sand, and some poorly exposed material, which may be a clay till.

Buried gravels of possible ice-contact origin are commonly reported in water-well logs from both the Paris and Galt Moraines. Small pockets of gravel of ice-contact origin occur within Wentworth Till, especially in the Galt Moraine.

Kettles

Kettle holes, resulting from the melting of buried or partly buried ice blocks, are not common within the area. The largest concentration occurs within the outwash apron fronting the Paris Moraine between Mount Vernon and Scotland; here ice masses were floated up to a mile from the Paris Moraine where they were partly buried. A few kettles occur 2 to 3 miles north of Paris in the Paris-Brantford outwash complex. These occur in a position where the Paris Moraine is largely missing and may represent blocks of ice stranded when meltwaters cut through the missing part of the moraine. Kettle holes occur in the Galt Moraine north of Blue Lakes and there are also a few south of Copetown, one of which now contains the Copetown Muskeg Preserve.

GLACIOLACUSTRINE DEPOSITS AND FEATURES

Drainage of the Erie Basin via the Niagara River and Lake Ontario was subjected to frequent blockages by the Late Wisconsinan ice sheet. This resulted in a considerable expansion of the Great Lakes to form the glacial Great Lakes; these lakes rose until an outlet was found through which the lake waters could drain. This recurred several times, with variable ice frontal positions, allowing outlets to occur at different locations having different elevations. Evidence of these lakes exists in the form of abandoned shorelines, deltaic deposits, and deep water lacustrine deposits at elevations considerably above levels of the present Great Lakes. Evidence of these former lakes within the Brantford area has been observed or discussed by a number of authors: these include Leverett and Taylor (1915), Leverett (1939), MacLachlan (1938), Chapman and Putnam (1951; 1966), Hough (1958; 1963), Karrow (1963a), Ryder (1963), and others. The most recent general survey of the glacial Great Lakes episodes is that of Hough (1963).

Abandoned Shorelines

Within the Brantford area, shoreline features representing water planes of five glacial-lake episodes are present. Most of the features are erosional bluffs, which are poorly developed and discontinuous; constructional features such as bars and spits occur in only a few places. In addition, shallow water lacustrine deposits lapping against morainal features usually appear to represent shoreline positions; many of these are highly speculative and were not mapped as shorelines except where erosional bluffs were present. Thin gravel deposits over till, and washed till, commonly provide evidence of shoreline processes but do not provide a well-defined shoreline feature.

The determination of shoreline elevations of former glacial lakes within the area is somewhat hindered by the poor development and discontinuity of the features. Elevations are generally related to spot heights on the NTS sheets, which may be considered accurate to about ± 5 feet (L.P. Robertson[1] 1968, personal communication). Correlation of these features with better known areas is also hampered by the lack of detailed studies in the Simcoe and Tillsonburg NTS areas to the south.

The highest shoreline features occurring within the area are found at altitudes of about 900 feet in the northern part of the area. As very little of the area attains these elevations they are largely confined to the Paris Moraine, south of Paris, and the Paris Moraine and Galt Moraine, north of Paris; no features at this elevation were found on the eastern

[1] Chief, Vertical Control Section, Geodetic Survey of Canada.

side of the Galt Moraine during the present survey. Lacustrine sands on the northern side of the Nith River appear to represent shallow water or deltaic deposition at or just below this level. Indistinct features on the Tillsonburg Moraine and possibly the outwash fronting the Paris Moraine, south of Mount Vernon, may represent this water plane in the southerly part of the area; because of post-glacial uplift these necessarily occur at lower levels than the 900 feet in the northern part of the area.

The next highest, and perhaps the best developed shoreline within the area occurs at about 870 feet in the northern area. It is best developed at St. George where it comprises the uppermost beach consisting of gravels derived from reworked Wentworth Till. From here it forms an erosional bluff that crosses Highway 5 just north of the junction with Highway 24 and it also appears on the Galt Moraine just east of Blue Lakes. As outlined on the present map (Map 2240, back pocket) this shoreline appears to change from about 870 feet to parallel the 850-foot contour from the 1:50,000 NTS sheet; recent 1:25,000 NTS sheets show this 850-foot contour to be erroneous as do field measurements. Fragments of this shoreline may be traced southward along the Galt Moraine but these are generally poorly developed. A flat-topped ice-contact deltaic feature associated with the Halton ice sheet and located 1 mile southeast of Summit station has its surface at 870 feet and would appear to correlate with the shoreline described above.

The next lowest shoreline, also best developed in the northern part of the area, occurs at St. George in the form of a gravel mass and bluff between 835 and 850 feet. Fragments of this shoreline occur near Summit station and along the Galt Moraine.

As reported by Karrow (1963a, p.24), two lower shorelines occur south of St. George at elevations of 810 and 790 feet respectively. Nowhere else are these shorelines represented by such well-developed features; this is probably because wave action from such low-level lakes was in many places upon gently sloping near-shore sediments resulting from earlier higher level lakes.

Correlation of the above shorelines with the standard glacial Great Lakes sequence has been carried out by several authors. MacLachlan (1938) traced a shoreline in the Blue Lakes-St. George area that appears to be the one described here at the 870-foot level and which he related to glacial Lake Warren; the topographic differences pointed out previously may render his altitudes difficult to relate to either the present work or that of Karrow (1963a) or Ryder (1963). Leverett (1939) visited southern Ontario with MacLachlan and revised many earlier correlations of glacial lakes with end moraines and indicated that glacial Lake Whittlesey reached an elevation of about 900 feet near Paris. Leverett also remarked that Lake Warren was dammed by an ice barrier overlapping the Escarpment near Copetown within the present map-area (Leverett 1939, p.467); this apparently relates to the Halton Till of Karrow (1963a) as mapped herein and the associated deltaic deposits at 870 feet. Chapman and Putnam (1951; 1966) referred to a Whittlesey beach at 875 feet 2 miles north of Scotland and they locate Lake Warren beaches at 830 to 840 feet about 1 mile southeast of Blue Lakes, although they thought this to be higher than might be expected. Karrow's (1963a) work correlated the 870-foot shoreline at St. George with shorelines at 930 feet in the Galt area to the north; these he interpreted as Lake Whittlesey shorelines and suggested that if this were so then Lake Whittlesey continued to exist during retreat of the Wentworth ice sheet from the Galt Moraine. The most detailed survey of shorelines within the Brantford area to date was that of Ryder (1963) who interpreted the shorelines of Brant County to include fragments of Lake Whittlesey, Upper Lake Warren, Middle Lake Warren, Lower Lake Warren, and Lake Wayne. Ryder's work gives the following correlations and elevations: Lake Whittlesey with the Tillsonburg Moraine and shorelines rising to 900 feet in the north; Upper Lake Warren with the Paris Moraine and shorelines rising to 900 feet north of Paris, apparently the same as the 900-foot levels observed by the present writer; Middle Lake Warren with the Galt Moraine and shorelines rising to 895 feet north of Blue Lakes; Lower Lake Warren with an ice front to the east of Brant County and rising to 903 feet in the north, this correlates with the 870-foot beach near St. George; and Lake Wayne rising to 870 feet near Branchton in the Galt area, apparently the beach at the 835- to 850-foot level at St. George. Ryder made no mention of the well-defined lower beaches south of St. George; she correlated her Lower Lake Warren levels with Karrow's Lake Whittlesey shorelines and her Lake Wayne with Karrow's Lake Warrren. Clearly the situation is confused; the problems stem from the discontinuity of most shorelines and the correlation of shorelines with various stages of the Port Huron advance in Michigan.

At the risk of further confusing the literature the following interpretations were made during the present survey. The most prominent shoreline observed is that at 870 feet at St. George from where it trends westward and thence south on the east side of the Galt Moraine. This has been correlated with the 870-foot delta associated with the Halton ice and is therefore of Lake Warren age; Karrow (1963a, p.56) correlated the Halton advance with Lake Warren II. It's relationship to Karrow's high shorelines north of the area is uncertain as the 900-foot shorelines near Paris are thought to be related to Lake Whittlesey and possibly Karrow's highest shorelines. The shoreline at the 835- to 850-foot level, as pointed out by Ryder (1963), provides some evidence to suggest that it is older than the 870-foot shoreline and she thought it might be related to glacial Lake Wayne. Hough (1963) pointed out that glacial Lake Wayne was at least older than the lowest Warren level and possibly older than the highest, although he preferred the former. It is thought that detailed work in the Niagara Falls area, presently being carried out by the Ontario Department of Mines and Northern Affairs, plus work to the south of the present area is required to decipher the lake history more precisely and provide additional data from points nearer the hinge line. Karrow's (1963a) interpretation of the lowest shorelines as glacial Lakes Grassmere and Lundy appears to be correct.

Shallow-Water Sediments

Shallow-water sediments consisting of beach deposits, deltaic deposits, and near-shore deposits are widespread within the Brantford area.

Beach deposits are relatively rare with the best development in the form of a bar deposit at St. George. This deposit appears to represent two ages of deposition and consists of sand and gravel that is currently being worked at two levels. Other beach deposits are associated, in many places, with outwash along the Paris and Galt Moraines. Elsewhere, thin gravel lag deposits over till, or reworked till, are present; in most places these were too small in area or too thin to map at the present scale.

Deltaic deposits occur mainly in the intermoraine areas west of Brantford, in the Copetown area, and at Brantford. Gravelly deposits have been described in conjunction with outwash deposits and the remainder of the deltaic material consists primarily of medium to fine or very fine sand with some silt and in some places silty fine sand. The large areas mantled with sand in the intermoraine areas west of Brantford are largely the result of sedimentation into Lakes Whittlesey and Warren. The area of sand in the Copetown-Lynden area resulted from sedimentation into glacial Lake Warren initially and then spread southwards as the waters receded to and below the levels of Lakes Grassmere and Lundy. The area of sand at Brantford is believed to represent deltaic sedimentation by waters of the late glacial Grand River as it entered one of these lowest lakes.

Near-shore sediments consisting of fine sand are most widespread on the eastern side of the Galt Moraine. These are largely sands washed from the Wentworth Till. In addition a thin veneer of sand is widespread over the area as a result of reworking of other sediments by the subsiding glacial lakes.

Figure 8 illustrates the grain-size distribution of some of these deltaic and near-shore sands. Samples 8, 9, and 24 are moderately well to well sorted; the deposits from which 9 and 24 were obtained have been used for commercial purposes. The poorly sorted sample 10 is somewhat more silty than the others and is more representative of the major part of the area mapped as glaciolacustrine sand. Mineralogical composition of these sands is given in Appendix D.

The thicknesses of these sands are variable and generally they pinch out near contacts with other materials. A few thicknesses for these sands are as follows: 2 miles southwest of Falkland, 60 feet; 1½ miles south of Harley, 35 feet; near Brantford airport, 80 feet; near Mount Pleasant, 45 feet. Near Lynden the sand thickness is small and clay outcrops in most of the valley walls. In Tuscarora Township sand is generally very thin and variable.

Soil developed on sands within the Brantford area is mainly that of the Fox Series[1] on which tobacco is the principal cash crop.

Deeper Water Sediments

A large part of the map-area was mapped as deeper water glaciolacustrine sediments consisting of laminated to varved silt, clay, and minor sand. Much of this was mapped by Bell and described by Logan (Logan 1863) as the 'Erie clay' and comprises part of the clay plain units of Chapman and Putnam (1951). These sediments generally occur at altitudes between 750 feet in the north and west and 650 feet in the southeast and are deeply incised by streams that easily erode these sediments.

The texture of these sediments is variable from laminated silt or clay to varved sediments in which the fine (winter) layer may range from 1/16 inch to more than 6 inches of clay and the coarse (summer) layer may range from ¼ inch of silt to nearly 3 feet

[1] For a general reference to soil series names see Hoffman *et al.* 1964.

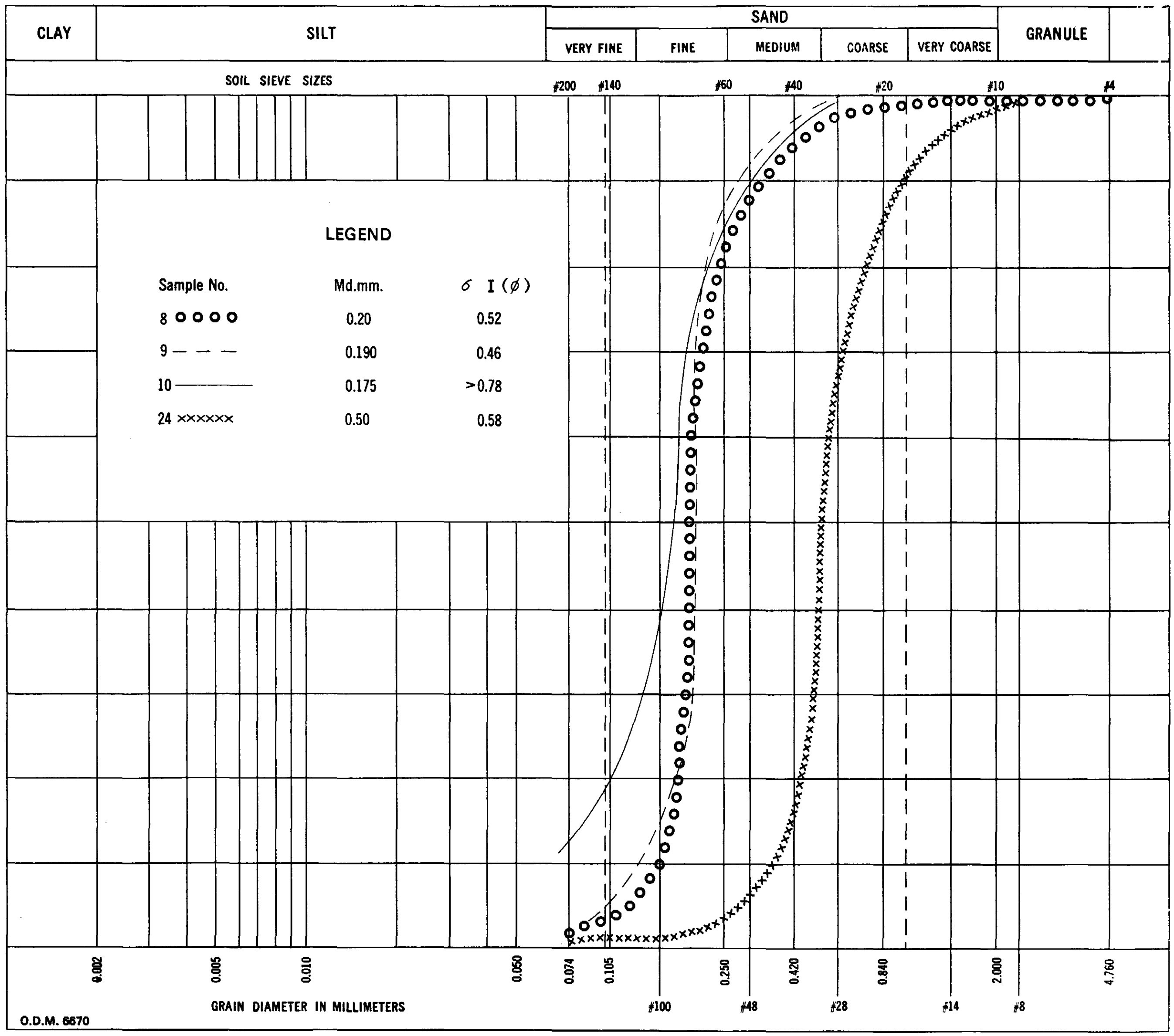

Figure 8—Grain-size distribution curves for some glaciolacustrine sands in the Brantford area; analyses by the Laboratory and Research Branch of the Ontario Department of Mines and Northern Affairs; analyses stopped at 200 mesh. Sample locations are shown on the Granular Deposits Map (Map 2241, back pocket). Median diameter and Inclusive Graphic Standard Deviation (σI, after Folk 1965, p.46) were calculated after replotting data on probability paper.

