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# Pleistocene Geology of the
# Guelph Area
## Southern Ontario

By
P. F. KARROW

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# ABSTRACT

The Guelph area, northwest of the west end of Lake Ontario, is underlain by Silurian dolomites of the Guelph and Amabel formations. Sandy Catfish Creek Till was deposited by ice flowing southward during Tazewell time. The origin of overlying clay till of Cary age is unknown.

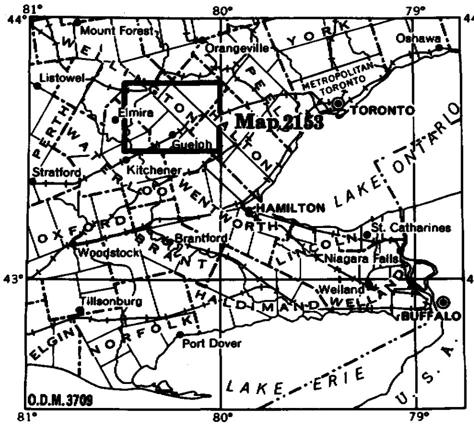


**Figure 1 — Key map showing location of the Guelph map-area.**

The youngest till, on top of the three-till sequence, is the Wentworth Till (Port Huron age), deposited by westward-moving ice of the Ontario lobe that formed the Guelph drumlin field and the Paris and Galt moraines. The edge of the Wentworth Till sheet crosses the northwest corner of the area. Clayey sand till, originating from the southeastward-moving Georgian Bay ice-lobe, is the surface till in the northwest corner of the area. Large sand and gravel deposits occur in outwash plains, kames, eskers, in extensive spillway terraces along the Grand River and in a network of spillway channels in the Guelph drumlin field.

# Pleistocene Geology of the Guelph Area

## Southern Ontario

By

**P. F. Karrow**[1]

## INTRODUCTION

**Location and access.** The Guelph area is situated in the southeastern part of the interlake peninsula of southern Ontario. It is covered by sheet 40 P/9 (Guelph) of the National Topographic Series and has an area of about 400 square miles. The area extends from latitude 43° 30′ N. to 43° 45′ N. and from longitude 80° 00′ W. to 80° 30′ W. The area includes parts of the counties of Waterloo, Wellington, and Halton.

Excellent access is available through a grid of township roads at about one-mile intervals. Several paved county roads cross parts of the area. Provincial highways, Nos. 6, 7, 24, 25, and 86 serve the area. Highway 401 passes within two miles of the south edge of the area.

Several lines of the Canadian National Railways and Canadian Pacific Railway serve the area.

**Population.** The area extends into the densely settled industrial core of the Province. The largest urban centre is Guelph, with a population[2] of 40,918; it is centrally located near the southern boundary of the area. Other, smaller, centres in the area include Acton (4,354), Fergus (4,009), and Elora (1,489), situated in the eastern and northwestern parts of the area respectively.

The suburban fringes of Kitchener and Waterloo, having a combined population of over 100,000, lie just beyond the southwestern corner of the area.

**Climate.** Climatic data (annual averages) for Guelph, obtained from the Meteorological Branch of the Canada Department of Transport, are as follows:

| PRECIPITATION ANNUAL AVERAGES | | |
|---|---|---|
| Rain | Snow | Total |
| 27.16 in. | 56.40 in. | 32.80 in. |

| TEMPERATURE ANNUAL AVERAGES | | |
|---|---|---|
| Maximum | Minimum | Mean |
| 53.3°F | 35.8°F | 44.6°F |

[1]Department of Earth Sciences, University of Waterloo, Waterloo, Ontario. Manuscript received by the Chief Geologist, Geological Branch, Ontario Department of Mines, 28 Jan. 1966.

[2]Ontario Department of Municipal Affairs 1963.