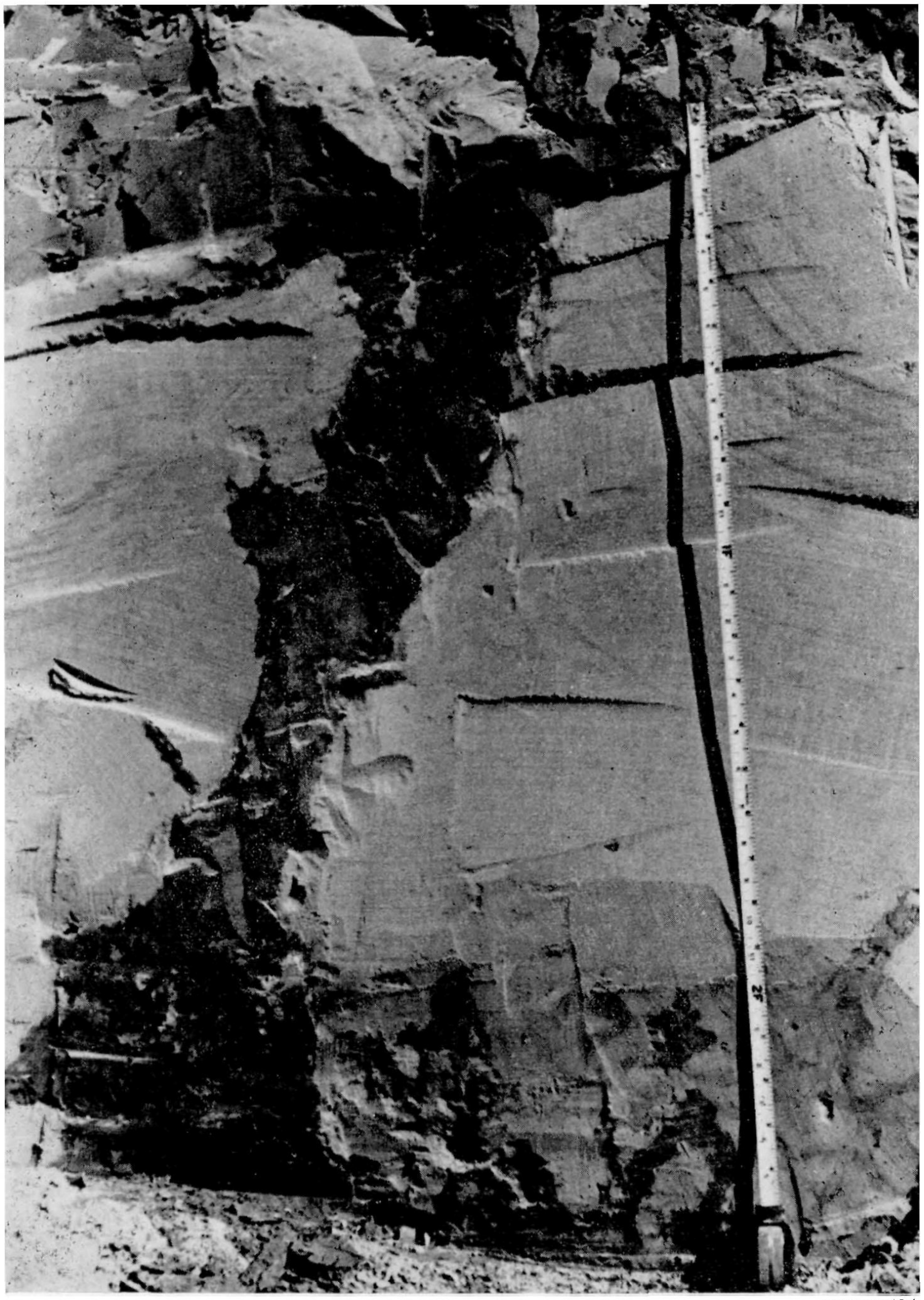

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Photo 8—Clay dike cutting fine sand in thick varve; flame structures at base.

of fine sand. Generally silt is more prominent in the northern part of the basin and clay in the south. A thin veneer of sand is usually present and in many places the stratification in the top 3 or 4 feet of the fine-grained sediments is missing or faint due to weathering processes. The thickness of these materials varies with the underlying topography and distance from the source area in the north. Thicknesses range from zero, where the materials lap against high features such as drumlins, to more than 100 feet. A few representative thicknesses are as follows: Harrisburg, 130 feet; 2 miles south of St. George, 150 feet; Burtch School, 90 feet; Ohsweken, 60 feet; near Canadian Gypsum Mine (in the southeast corner of the map-area), 10 to 20 feet; lot 19, concession IV, Ancaster Township, 120 feet. Generally these sediments thin toward the southeast where they form a thin cover over till; boulders from this till are encountered in many places at the surface here as they have worked up through the lacustrine sediments by either frost action or agricultural practices.

Dropstones deposited by floating ice are relatively rare within the glaciolacustrine sediments. Carbonate concretions locally occur in large numbers; these are usually related to white to pink clay layers within varved sidements. The concretions are irregularly shaped with maximum diameters of 6 to 8 inches (most commonly 1 or 2 inches) and maximum thicknesses of ½ inch.

A few chemical and mineralogical properties for the minus 200-mesh (0.074 mm) fraction of these materials are reproduced from Guillet (1967) in Tables 3 and 4 (see the section on 'Clay' in the 'Economic Geology' section).

Deformation of these sediments is not uncommon. Slump features were encountered in many places and many of these were interpreted as being sub-aqueous and penecontemporaneous with deposition. Clay dikes and associated flame structures were encountered in some places (Photo 8).

Most of the deep-water sediments are thought to be related to Lake Warren. Work on a varve chronology has been initiated and it is hoped that through this method a considerable knowledge of the sedimentation sequence will be obtained. Such information would be of use in further deciphering lake history and in engineering studies. Figure 9 (Chart A, back pocket) illustrates one of the best varve diagrams obtained to date; the sequence occurs at elevations between 650 and 675 feet, is underlain by about 25 feet of slumped varved sediments, and is overlain by 6 feet of gravelly sand. The illustrated sequence, with only a few breaks contains more than 200 varves. The diagram well illustrates a series of varves between numbers 1 and 42 that appear to be distal varves with thick winter layers, whereas the remainder of the diagram appears to illustrate two or more periods of glacial fluctuations with thick proximal varves having thick summer layers gradually giving way to a more distal varve type. This work is continuing on the basis of data obtained to date that suggests that a full sequence may be obtainable.

Soils developed on these parent materials are mainly those of the Brant and Brantford Series and their related drainage phases. These soils, particularly in the finest sediments, are susceptible to considerable erosion through sheet wash and gullying processes.

DEPOSITS AND FEATURES OF NON-GLACIAL ORIGIN

Interstadial Deposits

Interstadial sediments of Mid Wisconsinan age may be expected to occur between the Canning Till (Early Wisconsinan) and Late Wisconsinan tills consisting of the Catfish Creek Till and younger tills; to date however, no organic materials suitable for radiocarbon age dating have been found to confirm the presence of these sediments. Similarly no pollen analysis has been carried out on intertill sediments to provide evidence of interstadial climatic conditions. Without the above-mentioned evidence, the stratified sediments occurring between the Canning and Catfish Creek Tills may only represent a part of the Catfish Creek Drift and preexisting interstadial sediments may have been removed by fluvial erosion.

Although glaciolacustrine clay, silt, and sand representing the Erie Interstadial (Dreimanis 1958; 1959, p.28) occurring between the deposition of the Catfish Creek Till and the Port Stanley Till are present, no organic remains or fossil soils have been found within these sediments in the Brantford area.

Examination of water-well records for the entire area provides only one example of organic materials being found at depth. This occurrence is from a redrilled well at the milk factory at St. George; here decaying vegetation was reported within a clay and sand unit at 57 feet below the surface. A more complete record in an adjacent well indicates that the above material is part of a 10-foot unit of stratified sediments located between two possible tills. Because the organic materials were in the uppermost part of the redrilled section of the well, they may have been introduced from the surface and consequently may not represent interstadial organic deposition.

Older Alluvium

A number of remnant terrace deposits were mapped along the major water courses. These consist of sand and gravel deposits occurring below glacial lake levels and above modern alluvial deposits. The delimitation of these deposits is somewhat arbitrary and most probably they comprise, in part, some glaciofluvial materials as well as some higher deposits of modern alluvium. The age of these materials is of some question but they appear to represent fluvial deposition during the period following, or in part during, drainage of the glacial Great Lakes but prior to deforestration of the area.

Eolian Deposits

Although no sand dunes or wind blown loess deposits were found, evidence of wind blown sand and silt is present principally in areas adjacent to glaciolacustrine fine sands and silty sands. The thin deposits interpreted as eolian consist of 1 or 2 feet of yellow silt overlying either till or outwash gravels. This eolian activity probably occurred during a short period following drainage of the glacial Great Lakes and prior to the establishment of vegetal cover.

RECENT

Bog and Swamp Deposits

The number of bog and swamp deposits, representing the infilling of wet depressions by organic debris, is small within the Brantford area. The few deposits that have any considerable thickness occur in kettle holes whereas thin bog and swamp deposits occur largely in areas where the water table is at or near the surface.

Most of the bogs mapped as such consist of peat and muck and usually have a basal unit of shell-bearing marl. Generally thicknesses range between 3 and 5 feet; the Copetown Bog south of Copetown, and a bog located 1 mile south of Canning have thicknesses exceeding 20 feet and these are the thickest deposits found within the area. A reported radiocarbon date from near the base of the Copetown Bog gives an age of 9,230 ± 180 years before present (GSC-130, Dyck and Fyles 1964) and the pollen record extending below this level suggests that the bog is considerably older (Dyck and Fyles 1964, p.3-4).

In addition to the deposits described above, a considerable area located between Mount Vernon station and a point 1 to 2 miles north of Scotland and a second area east of Harley contain shallow bog and swamp deposits (all of these are too thin to show on Map 2240, back pocket.) These areas are largely forested and consist of sporadic layers of muck, 1 to 2 feet thick, overlying glaciolacustrine fine sand and silty sand. They are the consequence of a near-surface water table that permits much of the area to be partly inundated for much of the spring and early summer following run-off.

As mentioned, many of the bogs have a basal unit of shell-bearing marl. Shells collected from one such marl unit at Levey Lake, west of Falkland, give the following assemblage: (Identifications were made by Rev. H.B. Herrington of Westbrook, Ontario, and Mrs. M.F.I. Smith of the National Museum of Natural Sciences, Ottawa).

Pelecypoda
- *Pisidium ferrugineum* Prime (a form)
- *Pisidium nitidum* Jenyns
- *Pisidium nitidum f. pauperculum* Sterki

Gastropoda
- *Valvata tricarinata* Say
- *Valvata sincera* Say
- *Physa gyrina* Say
- *Helisoma anceps* (Menke)
- *Gyraulus deflectus*
- *Lymnaea humilis* Say
- Ostracode and(or) snail fragments

Modern Alluvium

Modern alluvium consists of valley-bottom deposits laid down by fluvial action within the recent past and continuing to the present. The distinction between this material and the older alluvium is somewhat arbitrary but the presence of abundant organic material within the modern alluvium and elevation differences were the principal distinguishing features.

The composition and texture of these materials varies considerably and is related to the materials available. Within the areas underlain by glaciolacustrine silt and clay, the modern alluvium consists primarily of silt with some clay, and muck in still-water and abandoned channel areas. Similarly, within the areas mantled by sand this alluvium consists primarily of locally derived sands. The major streams (Nith River, Horner Creek, and Grand River) traverse a wide range of materials and therefore have considerable variation. Modern alluvium along the Nith River and Horner Creek is derived from outwash gravels and various textured tills for the most part; this alluvium generally consists of gravel bars less than 10 feet thick overlain by silt, sand, organic material, including wood. The gravels were laid down in channel areas and the organic-bearing silts and sands in flood-plain areas; the meandering of these streams results in the flood-plain sediments overlying the channel deposits.

Alluvium along the Grand River to just east of Brantford is similar to that of Horner Creek and the Nith River; beyond this the material is usually silt and sand with deposits of gravelly materials in only a few places. Where major streams such as Fairchild Creek and Big Creek (the one entering the Grand River from the north, east of Middleport) enter the Grand River, and at other places along the Grand River where low banks are present, flood plans are extensive; here a veneer of alluvial silt less than 3 feet thick mantles the glaciolacustrine sediments beyond the limits of the mapped alluvium.

Shell remains usually are encountered within the modern alluvium; one sample was collected from an alluvial deposit consisting of gravel, sand, and silt. The shells were situated in a sand unit, 4 to 6 feet below the surface and 10 feet above present river level, located ½ mile southwest of the southernmost point in Birkett Lane, Brantford. The shells were identified by Rev. H.B. Herrington of Westbrook, Ontario and Mrs. M.F.I. Smith of the National Museum of Natural Sciences, Ottawa; the composition of these is given below:

Pelecypoda
- *Sphaerium striatinum* (Lamarck)
- *Sphaerium striatinum f. acuminatum* Prime
- *Pisidium compressum* Prime
- *Pisidium casertanum* Poli
- *Pisidium fallax* Sterki
- *Pisidium cruciatum* Sterki

Gastropoda

Land	Fresh Water
Anguispira alternata (Say)	*Campeloma decisum* (Say)
Triodopsis albolabris (Say)	*Physa gyrina* Say
Oxyloma retusa (Lea)	*Goniobasis liviscens* Menke
Ventridens intertextus (Binney)	*Ferrissia parallela* (Haldeman)
Discus sp.	*Amnicola sp.*

Hawaiia miniscula (Binney)
unidentifiable juvenile

Rev. Herrington reported that the only previous occurrence of *Pisidium curciatum* Sterki in Canada was from the Thames River near London and Dr. A.H. Clarke of the National Museum of Natural Sciences suggested that the environment in which the species listed lived was a medium- to large-size lake or river with a muddy bottom and submersed vegetation; the surrounding forest was of deciduous or mixed coniferous-deciduous composition.

Soils

Soil development is entirely upon Pleistocene sediments within the Brantford area. Soil classification and soil associations developed on these sediments are summarized by Hoffman *et al.* (1964) demonstrating the importance and use of Pleistocene as a base for such studies. Published soil maps for localities within the Brantford area include parts of Haldimand County (Ontario Agricultural College 1935) and Norfolk County (Ontario Agricultural College *circa* 1928) at a scale of 1 inch to 2 miles and parts of Oxford County (Wicklund and Richards 1961) and Wentworth County (Presant *et al.* 1965) at a scale of 1 inch to 1 mile; an unpublished soil map of Brant County was prepared in 1935 at a scale of 1 inch to 2 miles and new maps of Brant County at a scale of 4 inches to 1 mile are currently being prepared by C.J. Acton for the Ontario Soil Survey (Acton, in preparation). This latter mapping will greatly refine the knowledge of distribution of surficial materials and the soils developed thereon in Brant County.

The geological history of the area suggests that paleosols have had some opportunity to develop. No such soils have been found; one exposure in which two soil profiles were developed was located near Scotland adjacent to an irrigation dugout. The two A horizons were sampled for pollen content to determine whether in fact the lower profile was a paleosol or a result of human influence. The pollen content of the lower and upper soils is given below; the analyses were carried out by Dr. J.H. McAndrews of the Royal Ontario Museum who concluded that the abundance of Ragweed and Grass indicate a post-settlement (approximately 1820 A.D.) formation for both soil horizons.

	Upper Soil Horizon Percent	Lower Soil Horizon Percent
Trees		
Pine	44	25
Birch	2	....
Oak	6	7
Elm	2	2
Ironwood	1	....
Maple	....	2
Basswood	4	1
Hickory	....	2
Hemlock	....	3
Herbs		
Grass	24	41
Sage	1	....
Ragweed	12	8
Composits	2	....
Ferns etc.	2	8
	100	99
	Number of Species	Number of Species
Aquatics		
Sedge Family	27	18
Undeterminable	24	21
Unknown	....	5

STRATIGRAPHY

The Pleistocene succession of the Brantford area was established by Karrow (1963a) who carried out detailed studies along the Nith River. A number of additional measured sections are provided herein (Appendix A) although few of these are comparable to the sections found along the Nith River; the locations of both Karrow's and the author's sections are plotted on Figure 10. A few of the sections plotted on Figure 11 illustrate the lack of complete sections but these sections do demonstrate relationships of the Wentworth Till. The Wentworth Till is usually interbedded with gravels in the river sections and some of the sections indicate that deep-water glaciolacustrine sedimentation took place in the Grand River valley following retreat of the Wentworth ice and prior to deposition of the overlying deltaic-outwash gravels. This has also been noted west of Paris by L.J. Chapman (1970, personal communication) who observed varved sediments immediately beneath outwash gravels during drilling operations. Possibly these sediments relate to Lake Whittlesey. Relationships of the Port Stanley and Catfish Creek Tills have been discussed in detail by Karrow (1963a) and elsewhere in this report.

HISTORICAL GEOLOGY

Evidence of glacial events during Illinoisan time or interglacial events during Sangamonian time has not been found to date within the area. Thus the earliest glacial events known occurring within the Brantford area are those recorded by Karrow (1963a) in the form of the 'lower beds' and Canning Till. Karrow interpreted these to be of Early Wisconsinan age (approximately 70,000 to 53,000 years B.P.) and no evidence has since been uncovered to refute his findings. Both the 'lower beds' and the Canning Till appear to represent fluctuation of the Ontario-Erie glacial lobe. Westgate and Dreimanis (1967) have correlated the 'lower beds' with a till unit found near Zorra, Ontario, but they were unable to find a correlative in the Lake Erie area, south of London. They were however able to correlate the Canning Till with a till unit at Zorra and with the Upper and Lower Bradtville Drifts (Dreimanis *et al.* 1966) found south of London. Within the present study no further evidence regarding the 'lower beds' has been found and they still remain an unknown commodity. The Canning Till has been suggested as possibly coring part of the Tillsonburg Moraine.

Mid Wisconsinan events (53,000 to 22,000 years B.P., Dreimanis 1970) as recorded in the Port Talbot area (Dreimanis *et al.* 1966) and the Toronto area (Karrow 1967) have not been proven within the Brantford area. Stratified sediments between Early and Late Wisconsinan glacial events may be related to these events as no organic materials indicating interstadial climates have been found.

Deposits of Late Wisconsinan age (approximately 22,000 to 10,000 years B.P., Dreimanis 1970) comprise the bulk of the drift forming the present landscape within the Brantford area. The first major event was the deposition of the Catfish Creek Till by a glacier moving across the area, generally to the southwest, and extending well into the United States; this happened about 18,000 years ago (Goldthwait *et al.* 1965) where the Navarre, Kent, Hayesville, and Lavery Tills of Ohio are apparently correlatives of the Catfish Creek Till of Ontario (Goldthwait *et al.* 1965). The Catfish Creek Till within the present area appears to represent remnant ground moraine in most places.

Glacial retreat followed the deposition of the Catfish Creek Tills. This non-glacial event in the Erie Basin, about 15,000 years ago, is referred to as the Erie Interstadial (Dreimanis 1959) and is marked by glaciolacustrine sediments. Within the Brantford area these sediments consist of stratified to varved silts and clays and stratified sand occur-

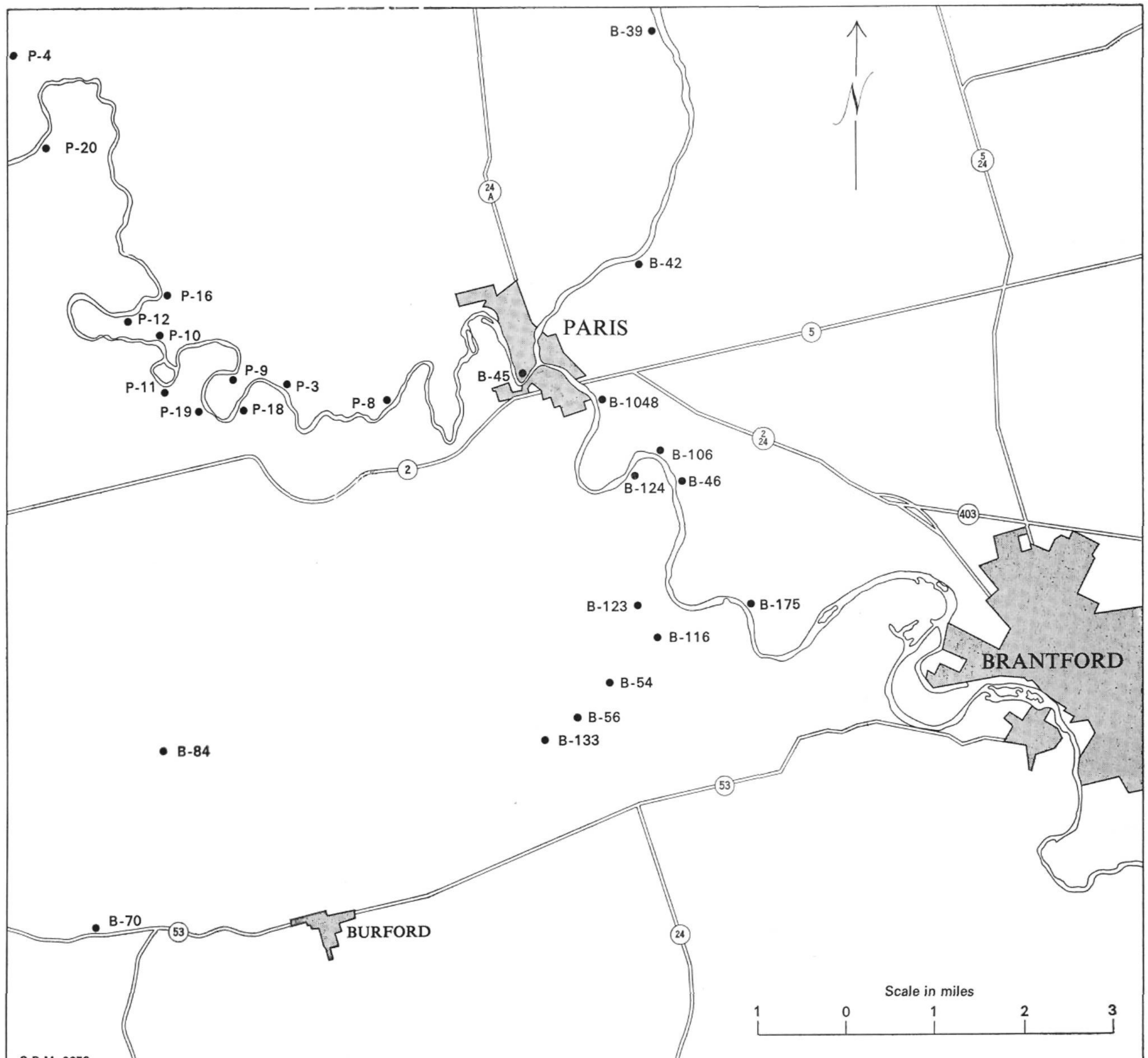

Figure 10–Sketch map showing locations of stratigraphic sections in the Brantford area; those locations lettered P are found in Karrow (1963a) whereas those locations lettered B are found in Appendix A of this report.

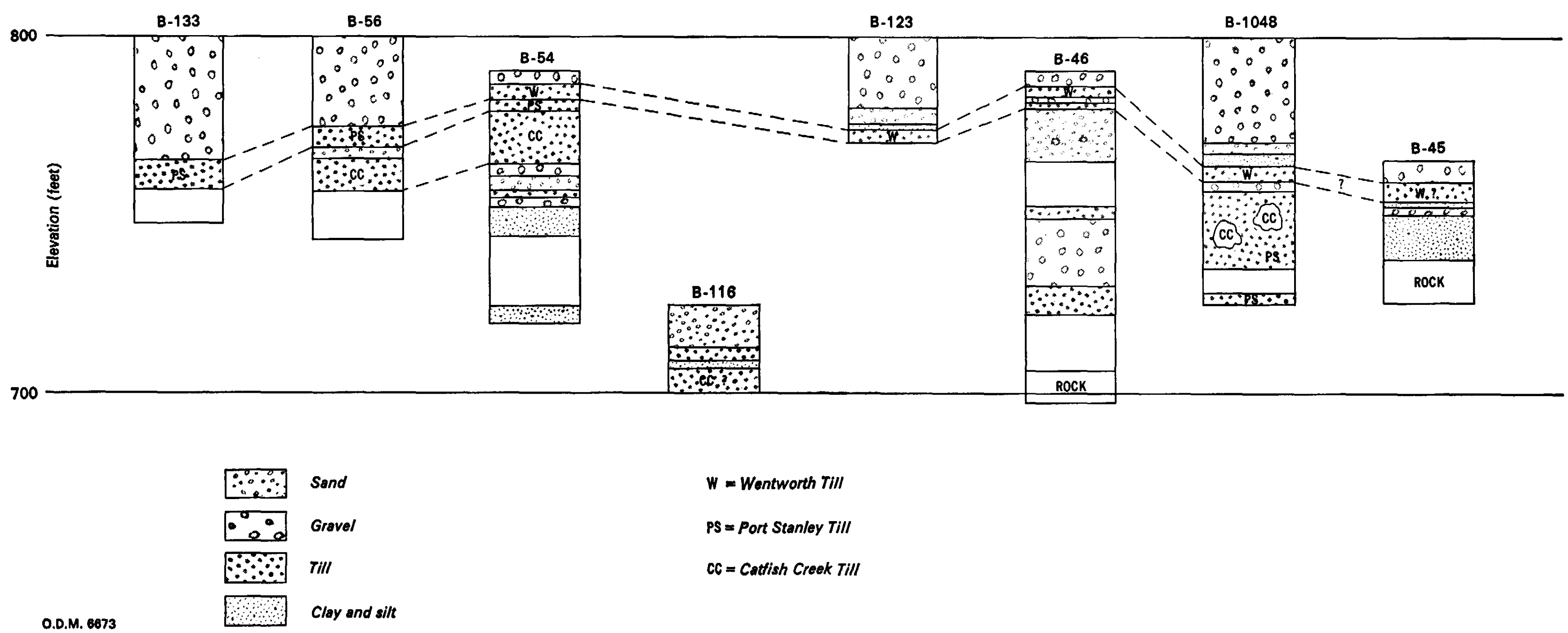

Figure 11—Stratigraphic sections near Paris and Horner Creek in the Brantford area; see Figure 10 for location of sections.

ring as far east as the Paris-Brantford City area. Readvance of the ice sheet across the area then occurred in a generally southeast to northeast direction about 14,000 years ago. The underlying fine-grained lacustrine sediments were reworked into the Port Stanley Till found in much of the Brantford area and extending to the vicinity of Woodstock to the west. This till has been correlated with fine-grained tills on the southern side of Lake Erie (Karrow 1963a; Goldthwait *et al.* 1965). The Port Stanley ice sheet then retreated from its maximum extent to east of the Brantford area, following several brief halts at the Ingersoll, Westminster, St. Thomas, Norwich, and Tillsonburg end moraines (the Ingersoll, Westminster, and St. Thomas end moraines are found west of the map-area).

Withdrawal of the Port Stanley ice sheet was followed by a brief interval of non-deposition (Cary-Port Huron Intersadial) in the Brantford area. This was followed by a strong glacial advance westward to at least the Paris Moraine. During this advance the Wentworth Till was laid down in association with quantities of advance outwash gravels. Recession of this ice sheet was accompanied by further outwash deposition (especially in conjunction with the Grand River meltwater channel), the formation of the Galt and Moffat Moraines, and glacial Lake Whittlesey (about 13,000 years B.P.), which may have existed until the Wentworth ice sheet retreated almost to the Niagara Escarpment (Karrow 1963a).

Karrow (1963a) suggested that lowering of the Lake Whittlesey water level resulted in the formation of Lake Warren I and this event was followed by advance of the Halton ice sheet and the formation of Lake Warren II. The work of Ryder (1963), and the present study, suggests that during retreat of the Wentworth ice, a lake level at 835 to 850 feet at St. George formed (Lake Wayne?) and advance of the Halton ice into the Dundas Valley resulted in the deposition of the Halton Till and the formation of a proglacial delta and shoreline having an altitude of 870 feet at St. George. This latter lake, at an altitude of 870 feet, is thought, by the present writer, to be the highest Lake Warren level although Ryder (1963) considered it to be the lowest Lake Warren shoreline and Karrow (1963a) related it to Lake Whittlesey. Lowering of this water level resulted in Lakes Grassmere and Lundy and final drainage of the area was accomplished 12,000 years ago (Dreimanis 1964; 1966).

Following the drainage of the glacial Great Lakes, bog development began in areas affected by these lakes and high-level alluvial deposits were laid down along the major water courses. Soil development and fluvial erosion and deposition in stream valleys was initiated and continues to the present.

ECONOMIC GEOLOGY

The importance of Pleistocene sediments as a source of construction materials has been exemplified recently by rapid urban expansion and the resultant problems of mineral resource zoning. The need for increased knowledge of the distribution, quantity, and quality of these materials has been expressed for some time, e.g. Hewitt (1962). The ability to produce sand and gravel in excess of local needs and its proximity to the Toronto-Hamilton area, has made the Brantford area critical as a resource base for much of southern Ontario. As a result, multiple or sequential land-use planning and extensive pit rehabilitation programs are required if the optimum use of land is to be achieved.

Sand and Gravel

Reported value of sand and gravel* products for the Brantford area exceeded $3,400,000** in 1968; in addition, numerous non-reporting pits operated on at least a part-time basis. Much of this material was freighted to Toronto via rail or Hamilton via truck. Descriptions of the major operations were published by Karrow (Hewitt and Karrow 1963) and have been updated by the present writer (Hewitt and Cowan 1969a); operations producing less than $100,000 in 1967 were described by the present writer in an Open File Report of the Ontario Department of Mines (Hewitt and Cowan 1969b).

Map 2241 (in pocket) illustrates the distribution of gravel and gravelly sand within the Brantford area and provides water-well information showing reported thicknesses of gravel and overlying overburden. Information on pebble lithologies, grain size of selected sand samples, and the mineralogy of the minus 24 plus 48 mesh fraction of these sand samples is given in Appendices E, C, and D.

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* In the descriptions of properties the author uses the term gravel when the size range starts at about 2 mm. but he uses the term stone when the size range starts at more than ¼ inch.

** Statistical files, Ontario Department of Mines and Northern Affairs.

ODM8595

Photo 9—Pit operations at Telephone City Gravel Company Limited, Pit No. 1, 1968.

Within the area glaciofluvial outwash gravels are of the greatest economic significance. The outwash complex between Brantford and Paris is presently being worked by several large companies that also control much of the adjacent land. The area north and northeast of Paris contains large reserves that have not yet been developed and this area must be considered as an important continuing reserve. Thicknesses of gravel in this complex vary from 30 to 60 feet and generally thin away from the river. Overburden consisting of fine sand and silt may be up to 10 feet thick where depressions and channels have been filled with glaciolacustrine sediments. Deleterious material in the pebble grade is generally not important but local concentrations of siltstone do occur; chert and shale are rare in this area.

Two other areas of outwash gravel are of potential importance. The first of these is located in the former Horner Creek meltwater channel extending 2 to 3 miles southwest of the confluence of Horner Creek and the Grand River. Water-well data indicates gravelly material, up to 40 or 50 feet in thickness, and deleterious materials are uncommon. Secondly, a large outwash apron fronting the Paris Moraine contains considerable reserves. Between Scotland and Burford this material consists of kame gravels and flaggy proximal-facies outwash adjacent to the moraine and grades westward into better sorted, cleaner, distal-facies outwash that includes some deltaic material. The greatest thicknesses probably occur nearest the moraine where variability and inclusions of less desirable material are more likely to occur. This area is believed to warrant prospecting for future reserves although much of the material would require considerable processing.

Deltaic gravels and gravelly sands located between Burford and Northfield Centre contain large reserves. Generally these gravels are medium to fine and become finer southwards where the thickness of fine sand and silt overburden also increases. The water table is generally within 15 feet of the surface in this area. Deleterious material in the pebble grade is not important.

Numerous smaller deposits of gravel and sand are of local importance. Outwash deposits located along the Galt Moraine between West Brantford and Oakland are generally discontinuous and on the east side of the moraine may have interbedded Wentworth Till (see Photo 1). Similarily the gravel found at the head of the Dundas Valley is locally important but this deposit is closely associated with the Halton Till, contains considerable siltstone and shale, and may contain masses of cemented material.

Kame gravels are limited in distribution and are not of great significance. The kame area at Mount Vernon is presently being worked whereas that area southeast of Falkland has not yet been exploited; this latter deposit is in part overlain by a veneer of clay and clay till. Minor amounts of kame gravel occur locally in the Wentworth Till but are too small to map as separate units.

Older alluvium in terrace remnants and Recent alluvium have been worked in the southern and southwestern parts of Brantford City. Other small deposits along Horner Creek and the Nith River contain small amounts of gravel and sand suitable for local usage.

Beach gravels of importance occur only in the deposits near St. George. This gravel bar has been worked sporadically for several years. Lesser amounts of gravel occur adjacent to mapped abandoned shorelines but usually these form only a thin veneer over till.

Buried deposits located within the Paris and Galt Moraines would probably require considerable exploration and removal of overburden before proving to be of economic worth.

In summary, the townships of South Dumfries, Brantford, and Burford contain large gravel reserves, many of which are not presently feasible to develop because of market or transportation requirements, or present land use. Because of the future importance of these reserves considerable care in mineral resource planning must be exercised. Those parts of Ancaster, Onondaga, Tuscarora, and Oneida Townships lying within the Brantford map-area are virtually without gravel deposits of major economic importance.

PROPERTY DESCRIPTIONS

A large number of pits were visited, mainly during the 1968 field season. A number of these are described below although not all. Of these only three operators (Consolidated Sand & Gravel Limited, Flintkote Company of Canada Limited, and Telephone City Gravel Company Limited) maintain full time commercial operations.

D. Albin (1)[1]

Small amounts of gravel have been excavated from a small pit on lot 2, concession II, Brantford Township. Reserves are probably large.

The deposit consists of outwash gravel. One 12-foot face consisted of gravelly sand and fine gravel containing up to 40 percent stone. Most of the pebbles are in the ¼- to 1¼-inch size range with only about 15 percent exceeding 1 inch in diameter and 5 percent exceeding 4 inches; boulders up to 12 inches in diameter occur.

A sieve analysis of a sand sample from this deposit is found in Appendix C (Sample 26) and mineralogical properties of the sand and pebble lithologies are given in Appendices D and E.

Blenheim Township (3)

A shallow glaciofluvial terrace deposit, on lot 2, concession II, Blenheim Township, has been worked to a depth of about 10 feet. The material was entirely slumped over at the time of the visit but it appears to consist of medium gravel and gravelly sand containing boulders up to 5 feet in diameter. A pebble count from this pit is found in Appendix E (Sample 30).

No operations were in progress at the time of the visit.

Brant County Roads Department (4)

This pit is located on lot 4, concession IV, Brantford Township, Brant County, ¼ mile east of Mount Vernon. Slump features, lack of sorting, and enclosed masses of nonstratified material suggest that this deposit is ice-contact in origin, most probably a kame. Reserves are unknown but the deposit extends southwards.

An 18-foot face consists of poorly sorted, weakly stratified gravels. Fine sand is mixed throughout the gravel; generally the coarse- and medium-sand fractions appear to be missing. Minor silt and clay occur but gravel comprises 95 percent of the material. Forty percent of the gravel exceeds 1 inch in dia-

[1] Number in brackets refers to property number on Map 2241, back pocket.

meter and ten percent exceeds 4 inches; the maximum size is 7 inches. A pebble count from this face is given in Appendix E (Sample 38).

A second 25-foot south face has 10 feet of horizontally stratified medium gravel as an upper unit; the remainder of the face is obscured by slumped materials. There is considerable cementation in this part of the pit, which impedes operations. Composition of this face is 95 percent gravel, of which 10 percent exceeds 4 inches in diameter and 40 percent exceeds 1 inch. Cobbles are sub-rounded to rounded and have a maximum size of 10 inches.

No operations were in progress at the time the pit was visited. Products are largely pit-run gravel and crusher-run road gravel.

Brantford City (5)

A pit operated by the city of Brantford is located on lot 19, concession II, Brantford Township. It is located in the Paris-Brantford outwash complex.

An 18-foot working face consisting of poorly sorted, weakly stratified gravel contains 60 to 75 percent stone; 60 percent of this stone exceeds 1 inch in diameter, 15 percent exceeds 4 inches, and the largest boulder observed was 10 inches in diameter.