## Guelph area

**Topography.** Elevations in the area range from a maximum of 1,525 feet above sea-level, in the extreme northwest corner of the area, to a minimum of 1,000 feet along the valleys of the Grand and Speed rivers, in the southwest part of the area; this yields a total relief of a little more than 500 feet. The area can be broadly described as a rough irregular plain that slopes gently southward. Local relief is generally less than 50 feet, although it is occasionally between 100 and 200 feet, such as along the Grand and Eramosa rivers, and at the Acton re-entrant in the Niagara Escarpment.

**Drainage.** The area lies mainly within the Lake Erie drainage basin and drainage is effected by the Grand River system. A narrow strip of land a few miles wide along the eastern edge of the area drains eastward to the Credit River and thence to Lake Ontario. As in the Galt area to the south, the drainage divide trends along the belt of strong morainic topography known as the Galt moraine. As yet substantial areas of poor drainage still exist, particularly in the areas of moraine and shallow drift deposits on bedrock in the eastern part of the area.

Erie basin drainage in the area is divided between the Grand and the Speed rivers. The Speed is a major tributary of the Grand but their confluence is at Preston, several miles south of the area.

The Grand River enters the area several miles northeast of Fergus. A conservation dam (Shand Dam) constructed across the river impounds a body of water, known as Belwood Lake, that extends several miles up the valley north of the area. The river flows almost continuously on bedrock from north of Belwood Lake, to about 1½ miles southwest of Elora. A channel of varying depth has been cut into the dolomite bedrock through this stretch; it gradually deepens from the Shand Dam to the deepest part, known as Elora Gorge. The average gradient in the eight-mile stretch of the river flowing on bedrock is about 25 feet per mile. Bedrock then rapidly drops below river-level and the river gradient decreases to 7 feet per mile in the next twenty-mile stretch where meandering is present. The meanders almost double the distance the river must flow from where it leaves the Elora Gorge to where it leaves the map-area south of Bloomingdale.

The Grand varies in its stage of development at various places along its course in the area. Where it cuts through bedrock, as in the Elora Gorge, it displays the characteristics of a vigorous youthful stream; where its bed is underlain by thick Pleistocene deposits it appears to be much older because of its wide sweeping meanders. The meanders extend downstream to Preston and appear to be caused by a bedrock sill south of Preston which acts as a local base-level (Karrow 1963a).

The first major tributary to join the Grand is Irvine Creek, which drains the area north of Elora and Fergus. With an average gradient of 20 feet per mile it drops from an elevation of nearly 1,400 feet to about 1,225 feet where it joins the Grand at Elora. In the lower part of its course, Irvine Creek flows on bedrock (see Photo 1) and like the Grand, has cut a deep rock gorge that extends from Salem to the confluence with the Grand.

Several small tributaries join the Grand between Elora and Conestogo. These include Carroll Creek flowing from the west (gradient 30 feet per mile), and Swan Creek (gradient 20 feet per mile) and Cox Creek (gradient 17 feet per mile) that flow from the east. The last two streams drain part of the till plain northwest of Guelph. At Conestogo another major tributary, the Conestogo

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**Photo 1 — Thin-bedded dolomite of the Guelph Formation at the head of Irvine Creek branch of the Elora Gorge at Salem.**

River, joins the Grand from the west, but less than a mile of its course is within the map-area. Hopewell Creek originates in springs in the outwash gravel west of Marden and drops from an elevation of about 1,125 feet to 1,040 feet at the south edge of the area for an average gradient of nearly 10 feet per mile. It joins the Grand at Breslau, 1½ miles south of the area.

The Speed River drains the central part of the area. It enters the area four miles east of Belwood Lake at 1,375 feet and drops nearly 400 feet (average gradient of 17 feet per mile) to where it leaves the area south of Guelph. Intermittent rock outcrop occurs along the stream in the southern half of its course in the area. The most important tributary of the Speed River is the Eramosa River that flows from the northeast corner of the area to where it joins the Speed at Guelph. Bedrock outcrops many places along its course, which follows a large glacial meltwater channel in front of (northwest of) the Paris moraine. The Eramosa drops 165 feet in 21 miles. Blue Springs Creek, a tributary of the Eramosa, has its source in springs in morainic hills near Acton and in bedrock along its course. It has a gradient of about 20 feet per mile.