A second 12-foot face consisted of medium to coarse gravel overlying south-dipping stratified sand. This face was estimated to contain 50 percent stone.

Sample 25 in Appendices C, D, and E provides information on sand sizes, sand mineralogy, and pebble lithology from this pit.

The principal products of this pit are pit-run sand and gravel, bedding stone, and winter-road sand. Screening equipment is rented as required.

Brantford Township, No. 1 Pit (7)

Several gravel pits are being operated sporadically by Brantford Township; only two are given property numbers on Map 2241, (back pocket) and described in the report, the designations No. 1 pit and No. 2 pit are used for convenience only in this report, Brantford Township does not use this differentiation for their pits. The first of these is located on lot 11, concession III, Brantford Township, Brant County. The deposit is thought to be glaciofluvial outwash in origin.

The 6-foot upper part of a 12-foot face consists of horizontally stratified sand and gravel; layers of medium to coarse sand, 4 to 6 inches thick, are interspersed with poorly sorted gravel layers. These gravel layers are 95 percent gravel of which 25 percent exceeds 1 inch in diameter and the maximum size is 4 inches. The lower 6 feet consist of poorly sorted fine gravels; crossbedding in this gravel dips toward the northeast but other factors suggest that this is the result of slumping. Ninety-five percent of this lower 6 feet is gravel of which twenty percent exceeds 1 inch in diameter and the maximum size is 3 inches.

The distribution of sand and gravel in this deposit is highly variable and excavation to depth appears to be limited as the pit is underlain by sand.

Sample 21 in Appendices C, D, and E illustrates some properties of the sand and pebble lithology of this pit.

No operations were in progress at the time the pit was visited.

Brantford Township, No. 2 Pit (8)

A second pit is located on lot 7, II Range, west of Mount Pleasant Road, Brantford Township. The gravel is glaciofluvial outwash or deltaic in origin and this is overlain by 8 to 12 feet of sand overburden. Reserves appear to be extensive but the overburden is considerable.

An 18-foot face on the eastern side of the pit is made up of three units. The upper 6 to 8 feet consist of poorly sorted gravels with weakly developed south-dipping cross-strata. Seventy percent of this material is gravel and thirty percent is sand. Twenty percent of this material exceeds 1 inch in diameter and the maximum size is 4 inches. This is underlain by 3 feet of crossbedded fine gravels that dip southerly at 20. Gravel comprises 95 percent of this material; 30 percent of the gravel exceeds 1 inch in diameter and the maximum size is 3 inches. The remainder of the face is covered by slumped materials.

The 20-foot southern face contains numerous scour and fill structures. Cementation is present but does not impede excavation.

The estimated composition of the gravels and gravelly sands in this face is 65 percent gravel, 30 percent sand, and 5 percent fines. The maximum cobble size in the face is 6 inches but erratics up to 3 feet in diameter are excavated in some places; 10 percent of the stone exceeds 4 inches in diameter and 25 percent exceeds 1 inch.

Pebbles and cobbles are sub-angular to sub-rounded or rounded. Pebble lithology from this pit is given in Sample 23, Appendix E and grain sizes and mineralogical composition of a sand sample are given in Appendices C and D.

No operations were in progress at this pit at the time of the visit.

Burford Township, Concession III, Lot 1 (9)

A small pit located here has not been operated for some time. The gravel exposed is about 12 feet thick and consists of poorly stratified, uniform, medium, well-rounded gravel of glaciofluvial origin. The material contains about 40 percent stone of which 15 percent exceeds 1 inch in diameter and the largest cobble observed was 6 inches in diameter. The deposit is large in areal extent.

Burford Township, Concession V, Lot 3 (10)

This pit is located in glaciofluvial outwash gravels located along the Horner Creek meltwater channel. The deposit has 2 to 3 feet of weathered sand and gravel overburden and the water table occurs near the base of the pit.

The west face of this pit contains 15 to 20 feet of weakly stratified, uniform, medium gravel containing about 60 percent well-rounded pebbles and cobbles. Fifty percent of this stone exceeds 1 inch in diameter and five percent exceeds 4 inches in diameter; the largest cobble noted was 8 inches in diameter. Minor cementation occurs but does not appear to affect excavation. Less than 5 percent of the material consists of silt and clay.

A pebble count from the west face is given in Appendix E, Sample 39.

On the north side of the pit the upper 6 feet consist of well-sorted fine gravel with southwest-dipping fore-set beds.

No operations were in progress at the time the pit was visited.

Consolidated Sand & Gravel Company (East Paris Pit) (11)

Division of Standard Paving Materials Limited

Grand River outwash terrace deposits are currently being worked on lot 26, concession I, South Dumfries Township, Brant County. Extensive excavations have been carried out previously on lots 27 and 28 where the plant is located. The pit area is located within the town limits of Paris, and in South Dumfries Township, east of the Grand River. Reserves in this deposit are large.

At the northern end of the pit cementation is prominent and impedes operations (see Photo 6). One 40-foot face consists of horizontally stratified gravels through which a 2-foot band of fine sand and silt courses about 10 feet above the base of the pit. Gravel comprises 95 percent of this material. Seventy percent of the gravel exceeds 1 inch in diameter and fifteen percent exceeds 4 inches; boulders have a maximum size of 14 inches. Pebbles and cobbles are rounded to well rounded.

At the southern end of the pit 20 feet of stratified gravel overlies 15 feet of crossbedded fine sand. The crossbedding dips in numerous directions but appears to have an overall southerly trend.

Sieve analysis and mineralogy of sand from this pit are given in Appendices C and D and a pebble count is given in Appendix E (Sample 17).

Pit operations are described in Hewitt and Karrow (1963, p.138) and Hewitt and Cowan (1969a, p.36).

Consolidated Sand & Gravel Company (West Paris Pit) (12)

Division of Standard Paving Materials Limited

Gravel deposits related to the Grand River meltwater system have been worked very extensively by this company, leaving a very large area of excavation. Present excavation is taking place on lot 33, concession II, South Dumfries Township, Brant County; former pits and the processing plant are located on lots 32, 33, 34, 35, concession I, South Dumfries Township. The complex is located about ½ mile west of Paris.

The thickness of gravel in the present working area is between 15 and 30 feet with about 2 feet of overburden. The gravel is underlain by a clay till and the water table occurs at the base of the pit. A 25-foot east face of the pit contains substratified, poorly sorted coarse gravel of which 60 percent is estimated to be stone. The largest boulder noted in the face was about 10 inches in diameter but boulders up to 4 feet in diameter had been excavated previously. Ten percent of the stone exceeds 4 inches in diameter whereas seventy-five percent exceeds 1 inch. Pebbles and cobbles are rounded to well rounded. Marble, siltstone, conglomerates, and rotted metamorphic rocks were noted in the cobble and boulder fractions.

The north face of the pit near the railway is 15 feet high and consists of substratified, poorly sorted, coarse gravel containing a few lenses of sand and a few thin layers of well-sorted gravel. Crossbedding was evident but did not indicate any predominant direction of current flow. The material contained 55 percent stone and up to 10 percent silt and clay with sand forming the remainder. Ten percent of the stone exceeds 4 inches in diameter whereas sixty percent exceeds 1 inch; the maximum cobble size was 6 inches.

Sample 5 in Appendices C, D, and E illustrates the grain size and mineralogy of sand from this pit and the pebble lithology. Pit and plant operations are described in Hewitt and Karrow (1963, p.137) and in Hewitt and Cowan (1969a, p.38-40).

The Flintkote Company of Canada Limited (13)

A large reserve of gravel in a Grand River outwash terrace is being worked on lots 16 to 21, concession II, Brantford Township, Brant County. The water table occurs at the base of the pit, 40 to 50 feet below the surface.

The main pit is located on lots 17 and 18.

At the lower lift a 40-foot face consists of unevenly sorted, stratified, coarse gravel. Estimated composition of the face is 50 percent gravel and 50 percent sand. Seventy percent of the gravel exceeds 1 inch in diameter and ten percent exceeds 4 inches; the maximum boulder size noted in the face was 12 inches but boulders up to 4 feet in diameter have been excavated.

Crossbedding occurs and this dips easterly where noted. In places layers of clean white sand up to 12 feet thick occur. A discontinuous 4-foot layer of gritty, silty, sand till (Wentworth) occurs about 20 feet below the surface. This till, where it occurs, impedes operations.

A 20-foot face at the upper lift consists of nonsorted sand and gravel in which stratification is only weakly developed. The material is variable with bands of sand up to 4 feet thick occurring. Generally gravel comprises 40 percent of this face and sand 60 percent. Forty percent of the gravel exceeds 1 inch in diameter and five percent exceeds 4 inches.

Sample 18 in Appendices C, D, and E illustrates grain sizes and mineralogical composition of sand from this pit as well as pebble lithology.

A second pit is located on lot 19, concession II, Brantford Township adjacent to the main pit. A 20-foot face consists of poorly sorted coarse gravel in which stratification is only weakly developed. Gravel comprises 50 percent of this material. Seventy percent of the gravel exceeds 1 inch in diameter and thirty percent exceeds 4 inches; cobbles have a maximum size of 8 inches.

A third pit in the same deposit is located on lots 16 and 17, concession I, Brantford Township.

A description of pit and plant operations for this company is found in Hewitt and Cowan (1969a, p.41).

Glass Pit (14)

This pit, operated on a demand basis, is located on lot C, Martin Bend Resurvey, Onondaga Township, Brant County.

The deposit consists of high-level alluvial sediments overlying glaciolacustrine silt and clay. The deposit is about 12 to 15 feet thick and contains about 25 percent stone of which 20 percent exceeds 1 inch in diameter and 5 percent exceeds 4 inches.

A number of other infrequently used pits are located in the same deposit.

Hi Way Construction (15)

This pit is located on lot 6, concession III, South Dumfries Township, Brant County at St. George. The deposit comprises a beach of glacial Lake Warren age. Reserves are restricted by the narrow shape of the deposit. Overburden in places consists of 2 to 6 feet of bouldery till (flow till?); although the till overlies the gravel, the two are thought to be almost contemporaneous.

One 20-foot face consists of crossbedded gravelly sand containing only 10 percent stone; 15 percent of the stone exceeds 4 inches in diameter and 30 percent exceeds 1 inch. The maximum boulder size noted was 14 inches. A second face contains 30 to 40 percent stone of which 10 percent exceeds 4 inches in diameter.

A sieve analysis of a sand sample from this pit and a mineralogical analysis of the minus 24 plus 48 mesh fraction are found in Appendices C and D (Sample 1).

No operations were in progress at the time the pit was visited.

Indian Reserve 40B (16)

This pit is located within the City of Brantford limits and is situated in an alluvial terrace deposit. The water table is near the surface.

The deposit was largely slumped over but one low face appeared to contain about 40 percent stone of which 20 percent exceeded 1 inch in diameter and only a few percent exceeded 4 inches. Clay balls up to 3 inches in diameter were observed and lenses of silt are present.

Sieve sizes of sand, mineralogy of sand, and pebble lithology from this pit are given in Appendices C, D, and E (Sample 13).

No operations were in progress at the time of the visit.

McComb Pit (18)

This pit is located on lot 17, concession II, South Dumfries Township, Brant County. Reserves are not large and this pit has not been operated for some time.

The gravel is an outwash in which crossbedding is variable but a northerly trend is distinguishable. The gravel contains up to 60 or 70 percent stone and is highly cemented.

F. McKinnon (19)

This pit, located on lot 2, concession I, Brantford Township has not been operated for several years. It is situated in an outwash deposit that extends eastwards.

A 20-foot face contains up to 75 percent stone of which 40 percent exceeds 1 inch in diameter, 10 percent exceeds 4 inches, and the largest boulder observed was 14 inches in diameter. A pebble count from this pit is given in Appendix E (Sample 31).

Cementation is prominent in this deposit.

E. Maguire and Sons (20)

This small pit located on lot 1, concession II, Oakland Township, Brant County is operated on a part-time basis.

The deposit consists of gravel and sand of ice-contact origin and forms part of the core of the Paris Moraine. The gravel is characterized by wide ranges of grain size and slump features, (see Photo 7), and lenses of Wentworth Till are present. The deposit is partly capped by this till. In parts of this pit, gravel comprises up to 70 percent of the deposit whereas elsewhere sand predominates.

Products are pit-run gravel and fill. No operations were in progress at the time of the visit.

J. A. Martin (21)

Glaciofluvial outwash gravels have been worked on the south half of lot 22, concession I, South Dumfries Township, Brant County. The deposit is not large and is poorly exposed.

Two to four feet of sand, silt, and in places, till-like material overlies 20 feet of well-sorted horizontally stratified gravel. This material is estimated to contain 50 percent gravel and 50 percent sand. Forty percent of this material exceeds 1 inch in diameter and five percent exceeds 4 inches; the maximum size is 6 inches. A pebble count from this face is given in Appendix E and a sieve analysis and the mineralogical composition of a sand sample are given in Appendices C and D (Sample 16).

Extraction of the sand and gravel is on an occasional basis.

Menary Construction Limited (22)

This pit is located on lot 22, concession IV, Brantford Township, Brant County, west of the Grand River. High-level terrace gravels laid down following withdrawal of the glacial lakes comprise this deposit. Reserves, limited by a thickness generally less than 15 feet, have considerable areal distribution.

One 20-foot face has 7 feet of stratified sand and fine gravel overlying 13 feet of poorly sorted coarse gravel in which stratification is only weakly developed. The lower unit contains 90 percent gravel and 10 percent sand. Cobbles have a maximum size of 6 inches; 10 percent of the gravel exceeds 4 inches in diameter and 60 percent exceeds 1 inch. Cementation does not impede operations.

A second 15-foot face, elsewhere in the pit, consists of poorly sorted gravels, which contain lenses of sand. Seventy percent of this material is gravel and thirty percent is sand. Fifty percent of the gravel exceeds 1 inch in diameter and ten percent exceeds 4 inches; rounded cobbles have a maximum size of 8 inches but angular boulders up to 15 inches in diameter occur.

A pebble count from this pit is given in Sample 20, Appendix E. A sieve analysis of a sand sample from this pit is given in Appendix C and mineralogical composition of the minus 24 plus 48 fraction is given in Appendix D.

Products are pit-run gravel and crusher-run road gravel.

G. I. Nichols (23)

This pit, located on lot 1, concession I, Windham Township, Norfolk County, is only operated on a sporadic basis. The deposit consists of outwash gravel; overburden is 1 to 2 feet thick.

A 10-foot face at this pit contains about 50 percent stone and 50 percent sand. The largest boulder observed was 3 feet in diameter; 25 percent of the stone exceeds 4 inches in diameter and 70 percent exceeds 1 inch. Lithology of the pebbles and cobbles consists primarily of carbonate rocks with some Precambrian material; cherty limestone derived from the Bois Blanc Formation is very deleterious.

Oakland Township, Concession I, Lots 4 and 5 (24)

A small pit is situated in a small outwash-terrace deposit consisting of well-rounded gravels and interbedded sand. The water table is at the base of the pit. One 8-foot face contained about 40 percent stone of which 90 percent exceeded 1 inch in diameter, 5 percent exceeded 4 inches, and the largest diameter was 6 inches.

Oakland Township, Concession I, Lot 5 (25)

This pit is located in a small outwash terrace and overburden consists of 2 feet of weathered sand and gravel. One 15-foot face consists of poorly stratified well-rounded gravel containing up to 50 percent stone. Seventy percent of the stone exceeds 1 inch in diameter, ten percent exceeds 4 inches, and the largest cobble noted was 6 inches in diameter. A pebble count from this pit is given in Appendix E (Sample 32).

Ontario Department of Highways (27)

This pit is located on lot 38, concession III, Ancaster Township, Wentworth County.

The deposit is of deltaic origin and consists primarily of sand containing less than 10 percent granule and fine pebble gravel. One 18-foot face consisted of 2 feet of gravelly sand overlying sand. The gravel unit contained 25 percent stone of which 20 percent exceeded 1 inch and the maximum cobble seen was 3 inches in diameter.

Red shale and siltstone fragments were prominent.

Fill is the principal product of this pit.

D. Pepper (28)

A pit owned by D. Pepper is located on lot 1, concession IV, Oakland Township, Brant County. It has not been operated for some time but is located in the extensive outwash apron fronting the Paris Moraine.

The pit has a 20- to 25-foot face consisting of stratified sand and coarse gravel in which gravel layers up to 8 feet thick are present. Gravel comprises about 70 percent of the deposit and the pebbles and cobbles are largely rounded to well rounded. Forty percent of the stone exceeds 1 inch in diameter, fifteen to twenty percent exceeds 4 inches in diameter, and the largest boulder observed was 1 foot in diameter.

Pebble lithology, a sieve analysis of sand, and mineralogical composition of the sand are found in Appendices E, C, and D (Sample 29).

Overburden is about 1 foot thick.

Polzier Pit (29)

This pit is located on lot 7, concession III, Oakland Township, Brant County, 1½ miles north of Oakland. The nature of the gravels suggest that they are outwash deposits related to the Galt Moraine. Two periods of deposition appear to be separated by a layer of glacial till (see Photo 1).

An 18-foot face on the northeastern side of the pit has an upper unit consisting of 1 foot of weathered gravel topsoil over 6 feet of poorly sorted coarse gravel, which has only weakly developed stratification. Composition of this gravel is 90 percent stone and 10 percent sand and in places up to 10 percent of the material may be silt and clay. Fifteen percent of the gravel exceeds 4 inches in diameter and sixty percent exceeds 1 inch and the maximum cobble size is 5 inches. This gravel is underlain by 2 feet of stratified, silty fine sand containing some stones. The material is contorted to some extent and this unit is equivalent to a till layer found elsewhere in the pit. The remainder of this face is covered with slump material.

Two feet of partly cemented gravel are found at the top of the fifteen-foot northwest face. This is underlain by 2 to 4 feet of stony, silty sand till (Wentworth), which has a slight fissile parting. Stones within the till are subangular to subrounded. Six feet of poorly sorted coarse gravel underlies the till and this is separated from the lower five feet of horizontally stratified, poorly sorted, medium gravel by a six-inch layer of sand. Pebbles and cobbles in the gravel are subrounded to rounded. The composition of the gravel in this face is 90 percent stone and 10 percent sand, silt, and clay. The maximum boulder size is 12 inches; 15 percent of the gravel exceeds 4 inches in diameter and 75 percent exceeds 1 inch.

A pebble count from this pit is given in Sample 4, Appendix E. In addition sandstone and grey shale were noted in the cobble to boulder fraction.

Properties of a sand sample from this pit are given in Appendices C and D (Sample 4).

Extraction of the gravel is on a contract basis at which time crushing equipment is brought to the pit by operators buying the gravel from the owner. The till unit limits the usefulness of this pit.

W. Smith (30)

The pit operated by W. Smith is located on lot 36, concession II, Ancaster Township, Wentworth County, about 1 mile west of Ancaster, near the eastern boundary of the map-area. The deposit is located in outwash-deltaic gravels. Overburden is less than 2 feet thick.

One 20-foot face consists of poorly sorted sand and gravel in which stratification is only weakly developed. Sand comprises 80 percent of this material and gravel 20. Thirty percent of the gravel exceeds 1 inch in diameter and five percent exceeds 4 inches; the maximum cobble size is 8 inches. A second 15-foot face has 4 to 8 feet of cemented gravel overlying crossbedded sands in which the exposed crossbedding does not indicate a preferred direction of dip. Calcareous cementation may impede operations in parts of the pit.

Pebble lithology, grain sizes, and mineralogy of sand from this deposit are found in Appendices E, C, and D (Sample 2).

The lithology of the stone and sand in this deposit renders it unsuitable for uses other than pit-run and crusher-run borrow.

Excavation is by a Payloader or a tracked International loader. Portable crushing equipment is brought to the pit as required.

South Dumfries Township, No. 1 Pit (31)

Glaciofluvial terrace deposits of the Grand River are being worked on lot 3, concession III, east of Grand River, South Dumfries Township, Brant County, on the east bank of the Grand River.

The upper terrace has a 40-foot face consisting of coarse gravel, which has only weakly developed stratification. Ninety percent of this material is gravel and ten percent is sand. Boulders up to 3 feet in diameter occur in this material; 20 percent of the gravel exceeds 4 inches in diameter and 70 percent exceeds 1 inch.

A pebble count from this face is given in Appendix E and a sieve analysis and mineralogical composition of a sand sample from this pit is given in Appendices C and D (Sample 14).

No operations were in progress at the time of the visit. The principal product is crusher-run road gravel.

South Dumfries Township, No. 2 Pit (32)

A second pit operated by South Dumfries Township is located on lot 30, concession III, South Dumfries Township. The deposit is primarily of glaciofluvial origin although an upper sand unit may be in part the result of glaciolacustrine shore deposition. A bluff south of the deposit is believed to be a terrace coinciding with a Lake Warren water plane.

One 26-foot face consists of an upper 1-foot unit of dirty gravel underlain by 5 feet of well-sorted, medium sands containing some southeast-dipping crossbeds and ripple marks; this is underlain by 20 feet of medium to coarse, poorly stratified, nonsorted outwash gravel, containing 60 to 70 percent stone. An estimated 30 to 40 percent of this stone exceeds 1 inch in diameter, 5 percent exceeds 4 inches in diameter, and the maximum boulder observed was 14 inches in diameter. Sample 28 in Appendices C, D, and E provides information on sand size distribution, sand mineralogy, and pebble lithology at this pit.

Excavation has taken place to 8 or 10 feet below the present base. No operations were in progress at the time the pit was visited.

R. L. Strickler (33)

This pit is located on lot 6, concession I, Oakland Township, Brant County, ¼ mile south of Oakland. The gravels and sands are apparently related to outwash deposits on the Galt Moraine but may be in part of glaciolacustrine origin.

One 25-foot face has 4 to 6 feet of fine gravel overlying 20 feet of stratified sand and gravel. The face is composed of 85 percent sand and 15 percent gravel. Thirty percent of the gravel exceeds 1 inch in diameter and ten percent exceeds 4 inches; cobbles have a maximum size of 6 inches.

A pebble count from this face is given in Appendix E (Sample 3) and a sieve analysis and the mineralogical composition of the minus 24 plus 48 mesh fraction are given in Appendices C and D.

Excavation is by a front-end loader. Stockpiles of ¾-inch crusher-run gravel are provided by contract crushers. Haulage of the crusher-run and pit-run gravel is by truck.

Townsend Township (property 37) operates a pit in the same deposit immediately west of the Strickler operation.

Telephone City Gravel Company Limited, No. 1 Pit (34)

Two pits are being operated by this company. The first of these is located on lots 19 and 20, concession III, Brantford Township, Brant County. The large gravel reserves form part of an outwash terrace of the Grand River system. The water table occurs near the base of the pit. Stratified silt and sand comprise the overburden, which varies from 0 to 8 feet in thickness.

A 30-foot face in the lower lift on lot 19 has a 20-foot upper unit consisting of clean medium to fine sand. Crossbedding is varidirectional but the sand mass tends to dip southeasterly; minor vertical faults are present in the sand. This sand mass thins to the west and thickens to the east and it appears as though it may be a small delta. Ten feet of stratified medium gravel underlies the sand. This gravel is partly cemented. Composition of the gravel is 80 percent gravel and 20 percent sand. Cobbles have a maximum size of 6 inches; 5 percent of the gravel exceeds 4 inches in diameter and 30 percent exceeds 1 inch. Pebble lithology of this gravel is given in Sample 19, Appendix E and a sieve analysis and mineralogical composition of the above-mentioned sand mass is given in Appendices C and D.

The upper lift in this part of the pit area consists of 20 feet of poorly sorted coarse gravel containing 95 percent stone. Fifty percent of the gravel exceeds 1 inch in diameter, ten percent exceeds 4 inches, and the maximum boulder size is 14 inches. Pebbles and cobbles are well rounded.

East of this an area of very coarse material is encountered. A 15-foot face consists of poorly sorted coarse gravel containing up to 5 percent fines. Ninety-five percent of the material is stone. Forty percent of this exceeds 4 inches in diameter and sixty percent exceeds 1 inch; boulders in the face have a maximum size of 16 inches but boulders up to 3 feet in diameter have been excavated.

On lot 20, gravel is being excavated from a 30-foot face. Five feet of stratified sand overlies twenty-five feet of medium gravel containing 80 percent gravel and 20 percent sand. Thirty percent of the gravel exceeds 1 inch in diameter and five percent exceeds 4 inches; cobbles have a maximum size of 6 inches.

Pit and plant operations for this pit are described in Hewitt and Karrow (1963, p.139) and Hewitt and Cowan (1969a, p.43).

Telephone City Gravel Company Limited, No. 2 Pit (35)

A second pit, Telephone City No. 2, is located on lot 14, concession V, Brantford Township. The gravel is largely outwash in origin but some of the upper materials may be deltaic. Reserves are dwindling; excavation is generally to a depth of 20 feet and the gravel extends to a depth of at least 30 feet below this. The water table occurs at the base of the pit. Overburden thickens from about 2 feet on the west to 15 feet on the east side of the pit. Cementation occurs but does not impede operations.

A 20-foot west face has 2 feet of weathered sand overburden containing a few layers of fine pebbles. This is underlain by 3 feet of crossbedded sands containing minor fine gravel. The lower 15 feet consists of poorly sorted medium gravels with weakly developed horizontal stratification. Gravel comprises 95 percent of this lower unit. Sixty percent of the gravel exceeds 1 inch in diameter and ten percent exceeds 4 inches; cobbles have a maximum size of 8 inches. Pebbles and cobbles are sub-rounded to rounded and largely ovoid in shape; the larger cobbles are rounded to a lesser degree and more variable in shape.

The south face has a 15-foot basal unit consisting of poorly sorted, sub-stratified coarse gravel containing 80 percent stone and 20 percent sand. Seventy percent of the gravel exceeds 1 inch in diameter, twenty percent exceeds 4 inches, and the maximum size is 8 inches. This is overlain by 6 feet of stratified sands, gravels, and silts.

A sieve analysis of a sand sample obtained from the south end of this pit is given in Appendix C and the mineralogical composition in Appendix D (Sample 22). A pebble count from this pit is found in Appendix E.

This pit was formerly described as Daiken Sand and Gravel Limited by Karrow (Hewitt and Karrow 1963, p.140) and more recently as a Telephone City property by Hewitt and Cowan (1969a, p.43-44).

S. Tota (36)

This pit, formerly Burford Sand and Gravel, located on lot 6, concession VIII, Burford Township was described previously by Karrow (Hewitt and Karrow 1963, p.140). The deposit consists of outwash-deltaic gravels and overburden is about 1 to 3 feet thick.

The material is largely below the water table but it appears to contain 40 to 50 percent stone of which 5 percent exceeds 4 inches in diameter and

25 percent exceeds 1 inch; the largest cobble observed was 6 inches in diameter. A sieve analysis of a sand sample from this pit, the mineralogical composition of the minus 24 plus 48 mesh fraction, and a pebble count are given in Appendices C, D, and E (Sample 6).

This pit has not operated since 1963 and is presently used as an irrigation pond.

Townsend Township (37)

See description of the R. L. Stickler property, page 46.

W. Williams (38)

A small amount of gravel has been removed from this outwash deposit on lot 1, concession I, Burford Township. The deposit is poorly exposed.

The gravel is estimated to contain up to 30 percent stone of which 20 percent exceeds 1 inch in diameter and 5 percent exceeds 4 inches; the largest cobble observed was 6 inches in diameter.

Pebble lithologies, and sand sizes and mineralogy from this deposit are given in Appendices E, C, and D (Sample 27).

Clay

The large area underlain by glaciolacustrine silt and clay represents a vast reserve of materials suitable for the manufacture of heavy clay products, principally drainage tile. At present however, there is only one producer of such products within the area, Brantford Clay Products Limited (property 6), a producer of drainage tile. This operation is located on lot 86, Lefferty Tract, Brantford Township, Brant County; the geology and plant of this operation were described by Guillet (1967, p.131-132). Two clay pits have recently been abandoned by clay producers. The first of these, located on lot 41, Range III east of Mount Pleasant Road, Brantford Township, was formerly operated by Kitchener Brick Company Limited (property 17) to provide colour control additive for the production of buff coloured bricks (Guillet 1967, p.81-82). The second pit recently abandoned is located on lot 1, concession II, Beverly Township, Wentworth County (property 2). No manufacturing of materials obtained from the above pits was carried out within the map-area.

Baker (1906) and Keele (1924) reported greater activity in the clay products industry in former years when both red and white bricks were produced at Brantford and at Harrisburg.

The clay and silt deposits are widespread and considerable thicknesses are readily available. The variation in varve thicknesses result in a great variation in the ratios of clay to silt and sand so that where these factors are important considerable testing would be necessary. Included stones are rare in most areas and do not present a problem; on the other hand concretions up to 8 inches in diameter occur locally in concentrations, usually confined to certain beds within a sequence. Where the latter occur in any number the material would probably prove unsatisfactory for manufacturing purposes.

Chemical, mineralogical, and ceramic test analyses were provided by Guillet (1967) for samples obtained from the Brantford Clay Products Limited pit and from the former Kitchener Brick Company Limited pit; some of these are reproduced here (Tables 3 and 4). The high calcium content of these clays imparts a cream or buff colour to most of the finished products; from Baker's (1906) descriptions the red-burning material formerly used for producing red bricks was apparently obtained from the upper parts of the lacustrine sediments from which the calcite had been leached. Keele (1924, p.159) stated that clays exceeding 7 percent lime content are unsuitable for the production of vitrified products; this would appear to render most of the clays and silts of the Brantford area of questionable suitability for these purposes.

Members of the Tuscarora Indian Reserve produce pottery from local clays. A settling method is usually used for obtaining the clay fraction from the material and where specific properties are required, as in glazing, a commercial product is utilized.

Some of the fine-grained tills that have very low stone content might also provide a source of clay in the westernmost part of the area.

Peat

No important commercial production of peat moss is presently taking place within the map-area nor is there record of any such production in the Statistical Files of the Ontario Department of Mines and Northern Affairs. One small operation was carried out on lot 30 or 31, concession I, Ancaster Township, Wentworth County, by the Ontario Peat Moss Company (property 26) owned by a Mr. Davis (deceased). Production was small and the material was used for horticultural purposes and top-dressing of lawns in the Hamilton area.

Table 3

CHEMICAL, MINERALOGICAL, AND CERAMIC TEST ANALYSES OF A 13-FOOT CHANNEL SAMPLE OBTAINED FROM PIT ON LOT 41, RANGE III, EAST OF MOUNT PLEASANT ROAD, BRANTFORD TOWNSHIP, AFTER GUILLET (1967, p.81-82). TESTS ON MINUS 200-MESH FRACTION.

Chemical Analysis: Kitchener Brick Company Limited

Height above floor (*feet*)	(1) 0.0–13.0
	(*percent*)
SiO_2	46.72
Al_2O_3	9.62
Fe_2O_3	4.22
CaO	16.7
MgO	3.90
Na_2O	1.42
K_2O	2.73
TiO_2	0.48
CO_2	13.32
H_2O+	1.44
H_2O-	0.67
SO_3	0.25
TOTAL	101.5
Loss on ignition	16.26

Mineral Analysis: Kitchener Brick Company Limited (B = moderate; C = minor)

Height above floor (*feet*)	(1) 0.0–13.0
	(*percent*)
Non-clay minerals	
Quartz	22
Calcite	17
Dolomite	8
Soda-lime feldspar	5
Potash feldspar	1
Clay minerals	
Illite	B
Chlorite	B
Expanding minerals	C

Ceramic Tests:

SAMPLE 1:0.0′–13.0′

Water of plasticity (*percent*)	19
Lineal drying shrinkage (*percent*)	3.2
Pyrometric cone equivalent	2

	Cones 010 (1660°F)	06 (1840°F)	03 (1980°F)
Lineal firing shrinkage (%)	0	0.5 (expansion)	0.7 (expansion)
Colour	tan	light tan	cream
Hardness	soft	soft	almost hard
24-hour absorption (%)	21.0	20.4	19.0
5-hour boil absorption (%)	20.9	22.9	23.8
Specific gravity	1.68	1.65	1.64

Table 4

CHEMICAL, MINERALOGICAL, AND CERAMIC TEST ANALYSES ON MATERIAL FROM BRANTFORD CLAY PRODUCTS LIMITED PIT LOCATED ON LOT 86, LEFFERTY TRACT, BRANTFORD TOWNSHIP (AFTER GUILLET 1967, p.131). TESTS ARE ON MINUS 200-MESH MATERIAL. NOTE THAT CHEMICAL AND MINERALOGICAL DATA ARE COMPOSITE CHANNEL SAMPLES FROM 0–37 FEET IN THE PIT WHEREAS THE CERAMIC TEST IS ON A 21-FOOT CHANNEL SAMPLE FROM THE 9- TO 30-FOOT LEVEL IN PIT. ADDITIONAL TESTS ARE FOUND IN GUILLET'S REPORT.

Chemical Analyses

Sample	Composite
Height above floor (*feet*)	0.0–37.0
	(*percent*)
SiO_2	41.81
Al_2O_3	10.2
Fe_2O_3	4.05
CaO	19.6
MgO	2.90
Na_2O	1.10
K_2O	2.56
TiO_2	0.58
CO_2	14.49
H_2O+	1.96
H_2O-	0.67
SO_3	0.74
TOTAL	100.7
Loss on ignition	18.15

Mineral Analyses B = moderate; C = minor

Sample	Composite
Height above floor (*feet*)	0.0–37.0
	(*percent*)
Non-clay minerals	
Quartz	26
Calcite	28
Dolomite	5
Soda-lime feldspar	6
Potash feldspar	2
Amphibole	<1
Clay minerals	
Illite	B
Chlorite	B
Expanding minerals	C

Ceramic Tests

SAMPLE 2:9.0′–30.0′

Water of plasticity (*percent*)	21
Lineal drying shrinkage (*percent*)	4.3
Pyrometric cone equivalent	3–4

	Cones 010 (1660°F)	06 (1840°F)	03 (1980°F)
Lineal firing expansion (%)	0.5	0.3	0.3
Colour	tan	cream	light buff
Hardness	almost hard	almost hard	almost hard
24-hour absorption (%)	22.6	24.6	24.5
5-hour boil absorption (%)	23.7	26.5	27.1
Specific gravity	1.58	1.58	1.60

REMARKS: Briquettes are smooth-textured and atttractive at cone 03.

There are very few bogs within the map-area; generally these are small in extent, have only small thicknesses of organic material (3 to 5 feet), and the material is usually woody muck with few occurrences of peat composed of sphagnum moss, which provides the best quality peat (a useful summary of peat moss and the evaluation of deposits is found in Graham and Tibbetts 1961). Perhaps the best potential peat deposit within the map-area is the Copetown Bog located between Copetown and Summit station. This bog is reported by a former part-owner to contain more than 25 acres of peaty material with depths up to 20 or 25 feet. Because of its botanical interest this bog has been purchased by the Hamilton Area Conservation Authority (formerly Spencer Creek Conservation Authority) and comprises the Copetown Muskeg Preserve. The only other bog within the map-area found to have any depth of organic material is located about ¾ mile southwest of Canning. Soundings made during an attempt to construct a road across this bog indicate thicknesses up to 20 feet.