The headwaters of several streams draining to Lake Ontario rise in the poorly-drained belt of land along the eastern edge of the area. These include Bronte Creek and Oakville Creek, near Moffat, and tributaries of the Credit River near Acton.

**Previous work.** Geological studies in the Guelph area have been relatively few. Several regional studies of the bedrock (Williams 1919) (Caley 1941) (Bolton, 1957) (Sanford and Quillian 1959) (Sanford 1961) include the Guelph area. Attention to Pleistocene features has been quite recent, the most comprehensive previous to this study being that of Chapman and Putnam (1951), which classified the major physiographic divisions of the area and described such landforms as the Galt and Paris moraines, meltwater spillways, and the Guelph drumlin field. Some of these features were earlier described by Taylor (1913).

Results of detailed mapping of the Pleistocene geology of adjacent areas to the south have been published recently (Karrow 1963a). Much of the geology of the Guelph area is similar to that of the Hamilton-Galt area and will be treated only briefly here; additional information can be gained by consulting the already-published material on the Hamilton-Galt area.

Part of the area is covered by the Wellington County soil report (Hoffman, Matthews, and Wicklund, 1963).

**Field work.** Field work in this area was begun in 1961, continued in 1962, and was completed early in the field season of 1963. Field work included the checking for location of several hundred water wells in order to determine bedrock surface topography; mapping of Pleistocene deposits was accomplished by hand augering, test pitting, and the examination of river bank exposures, road cuts, building excavations, and pits and quarries.

A preliminary map, with brief notes, has already been published (Karrow 1963b).

**Acknowledgments.** Competent field assistance was provided in 1961 by R. C. Ostry (senior), D. L. Shorten, and G. D. McKenzie; in 1962 by B. C. McDonald (senior), L. L. Davies, and W. R. McClymont; in 1963 by W. R. McClymont and W. D. Morrison.

Helpful information was supplied by the Ontario Water Resources Commission, the Geological Survey of Canada, the Engineer for the City of Guelph, and the Grand River Conservation Commission, and A. A. Kingscote of Rockwood. R. E. Wicklund of the Canada Department of Agriculture, A. Dreimanis of the University of Western Ontario, and L. J. Chapman of the Ontario Research Foundation, discussed some of the problems of the area with the author.

The author is grateful for the information and access to private land provided by residents of the area.

Laboratory analyses were carried out by the Laboratory Branch, Ontario Department of Mines.

## PALEOZOIC GEOLOGY

### ORDOVICIAN

No rock of Ordovician age is exposed in the area. However, red shale or mudstone of the Queenston Formation is believed to occur in subcrop in a re entrant of the Niagara Escarpment east of Acton. An exploratory hole drilled for gas in lot 25, concession IV of Esquesing township encountered the top of the Queenston at an elevation of 1,014 feet above sea-level, but two water wells drilled nearer the centre of the valley penetrated to elevations of 980 and 952 feet without reaching rock. The elevation of the bedrock surface in the valley is unknown.

The Queenston Formation outcrops extensively east of the area and is described by Caley (1941).

### Silurian

Silurian rocks older than the Amabel Formation are also assumed to occur in the valley east of Acton, although they do not outcrop there. Outcrops may be studied in the Hamilton area to the south, or the Orangeville area to the north. Descriptions have been published by Caley (1941) and Bolton (1957).

The oldest exposed rocks are dolomites of the Amabel Formation (Albemarle Group), which is the northward equivalent of the Lockport Formation and is distinguished from it by the presence of numerous reef structures. The Amabel Formation includes white, grey, and brown dolomite. The upper part of the formation is thin-bedded and gives off an oily smell on freshly-broken surfaces; this characteristic smell is often encountered when cracking pebbles for pebble counts on till samples from west of the outcrop of these beds. The total thickness of the Amabel approaches 100 feet but decreases northward. Outcrops are numerous south of Acton and along the Eramosa River between Everton and Guelph.