Graham and Tibbetts (1961, p.89) suggested that a bog in concessions I to VI, Oakland Township, Brant County, might be a possible prospect for peat. Examination of this area indicated that organic sediments were generally 1 or 2 feet thick and overlie glaciolacustrine fine sand and silty sand.

Many of the bogs consist of a few feet of muck and peaty material underlain by 2 or 3 feet of marl. A mixture of these materials produces a useful soil conditioner for horticultural purposes. Bogs within the map-area are most suitable for products of this nature.

Marl

Marl was formerly extracted from a deposit at Blue Lakes near Paris for the production of portland cement by the Ontario Portland Cement Company. Production was maintained between 1904 and 1917 and the company was liquidated in 1919. Gillespie (1905, p.154) provided a description of the deposit and operation and gave some test results on the marl, mixing clay, and cement (Gillespie 1905, p.182-183). Gillespie described the marl deposit as having a thickness of 35 to 50 feet; Guillet (1969, p.29-30) revisited the property and found no thicknesses remaining in excess of 7 feet although most of the area was disturbed. His report gives additional information on the properties of this marl deposit.

No additional marl deposits of significant thickness were found during the present survey; most had a thickness of 2 or 3 feet. These deposits are usually found at the base of bogs and are overlain by muck and peat.

ENGINEERING GEOLOGY

Although no specific engineering problems were studied within the scope of the present work, a few observations may be made.

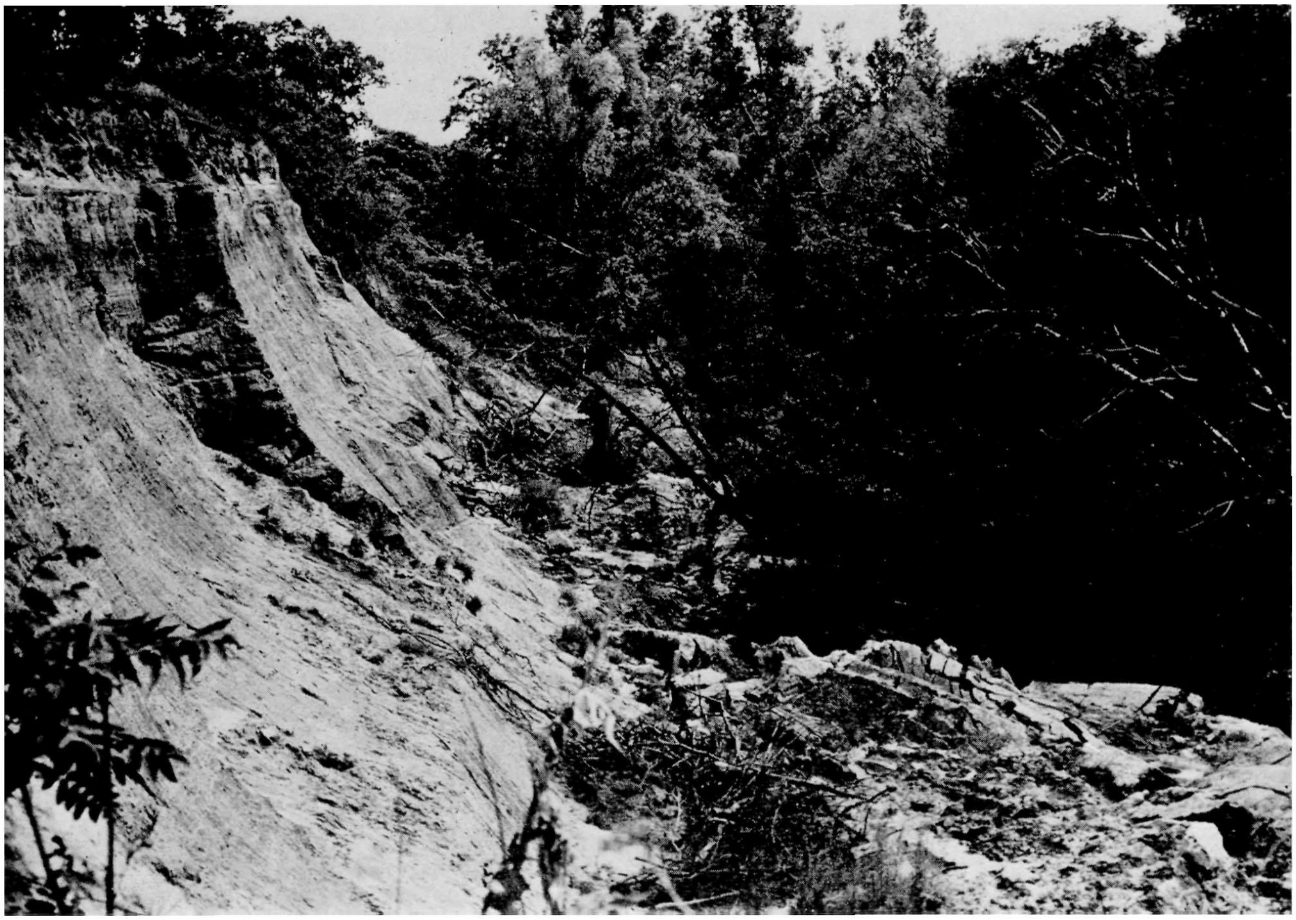
Where shaly dolomites of the Salina Formation form the bedrock surface a small thickness of rubble may be expected. For certain engineering purposes this surface layer would have to be penetrated or removed to provide sufficient bearing capacity. Rock bolting has been found necessary for underground work in the Salina Formation by the Canadian Gypsum Company.

The Catfish Creek Till is extremely stiff at depth and excavation in this material would undoubtedly incur costs beyond expectations possibly requiring blasting or ripping. A perched water table is found in many places at the surface of this till that could impede operations. This latter condition is also associated with the Wentworth Till in river sections.

The fine-grained Port Stanley and Halton Tills are susceptible to frost heaving; low cost roads on these tills prove troublesome during the spring. Phases of the sandy Wentworth Till are suitable for sand cushion whereas coarse phases are adequate for granular borrow. Bouldery phases of this material pose excavation problems for certain types of equipment.

The major engineering problems within the area are associated with the lacustrine sediments. The silts and clays are susceptible to frost heaving and where low-cost roads are built directly on these sediments they are usually impassable in the spring due to heaving and at other times due to wet conditions. A number of landslide scars in these sediments were located along the Grand River and plotted on the accompanying map; some of these are fossil features whereas others are recent (Photo 10) and recurring. Such slides have resulted in the relocation of Highway 54 at Onondaga and present a potential hazard wherever highways are adjacent to steep river banks cut into these sediments. Preliminary studies suggest that the varve series consisting of thick winter layers (Figure 9, Chart A, back pocket) may provide a glide plane for the slumping of overlying sediments.

Quicksand conditions were encountered in a few places during field studies and these conditions are reported in many water-well records.



ODM8596

Photo 10—Recent slump in glaciolacustrine varved sediments.

APPENDIX A

Descriptions of Measured Sections
(for locations see Figure 10)
All measurements in feet from surface downward

B–2	section, elevation approximately 710 feet, (located ½ mile west of Mineral Springs, not shown on Figure 10)
0–8	very pale brown silt till (sample B–2)
8–48	stratified sand, some silt, 10 percent gravel (sand sample 7)
48–50	extremely stiff, dark brown, silt till (sample B–2b).

B–39	section, elevation approximately 880 feet
0–20	coarse outwash gravel, partly cemented
20–50	bouldery sand till (sample B–39a)
50–80	silt to clay till-like material, few stones, reworked lacustrine material (sample B–39b)
80–100	slump to river.

B–42	section, elevation approximately 750 feet
0–19	stony sand till (sample B–42)
19–45	shale, shaly dolomite, thin gypsum seams.

B–45	section top indefinite, elevation 765 feet approximately
0–6	sand and gravel; top not located
6–12	yellowish brown, stony, silty sand till (sample B–45)
12–13	stone-free purple clay similar to 15–23-foot unit
13–15	stratified sand and gravel
15–23	purplish clay, few stones, thicker elsewhere
23–35	shaly dolomite with gypsum seams up to 1 foot thick; gypsum is sugary to massive with few selenite eyes.

B–46	section, elevation 790 feet approximately
0–2	dirty gravelly material
2–4	gravel, coarse lag base, crossbeds dip south-southeast
4–7	greyish brown, gritty silt-sand till
7–8	poorly sorted fine gravel
8–10	gritty silt till
10–25	slumped material, mainly gravel?
25–38	slump, section moved south
38–41	rusty weathered till-like material
41–60	sand and gravel dipping south-southwest
60–68	purple-tinged grey stony clay till (sample B–46)
68–83	slump
83–93	dolomite and shaly dolomite to river.

B–1048	section, elevation 800 feet approximately (composite section)
0–30	well-rounded medium to coarse outwash gravel, lower 10 feet bouldery, calcite and gypsum cementation
30–31	reddish brown medium to fine sand
31–33	silt and fine sand, compact
33–37	stratified to varved sand silt and clay
37–41	brown, silty sand till, springline near top (sample B–1048C) in places thicker and interstratified with gravel
41–43	poorly sorted, subangular gravel
43–74	complex of clayey-silt till (sample B–1048B) containing large blocks of stony silty sand till (sample B–1048A), much of lower 10 feet slump covered to river.

B–133	section, elevation 800 feet approximately
0–35	sand and fine gravel, largely slumped
35–43	greyish brown, dense clay till, few stones
43–53	slump to creek level.

B–175a	section, elevation 725 feet approximately
0–20	outwash gravel, cemented, base slopes eastward
20–25	hard brown stony sand-silt till
25–28	medium to fine yellowish sand
28–37	greyish brown, plastic, clayey silt till, undulating contact with lower unit, basal contamination (sample B–81)
37–40	dark grey clay, disturbed stratification, layers of reddish clay.

B–175b	section, 100 feet east of above section
0–2	sand with coarse gravel lag at base
2–3	rusty fine gravel and grit
3–4½	olive gravelly sand
4½–6	dark yellowish brown clayey silt till (sample B–79a)
6–8	yellowish medium sand, inclusions of underlying material
8–11	yellowish brown silty sand till, red shale, marble (sample B–79b)

11–30	gritty stony silt-sand till, largely slumped over (same as 20–25 unit in B–175a).
B–70	section, elevation 870 feet approximately
0–3	soil and disturbed till
3–9½	yellowish brown sandy silt till, basal contamination (sample B–70a)
9½–12	substratified silt and fine sand, ½ to 1 inch bands
12–13½	reddish brown, silty sand till, sand stringer, sandstone in many places (sample B–70b)
13½–16	yellowish brown, sandy silt till, clay inclusions possibly derived from underlying unit (sample B–70c)
16–18	clayey silt till, minor grit, few stones, sand inclusions, red shale fragments (sample B–70d).
B–84	section, elevation 890 feet approximately
0–2	yellowish brown silt till (sample B–84a)
2–3	brown silty sand till
3–5½	reddish brown silt till (sample B–84b)
5½–6	fine sand and silt, few stones
6–7	clean fine to medium sand.
B–106	section, elevation 780 feet approximately
0–10	sand and gravel, 3-inch layer of buff silt at base
10–52	slump
52–55	fine gravel
55–65	stony clay complex containing varved clay
65–80	dolomite and shaly dolomite to river level.
B–54	section, elevation approximately 790 feet
0–3	dirty, poorly stratified sand and gravel
3–8	very compact, silty sand till (sample B–54)
8–11	dark grey, clay till, very few pebbles, remnant stratification (sample B–54a)
11–16	yellowish brown, extremely stiff sand till, cobble pavement at top (sample B–54b)
16–26	greyish brown sandy silt till, unoxidized equivalent of above unit (sample B–54c); finer texture may represent a facies change
26–28	medium gravel
28–33	medium sand
33–35	very stony till, fine sand matrix, gravelly in part
35–37	gravel
37–38	brown blocky clay
38–46	dense grey clay, few pebbles
46–66	slump
66–70	dark grey clay, few stones.
B–56	section, elevation 800 feet approximately
0–25	slumped medium gravel and sand
25–31	dark greyish brown, blocky, silty clay till? remnant stratification in part
31–33	stratified yellow sand and silt, few pebbles
33–43	hard, gritty sand till (sample B–56)
43–58	slump to stream level.
B–52	section, elevation 725 feet approximately
0–12	sand and silt, few pebbles, largely slumped
12–16	hard, brown, silty sand till (sample B–52)
16–17	weakly stratified silt and clay
17–25	yellowish brown, stony, gritty sandy silt till (sample B–52A) stream level.
B–123	section, elevation 800 feet approximately
0–20	gravel
20–25	medium sand
25–26	stratified to varved silt and clay
26–30	hard, gritty, sand till.
B–124	section, elevation 735 feet approximately
0–1	dirty gravel
1–3	clay till, few stones and grits
3–4	contorted yellow silt
4–6	dark greyish brown clay till, few stones and grits
6–12	stratified to varved silt and clay, clay predominates towards top
12–13	compact, dark brown, gritty sand-silt till
13–21	thick-bedded massive dolomite
21–33	shaly dolomite.

APPENDIX B

Till analyses*; texture and carbonate analyses by the Laboratory and Research Branch of the Ontario Department of Mines and Northern Affairs.

Symbols

- Md. — median diameter
- B — Brantford Area
- S — Simcoe Area
- H — Halton Till
- W — Wentworth Till
- wse — Wentworth Till, southeastern facies
- wfg — Wentworth Till? fine-grained facies
- PS — Port Stanley Till
- abl — ablation till
- CC — Catfish Creek Till
- C — Canning Till
- lb — lower beds till unit

Notes

1 — silt-clay boundary — 0.002 mm
sand-silt boundary — 0.062 mm
2 — pebble counts on pebbles ½–2-inch diameter
3 — carbonate analysis on till, matrix passing 200 mesh sieve using Chittick apparatus.

* Absence of pebble lithology entries does not necessarily mean absence of pebbles in the samples. Locations of Till samples are shown on Map 2240, back pocket.

Sample No.	N.T.S. Grid Ref.	Till	Texture: Clay	Texture: Silt	Texture: Sand	Md.	Pebble Lithology: Limestone	Dolostone	Chert	Sandstone	Siltstone	Shale	Precambrian Crystalline Rocks	Ratio Limestone/Dolostone	Carbonates: Total	Ratio Calcite/Dolomite	Colour Fresh
B–1	809885	H	11	77	12	0.016	...	...	...	...	...	...	...	...	18.0	2.7	2.5Y 7/3
B–2	792874	H	14	64	22	0.020	...	...	...	...	...	...	...	...	16.6	4.4	10YR 7/4
B–2b	792874	H?	16	73	11	0.015	...	...	...	...	...	...	...	...	18.5	1.7	10YR 4/3
B–6	784867	H	22	69	9	0.008	...	28	...	...	45	26	1	...	...	...	2.5Y 7/3
B–7	814853	H	13	72	15	0.015	...	...	...	...	...	...	...	...	16.4	2.2	...
B–11X	700764	Wse	18	59	23	0.024	...	98	...	...	...	...	2	...	26.4	0.1	7.5YR 4/4
B–13	624663	Wfg	50	45	5	0.002	4	94	1	...	...	...	1	.04	37.6	0.4	10YR 4/3
B–14	631675	Wfg	57	39	4	0.0015	...	...	...	...	...	...	...	...	25.6	1.0	10YR 5/1
B–15	613694	Wfg	42	50	8	0.003	...	...	...	...	...	...	...	...	35.1	0.8	10YR 5/1.5
B–16a	433826	PS	35	58	7	0.004	...	...	...	...	...	...	...	...	32.4	2.4	10YR 5/4
B–16b	"	CC	16	39	45	0.041	...	...	...	...	...	...	...	...	36.2	0.7	10YR 5/2
B–16c	"	C	42	48	10	0.003	...	...	...	...	...	...	...	...	31.6	0.9	10YR 4/1
B–16d	"	lb	33	46	21	0.005	...	...	...	...	...	...	...	...	34.3	1.3	10YR 4/1
B–20	755647	Wse	16	54	30	0.016	...	100	...	...	...	...	...	...	35.3	0.1	10YR 4/4
B–21	768638	Wse	22	47	31	0.016	4	92	2	1	...	...	1	.04	46.8	0.2	...
B–22	804610	Wse	16	47	37	0.023	...	96	...	...	...	...	4	...	50.6	0.3	10YR 5/4
B–23	779612	Wse	36	47	17	0.004	...	...	...	...	...	...	...	...	...	...	10YR 4.5/3
B–24	763667	Wse	20	47	33	0.016	7	92	...	...	...	...	1	.08	45.3	0.1	10YR 5/4
B–25	680705	Wfg	57	40	3	0.0015	...	...	...	...	...	...	...	...	37.7	1.0	10YR 4/3
B–26	616718	Wfg	41	47	12	0.0029	...	...	...	...	...	...	...	...	34.3	0.8	7.5YR 4/2
B–28	795674	Wse	25	43	32	0.013	...	...	...	...	...	...	...	...	46.4	0.5	7.5YR 5/4
B–32	772614	Wse	20	51	29	0.014	...	...	...	...	...	...	...	...	52.0	0.2	10YR 4/3
B–33	622633	Wfg	41	47	12	0.0035	...	...	...	...	...	...	...	...	36.2	1.1	10YR 5/3

B-36	**728728**	**Wse**	**28**	**49**	**23**	**0.012**	**4**	**79**	**. . .**	**3**	**. . .**	**1**	**10**	**.05**	**51.4**	**0.4**	**7.5YR 5/3**
																	includes 3 gypsum pebbles
B-38	545873	W	7	54	39	0.125	3	92	. . .	1	. . .	. . .	3	.03	60.0	0.2	. . .
B-39a	523880	W	7	28	65	0.249	13	82	. . .	. . .	. . .	. . .	5	.16	36.3	0.9	. . .
B-39b	″	PS	9	71	20	0.026	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	29.5	0.9	. . .
B-42	510836	W	17	23	60	0.297	33	61	. . .	1	. . .	. . .	4	.54	36.6	0.6	. . .
B-43	519841	PS	34	62	4	0.0045	7	84	. . .	1	1	. . .	7	.08	21.4	1.3	10YR 3/2
B-45	499819	W	13	47	40	0.039	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	46.9	0.4	10YR 5/4
B-46	525803	C?	24	36	40	0.017	7	92	. . .	1	. . .	. . .	. . .	.07	43.2	0.4	10YR 4/2
B-47	535803	W	14	42	44	0.047	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	47.1	0.4	. . .
B-49	503800	W	9	31	60	0.095	12	82	. . .	2	2	. . .	2	.14	35.7	0.6	. . .
B-52A	523773	CC?	25	44	31	0.010	17	79	. . .	1	1	. . .	2	.21	44.2	0.5	10YR 5/4
B-52	″	W?	21	39	40	0.026	11	84	. . .	1	. . .	. . .	4	.13	34.5	0.8	10YR 5/3
B-53	519775	W	21	42	37	0.017	7	87	. . .	. . .	. . .	. . .	6	.08	35.4	0.5	10YR 4.5/4
B-54	516765	W	22	38	40	0.020	10	89	. . .	. . .	. . .	. . .	1	.11	32.2	0.8	10YR 4/2
B-54a	″	PS	51	46	3	0.0018	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	33.4	0.9	10YR 4/1
B-54b	″	CC	14	28	58	0.112	10	81	. . .	. . .	. . .	. . .	9	.12	46.1	0.7	10YR 5.5/4
B-54c	″	CC	21	42	37	0.027	11	79	. . .	3	. . .	. . .	7	.14	38.9	1.0	10YR 5/2
B-56	509758	CC	11	16	73	0.160	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	41.4	0.9	10YR 5.5/4
B-61	506753	CC?	10	52	38	0.030	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	39.5	0.6	10YR 5/2
B-62	506756	PS	35	38	27	0.0063	5	94	. . .	. . .	. . .	. . .	1	.05	35.4	0.8	2.5Y 5/2
B-64	500745	?	49	46	5	0.0022	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	36.8	0.9	10YR 5/2
B-65	494740	W	13	39	48	0.051	6	94	. . .	. . .	. . .	. . .	. . .	.06	37.1	1.1	10YR 5/3
B-66	486798	W	4	26	70	0.135	11	83	. . .	2	1	. . .	3	.13	36.9	1.0	10YR 5/5
B-68	601727	Wfg	35	61	4	0.0052	4	95	. . .	1	. . .	. . .	1	.04	35.4	0.6	10YR 5/1.5
B-70a	423719	PS	13	45	42	0.0079	16	68	. . .	6	. . .	. . .	10	.24	31.3	1.2	10YR 5.5/4
																	basal contamination
B-70b	″	abl	13	38	49	0.027	31	25	2	28	. . .	. . .	14	1.2	28.9	2.2	5YR 4/4
B-70c	″	CC	20	50	30	0.064	19	79	. . .	. . .	. . .	. . .	2	.24	34.4	0.9	10YR 5/5
B-70d	″	C	29	52	19	0.042	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	35.8	1.2	10YR 4.5/2
B-74	556752	W	11	34	55	0.095	5	92	1	1	. . .	. . .	1	.05	51.2	0.3	10YR 5.5/4
B-75	589680	Wfg	29	68	3	0.0059	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	34.4	2.0	10YR 4/1
B-76	613628	Wfg	43	48	9	0.0029	8	89	. . .	. . .	. . .	1	2	.09	36.1	1.5	10YR 5.5/4
B-77	568633	Wfg	34	54	12	0.005	12	58	. . .	3	. . .	1	26	.21	34.0	0.9	10YR 5/1.5
B-78	551617	W	11	55	34	0.023	11	84	2	1	. . .	. . .	2	.13	44.6	0.4	10YR 6/3
B-79a	539778	PS	35	46	19	0.0044	2	96	. . .	. . .	. . .	. . .	2	.02	37.0	0.9	10YR 4/4
B-79b	″	abl	15	39	46	0.053	17	25	. . .	31	. . .	. . .	26	.68	32.7	1.2	10YR 5/4
																	1 piece of marble
B-81	539778	C?	24	48	28	0.013	2	97	. . .	. . .	. . .	. . .	1	.02	52.1	0.4	10YR 5/2
B-82	430616	PS	30	60	10	0.0034	30	29	30	10	. . .	. . .	1	1.0	35.1	1.6	10YR 5/4
B-84a	435752	PS	24	54	22	0.011	9	85	. . .	. . .	. . .	. . .	6	.11	28.2	1.2	10YR 5/4
B-84b	″	abl	29	49	22	0.0095	11	69	3	11	. . .	. . .	5	.16	. . .	. . .	2.5YR 4/4
B-85	443796	PS	12	46	42	0.039	37	48	1	6	. . .	1	9	.76	25.4	1.3	10YR 4.5/3
B-100	432858	PS	25	66	9	0.0063	26	71	. . .	. . .	. . .	. . .	3	.35	30.4	2.6	10YR 6/4
B-109	535684	W	11	34	55	0.085	. . .	97	. . .	1	. . .	. . .	2	. . .	30.9	0.02?	10YR 4/4
B-222	464858	PS	16	56	28	0.017	19	71	3	4	. . .	. . .	3	.27	33.2	1.1	10YR 5.5/4
B-256	431833	CC	11	43	46	0.048	22	76	. . .	. . .	. . .	. . .	2	.29	30.4	1.1	10YR 4.5/4
B-263	504646	W	6	54	40	0.039	20	74	. . .	. . .	1	. . .	4	.27	39.6	0.6	10YR 5/4

Appendix B—*continued*

Sample No.	N.T.S. Grid Ref.	Till	Texture Clay	Texture Silt	Texture Sand	Md.	Pebble Lithology Limestone	Pebble Lithology Dolostone	Pebble Lithology Chert	Pebble Lithology Sandstone	Pebble Lithology Siltstone	Pebble Lithology Shale	Pebble Lithology Precambrian Crystalline Rocks	Ratio Limestone/Dolostone	Carbonates Total	Carbonates Ratio Calcite/Dolomite	Colour Fresh
B-264	481641	W	14	48	38	0.028	14	84	...	...	...	...	2	.17	41.8	1.0	10YR 5.5/4
B-265	562615	W?	17	25	58	0.103	...	...	...	...	...	...	...	...	...	...	10YR 4/3
B-266	542643	W	9	28	63	0.149	2	89	...	1	...	...	7	.02	35.1	0.7	10YR 5.5/4
B-271	429819	PS	31	63	6	0.0051	14	76	...	...	3	7	...	.18	31.8	2.4	10YR 4/3
B-309	450859	PS	22	67	11	0.0074	22	71	2	2	...	...	3	.31	32.6	1.8	10YR 5/3.5
B-310	485868	W?	14	41	45	0.048	...	...	...	...	...	...	...	...	25.4	0.9	10YR 5/3
B-313	559660	W	24	48	28	0.010	2	93	...	3	...	2	...	.021	35.2	0.3	10YR 5/3.5
B-626	507626	W	14	65	21	0.019	...	...	...	...	...	...	...	...	42.0	0.6	10YR 5.5/3
B-632	505617	W	6	25	69	0.180	20	60	8	10	...	1	1	.33	37.5	0.5	10YR 5/3.5
B-692	493616	W	5	27	68	0.190	16	42	25	15	...	...	2	.38	35.2	0.7	10YR 5/4
B-1004	497827	PS	39	52	9	0.0039	7	91	...	...	...	...	2	.08	19.9	1.6	10YR 5/4
B-1023	452791	PS	31	63	6	0.0035	14	64	4	6	1	1	10	.22	29.0	5.4	10YR 4/3
B-1037	443796	PS	11	50	39	0.031	38	58	...	...	...	...	4	.65	34.0	1.4	10YR 5/4
B-1048C	513814	W	9	40	51	0.065	20	70	4	1	...	...	5	.29	36.2	0.9	10YR 4.5/3.5
B-1048B	"	PS	38	55	7	0.0038	39	49	6	...	...	...	5	.80	32.8	2.1	10YR 4/1
B-1048A	"	CC	17	35	48	0.052	66	30	...	...	...	...	4	2.2	38.5	0.8	10YR 3.5/1
B-1544	417691	PS	24	58	18	0.010	22	68	...	2	...	4	4	.32	36.5	1.0	10YR 3/4
B-1570	421713	PS	23	64	13	0.011	5	84	3	1	...	...	7	.03	34.2	0.9	10YR 4/3
B-1684	423656	PS	36	56	8	0.0056	...	...	...	...	...	...	...	...	23.3	1.1	10YR 4/3
B-1685	419627	PS	38	56	6	0.0045	...	...	...	...	...	...	...	...	27.2	1.1	10YR 3/3
S-1	507591	W	14	41	45	0.046	51	14	31	3	...	...	1	3.6	39.6	1.2	10YR 5/4
S-2	504563	W	13	35	52	0.07	88	8	1	1	...	...	2	11.0	43.4	0.8	10YR 6/4
S-3	487531	W	11	37	52	0.071	69	17	7	...	...	...	7	4.1	46.2	1.0	10YR 5/4

APPENDIX C

Sieve analyses of sand samples located on Map 2241 (back pocket). Analyses by Laboratory and Research Branch, Ontario Department of Mines and Northern Affairs.

Sample Number	Lot	Conc.	Township	N.T.S. Grid Reference	Operator Where Applicable	Origin of Material	Weight Percent								
							+4	−4 +8	−8 +14	−14 +28	−28 +48	−48 +100	−100 +200	−200	Fineness modulus
1	6	III	S. Dumfries	608886	Hi Way Construction	Beach	1.1	1.3	8.2	33.7	34.6	15.2	2.7	3.2	2.31
2	36	II	Ancaster	798850	W. Smith	Outwash	9.1	33.1	36.6	13.1	3.0	0.9	0.6	3.6	4.13
3	6	I	Oakland	544634	R.L. Strickler	Outwash-beach	2.4	4.3	2.7	4.3	17.6	49.9	14.1	4.7	1.45
4	7	III	Oakland	540664	Polzier (owner)	Outwash	4.2	13.9	14.5	12.1	10.6	13.7	11.3	19.7	2.24
5	33-34	II	S. Dumfries	479834	Consolidated Sand and Gravel Paris West	Outwash	8.1	9.7	11.4	18.1	32.3	16.0	2.4	2.0	2.79
6	6	VIII	Burford	455695	formerly Burford Sand and Gravel	Outwash-deltaic	1.0	1.1	3.3	17.3	44.5	24.5	4.0	4.3	1.86
7	36	I	Ancaster	792875		Outwash	0.9	3.4	15.4	34.0	27.7	12.1	2.0	4.5	2.54
8	31	III	Ancaster	774851	Roadcut	Glaciolacustrine	...	0.1	0.6	1.7	9.2	78.6	7.4	2.4	1.05
9	Park Road		Brantford City	618777	Former sand pit	Glaciolacustrine–deltaic?	...	...	...	0.2	8.4	76.3	13.6	1.6	0.93
10	17	I	Oakland	613644	Roadcut	Glaciolacustrine	...	...	...	0.5	9.4	51.5	25.9	12.7	0.72
11	6	III	Tuscarora	758642	K. Monture farm		0.6	4.5	8.5	28.4	41.7	11.7	1.6	3.0	2.40
12	17	Oxbow Tract	Brantford	642748		Outwash or alluvium	3.4	10.2	16.1	30.3	32.0	6.7	0.3	1.0	2.97
13	IR40B		City of Brantford	617757		Old alluvium	1.5	4.4	6.4	16.8	50.3	18.6	0.8	1.2	2.26
14	3	III EGR	S. Dumfries	530877	S. Dumfries Township P.4	Outwash	...	5.4	12.0	42.6	35.1	0.7	2.0	2.2	2.74
15	70	River Range	Onondaga	767712	B. McBlane farm	Alluvium	...	1.0	3.6	29.6	56.7	7.4	0.3	1.4	2.29
16	22	I	S. Dumfries	543828	J. Martin	Outwash or beach	4.0	9.4	17.0	31.1	29.1	6.6	0.9	1.9	2.97
17	26	I	S. Dumfries	517834	Consolidated Sand and Gravel	Outwash	4.7	10.5	13.8	21.8	33.7	12.6	1.0	1.9	2.81
18	18	II	Brantford	534802	Flintkote Co.	Outwash	0.7	2.0	5.4	27.4	55.1	8.2	0.6	0.6	2.36

Appendix C—*continued*

Sample Number	Lot	Conc.	Township	N.T.S. Grid Reference	Operator Where Applicable	Origin of Material	Weight Percent +4	−4 +8	−8 +14	−14 +28	−28 +48	−48 +100	−100 +200	−200	Fineness modulus
19	19	III	Brantford	542783	Telephone City # 1.	Outwash–deltaic	. . .	0.2	0.4	3.3	55.9	36.8	2.5	0.9	1.61
20	22	IV	Brantford	562766	Menary Construction	Outwash-alluvium	. . .	1.2	1.7	14.1	56.3	25.7	0.1	0.9	1.93
21	11	III	Brantford	511775	Brantford Twp.	Outwash	. . .	0.4	1.2	5.6	13.4	53.3	18.7	7.4	0.94
22	14	V	Brantford	533743	Telephone City # 2.	Outwash–deltaic	. . .	0.5	4.8	44.7	48.8	1.1	0.05	0.05	2.54
23	7	II Range W. of Mt. Pleasant Road	Brantford	541711	Brantford Twp.	Outwash	.09	3.3	8.9	24.8	41.0	17.3	2.6	1.2	2.28
24	Hillcrest Street		Brantford City	584752		Glaciolacustrine	0.3	0.5	2.4	32.1	58.0	5.4	0.3	1.0	2.32
25	19	II	Brantford	540789	Brantford City	Outwash	3.9	. . .	6.2	34.3	43.2	10.8	0.9	0.7	2.48
26	2	II	Brantford	473780	D. Albin (owner)	Outwash–deltaic	17.2	29.1	24.1	22.8	5.0	0.7	0.2	0.9	4.24
27	1	I	Burford	459799	W. Williams	Outwash	0.9	1.6	3.4	17.1	48.5	26.8	1.0	0.7	2.02
28	30	III	S. Dumfries	493854	Township of S. Dumfries	Outwash	3.2	4.9	8.0	15.1	36.1	27.5	3.2	2.0	2.21
29	1	IV	Oakland	500672	D. Pepper (owner)	Outwash	1.2	1.1	1.0	3.8	27.4	50.6	11.6	3.3	1.34

Note: Fineness modulus for Masonry Mortar (A.S.T.M. Designation: C 144-66T)

APPENDIX D

Mineralogical composition, in percent, of minus 24 to plus 48 mesh fraction of sand samples, from the Brantford area, located on Map 2241 (back pocket). Analyses by Laboratory and Research Branch, Ontario Department of Mines and Northern Affairs.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Components																													
Quartz	22	29	37	29	34.5	34	20	19	35	46	21	35	36	28.5	36	26.5	33	34.5	34.5	33	36	26.5	29.5	29	31	21.5	30.5	30	28
Feldspar	6	5	9	8.5	16	10	7.5	8	13	12.5	8	16	16.5	9.5	15.5	11.5	6.5	15.5	12.5	12	12	12.5	15	9	13.5	8.5	14.5	11	11.5
Paleozoic limestone	58.5	34	36	43.5	37	43	23.5	18.5	33	29	32	33	30	49.5	19.5	37	32.5	42.5	42	39	36.5	46	39.5	36	39.5	41.5	39	35.5	44.5
Grey shale and siltstone	6	22.5	10.5	9	7	9	40	27.5	13.5	11	35	13.5	13	8.5	26.5	20	22.5	5	5.5	15	7	13.5	11	16	9	19	12	14	11
Red shale and siltstone	...	5	...	...	...	...	7	24.5	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Black shale and siltstone	...	...	4	1	1	2.5	1	1.5	1	0.5	...	1	2	2	...	1.5	2	2	3	0.5	4	0.5	0.5	2.5	2	0.5	1	4.5	2
Garnet	0.5	1	0.5	...	...	...	...	...	0.5	...	...	...	...	...	...	1	...	...	0.5	...	0.5	...	1.5	0.5	1.5	1	...	0.5	...
Hornblende	...	1.5	1	1	...	0.5	...	...	0.5	...	...	1	0.5	1.5	...	...	1.5	...	2	...	0.5	0.5	2	1	2.5	1	1.5	2.5	1.5
Mica	...	...	...	1.5	1	...	...	...	...	...	...	0.5	...	...	...	0.5	0.5	...	...	...	0.5	...	...	...	...	0.5	...	1	...
Pyroxene	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Limonite/hematite	...	...	...	0.5	0.5	...	...	...	...	0.5	2	...	...	...	...	1	1.5	...	...	...	1	0.5	...	...	...	1	0.5	0.5	...
Precambrian limestone	0.5	0.5	1.5	...	0.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.5
Magnetite	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.5	...	...	...
Sandstone	...	...	...	1	0.5	1	1	...	...	...	...	...	...	...	0.5	...	...	...	...	0.5	1	...	1	1	0.5	3.5	...	...	...
Felsic igneous rocks	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.5	...	...	...	0.5	1	...	0.5	...
Mafic igneous rocks	...	...	...	0.5	...	...	...	...	...	0.5	...	...	1	0.5	0.5	0.5	...	0.5	...	...	...	...	...	...	...	...	...	...	...
Scapolite	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Epidote	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Chert	...	...	...	...	...	...	...	...	...	...	...	...	0.5	...	0.5	...	...	...	...	...	...	...	...	...	...	0.5	...	...	...
Tourmaline	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cemented aggregates	...	...	...	0.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dolomite	4.5	1.5	0.5	4	2	...	...	1	2.5	...	2	...	0.5	...	1	0.5	...	...	...	...	0.5	...	...	5	...	...	1	...	...

APPENDIX E

Pebble counts from gravel masses shown on Map 2241 (back pocket)
Sample numbers and locations from map
Samples taken from ½- to 2-inch size range.

Percentage of Total Sample

Sample No.	2	3	4	5	6	12	13	14	16	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Rock Types																															
Dolostone	33	88	90	59	85	82	50	88	55	60	51	74	69	66	56	90	54	77	60	75	79	52	65	77	58	58	59	79	75	84	78
Limestone	45	10	6	18	12	5	24	3	22	3	34	13	16	21	22	3	19	6	15	13	11	41	14	11	10	31	21	18	17	12	15
Precambrian felsic rocks	...	...	2	5	2	6	3	1	4	5	3	2	2	4	7	*P	8	3	12	1	1	7	7	4	3	6	5	2	5	1	3
Precambrian mafic rocks	...	*P	...	5	...	5	4	...	P	P	2	1	P	4	4	...	6	P	...	5	1	...	P	...	P	...	1	...	...	1	2
Precambrian metamorphic rocks	...	P	2	11	P	...	6	3	7	2	7	8	7	5	5	7	13	7	13	5	7	...	13	7	3	4	9	1	3	2	...
Chert	...	...	...	**	1	...	3	1	4	2	...	2	2	P	P	...	...	5	...	...	...	...	...	...	25	...	1	...	...	...	...
Siltstone	13	...	...	2	**	...	...	...	3	***28	**	**	...	...	**	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Shale	9	...	...	...	...	...	4	...	3	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	P	...	...	...	...	...
Sandstone	...	...	...	...	...	1	6	3	P	...	2	**	2	...	6	...	...	3	...	1	1	...	...	1	P	P	4	...	...	...	1
Other	...	...	...	...	**quartzite	1 quartzite	...	1 gypsum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

* P indicates less than 1 percent of sample
** noted at pit but not appearing in pebble count
*** exceeds average for pit

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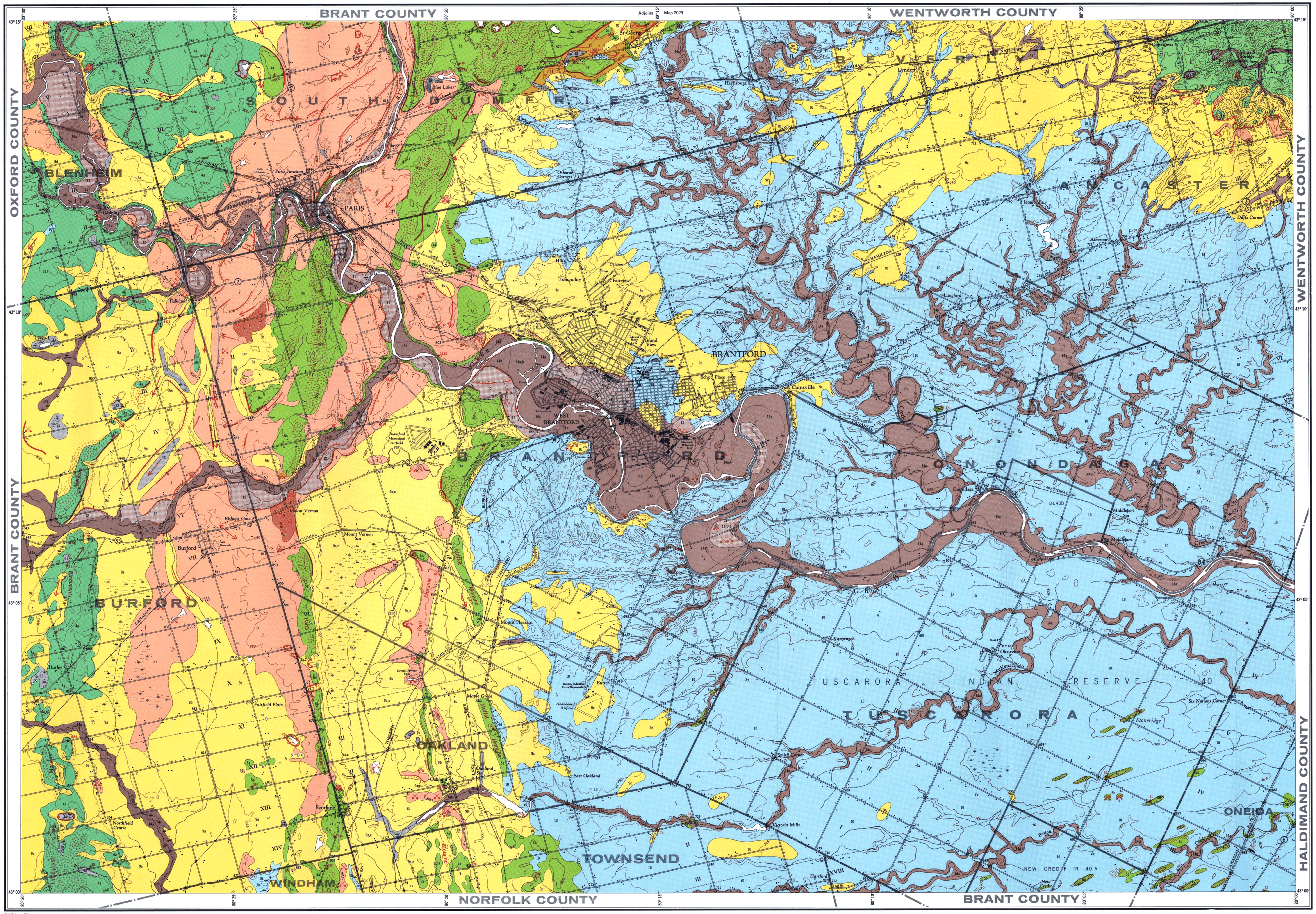
INDEX

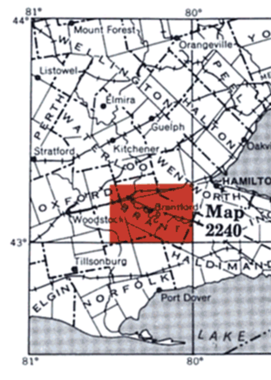
Fig. 9.

Varve diagram for section located 1 mile southeast of Brantford. Methods after Anteus (1925) and Hughes (1965). Dark layers indicate clay or silty clay winter layers whereas light layers consist of silt and fine sand.

Map 2240
Brantford Area
Pleistocene Geology

ONTARIO
DEPARTMENT OF MINES
AND NORTHERN AFFAIRS
HONOURABLE LEO BERNIER, *Minister*
D. P. Douglass, *Deputy Minister* J. E. Thomson, *Director, Geological Branch*





Scale 1 inch to 50 miles

LEGEND

CENOZOIC
PLEISTOCENE
RECENT

- 14a Modern alluvium, unsubdivided: silt, sand, gravel, clay, muck.
- 14b Modern alluvium: mainly gravel and gravelly sand.
- 13 Bog deposits: muck, peat, marl.

WISCONSINAN

- 12 Older alluvium in terrace remnants: gravel, sand.
- 11 Glaciolacustrine beach deposits, mainly Lake Warren and younger: gravel, sand, washed till.
- 10 Glaciolacustrine deep water sediments, mainly Lake Warren and younger: stratified to varved silt and clay, minor sand; locally overlain by veneer of sand.
- 9 Sand.
- 9a Glaciolacustrine shallow water and deltaic sediments, mainly Lake Whittlesey, some silt.
- 9b Glaciolacustrine sand underlain by patchy deltaic or outwash gravels.
- 9c Glaciolacustrine shallow water and deltaic sediments, mainly Lake Warren and younger, some silt.
- 9d Glaciofluvial sand.
- 8 HALTON TILL: calcareous grey to yellowish brown silt till.
- 7 Glaciofluvial outwash and deltaic deposits: gravel, and gravelly sand in many places overlain by several feet of sand.
- 6 Ice-contact deposits: mainly kame gravel.
- 5a WENTWORTH TILL: stony, silty, sand till; in many places modified on surface.
- 5b WENTWORTH TILL, southeastern facies: loam till.
- 5c WENTWORTH TILL, fine-grained facies(?): clay till.
- 5d River or stream section: may include 5, 4, 3, 2 and stratified sediments.
- 4a PORT STANLEY TILL: silt till.
- 4b River or stream section: may include 4a, 3, 2, associated stratified sediments and some material older than 2.
- 3 CATFISH CREEK TILL: stony silty, sand till.
- 2 CANNING TILL: clayey silt till.

UNCONFORMITY

PALEOZOIC
SILURIAN

- 1a Salina Formation: dolomite, shale, gypsum.
- 1b Lockport Formation: dolomite.

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

SYMBOLS

- County boundary.
- Township or Indian Reserve boundary.
- Topographic contours.
- Drumlin.
- Glacial meltwater channel with inferred direction of flow.
- Hummocky topography.
- Terrace escarpment.
- Ice-contact slope; enclosed area indicates kettle hole.
- Abandoned shoreline.
- Small landslide scar.
- Geological boundary, position interpreted.
- Bedrock outcrop.
- Gypsum mine.
- Clay pit and tile factory.
- Clay pit (abandoned).
- Sand and gravel pit.
- Till sample locality; (see report).

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

SOURCES OF INFORMATION

Geology by W. R. Cowan and assistants 1968, 1969.

Aerial photography: Forest Resources Inventory, Ontario Department of Lands and Forests; National Air Photo Library, Department of Energy, Mines and Resources, Ottawa.

Water well records of the Ontario Water Resources Commission.

Preliminary maps, P. 516 Pleistocene Geology of the Brantford Area (East half), scale 1:50,000, issued 1969 and P. 582 Pleistocene Geology of the Brantford Area (West half), scale 1:50,000, issued 1970.

Cartography by P. A. Wisbey and assistants, Ontario Department of Mines and Northern Affairs, 1971.

Topography from map 40 P/1 (East and West sheets) of the National Topographic System, with additional information by W. R. Cowan.

Magnetic declination in the area was approximately 5°40′ West in 1963.

Map 2240

Pleistocene Geology of the BRANTFORD AREA

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
DEPARTMENT OF MINES
AND NORTHERN AFFAIRS
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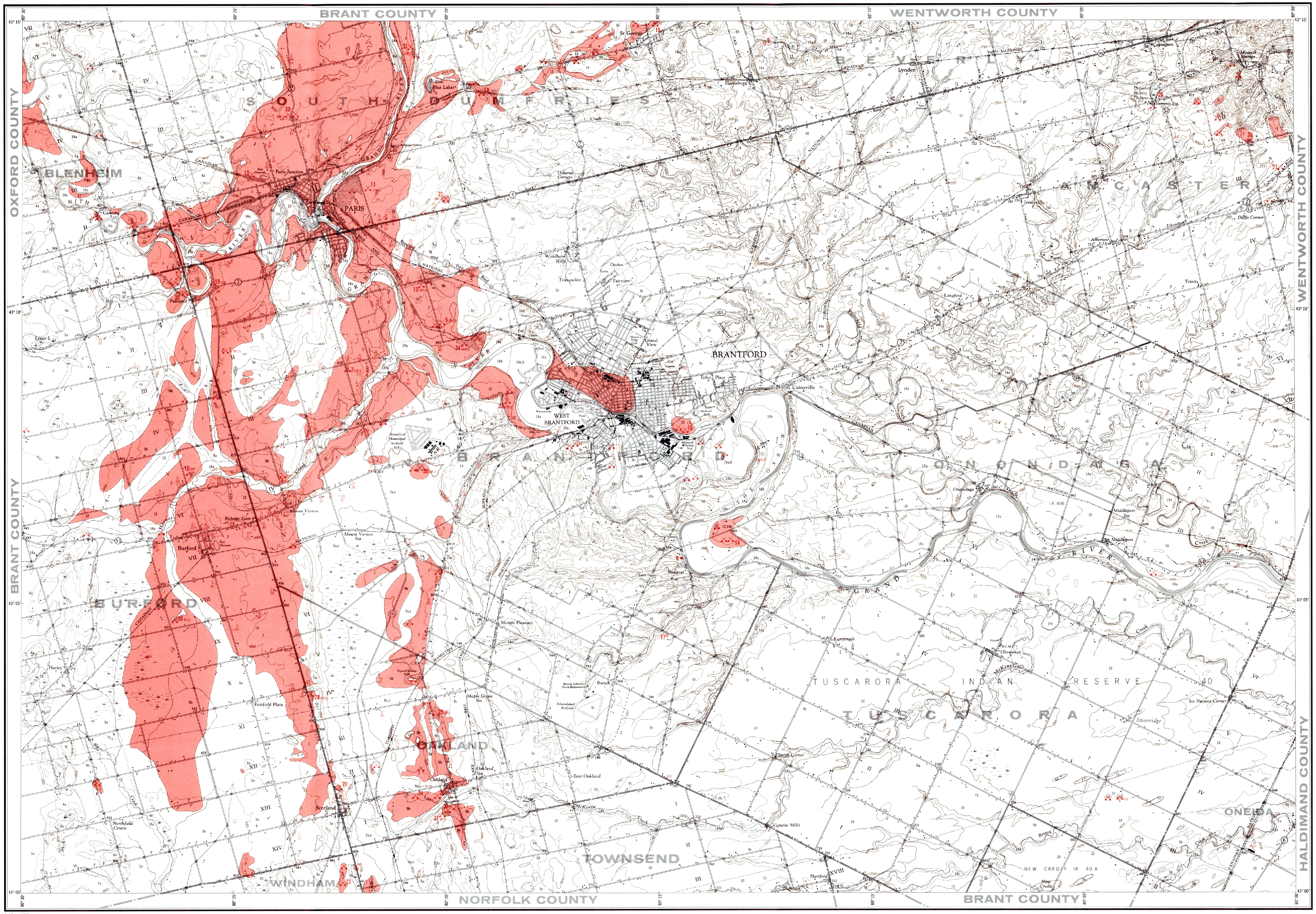

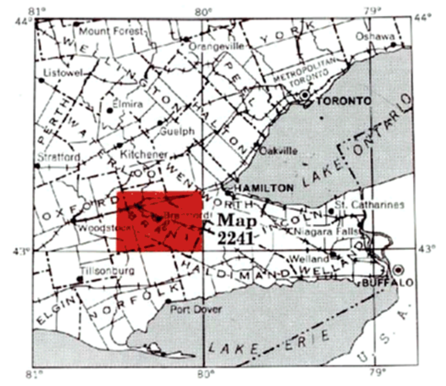

Scale 1 inch to 50 miles

SYMBOLS

- County boundary.
- Township or Indian Reserve boundary.
- Topographic contours.
- Geological boundary, position interpreted.
- Bedrock outcrop.
- Gypsum mine.
- Clay pit and tile factory.
- Clay pit (abandoned).
- Sand and gravel pit.
- 10/65 Water well location indicating thickness of overburden overlying reported thickness of buried gravel.
- 30P Location of pebble count sample; (see report).
- 7S Location of sand analyses sample; (see report).
- 32 Location of property; (see report).

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

LIST OF PROPERTIES

1. Albin, D.
2. Beverly Township, conc. II, lot 1.
3. Blenheim Township.
4. Brant County Roads Dept.
5. Brantford City.
6. Brantford Clay Products Ltd.
7. Brantford Township, No. 1 pit.
8. Brantford Township, No. 2 pit.
9. Burford Township, conc. III, lot 1.
10. Burford Township, conc. V, lot 3.
11. Consolidated Sand and Gravel (East Paris pit).
12. Consolidated Sand and Gravel (West Paris pit).
13. Flintkote Co. of Canada Ltd.
14. Glass pit.
15. Hi-Way Construction.
16. Indian Reserve 40B.
17. Kitchener Brick Co. Ltd.
18. McComb pit.
19. McKinnon, F.
20. Maguire, E., and Sons.
21. Martin, J. A.
22. Menary Construction Ltd.
23. Nichols, G. I.
24. Oakland Township, conc. I, lots 4 and 5.
25. Oakland Township, conc. I, lot 5.
26. Ontario Peat Moss Co.
27. Ontario Dept. of Highways.
28. Pepper, D.
29. Polzier pit.
30. Smith, W.
31. South Dumfries Township, No. 1 pit.
32. South Dumfries Township, No. 2 pit.
33. Strickler, R. L.
34. Telephone City Gravel Co. Ltd., No. 1 pit.
35. Telephone City Gravel Co. Ltd., No. 2 pit.
36. Tota, S.
37. Townsend Township.
38. Williams, W.

Published 1972

LEGEND

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PLEISTOCENE
RECENT

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SILURIAN

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Map 2241

Granular Deposits of the BRANTFORD AREA

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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