Overlying the Amabel Formation, and extending under the central and western parts of the area, is the Guelph Formation that consists of buff to cream-colored crystalline dolomite. It outcrops along the Speed River north and south of Guelph, along the Grand River and Irvine Creek at Elora in high cliffs, and in numerous areas along the bottom of deeper valleys north and west of Guelph. It has a total thickness of over 100 feet but, with the Amabel, thins northward.

Extending along a narrow belt one to three miles wide along the western edge of the area is the youngest bedrock unit, the Salina Formation. This unit does not outcrop in the area but does so at Paris to the south. It has been described by Caley (1941) as an alternating series of grey shales and brown dolomites with a total thickness of about 400 feet.

No evidence of tectonic disturbance of the bedrock was observed by the writer. Where the beds are tilted, this can almost always be attributed to initial dips over reefs in the Amabel and Guelph Formations.

## ECONOMIC GEOLOGY

Both the Amabel and Guelph formations are exploited in dolomite quarries. Active quarries are located at Acton, Rockwood, and Guelph; inactive quarries are to be found at Rockwood, Guelph, Fergus, and Elora. Studies of the products of these quarries have been published by Hewitt (1960, 1964).

Drilling for oil and gas, as yet widely scattered, has yielded little success. Hope continues however, that production may be achieved from deeper formations.

## BEDROCK TOPOGRAPHY

The general form of the bedrock surface has been traced by the location of all outcrops and known drilled wells that reach rock. All told, over 700 wells, mostly drilled for water, were located in the area and provide a generally good picture of bedrock topography. Sparse distribution of wells along the western edge of the area, underlain by the Salina Formation, and in part of the moraine belt north of Acton lead to greater uncertainties in those areas.

## Guelph area

The general trend of the bedrock surface is that of a plain sloping gently to the southwest at about 12 or 15 feet per mile. The highest bedrock elevations are to be found along the north edge of the area, being about 1,325 feet; the lowest are in buried valleys along the southern edge of the area where they go below 900 feet. This broad regional slope southwestward can be related to the structure of the Paleozoic rocks that dip gently in the same direction; this in turn is related to the form of the Precambrian surface on which the Paleozoic rocks rest. It is this regional slope of the bedrock surface that in the main controls the ground surface slope of the area.

Superimposed on the regional bedrock surface slope are many rises and hollows; the most notable of these are the buried valleys. Many of the buried valleys, particularly the larger ones, appear to be abandoned segments of earlier courses of present-day streams. Thus an earlier course of the Grand River can be traced from north of the area southward between Fergus and Elora to the vicinity of Swan Creek and then is lost; where it crosses the Grand River, bedrock outcrops are missing along the walls of the present (Elora) gorge. This buried valley is narrow, steep-walled like the present Grand River gorge, and nearly 200 feet deep. Other vague bedrock channels over 50 feet deep west and east of Bloomingdale may be part of the same old valley but no connection has been found.

Another channel more than 100 feet deep enters the northwest corner of the area and joins the Grand north of West Montrose. It is the long slope on the northeast side of this valley that causes the rock surface to drop below the bed of the Grand River at Inverhaugh, and brings to an end the gorge of the Grand River.

A prominent valley, probably the ancestral Speed River, has been traced from east of Eramosa, south to the Reformatory where it jogs southwest and joins the Eramosa River at Victoria Street in Guelph. Again an interval of no bedrock outcrop in the south wall of the valley records where it trends south under the University of Guelph; farther southwest it joins the Speed River and leaves the area. Its continuation has been recorded in the Galt area to the south (Karrow 1963a); to the north it can be traced to east of Oustic. This valley is also narrow and steep-walled, with a depth of about 100 feet. Another valley that appears to originate northeast of Brisbane is probably a tributary of the preceding one, and is probably the course of an ancestral Eramosa River. It passes near the springs used by Guelph on the south bank of the Eramosa River, north and west of Arkell, and leaves the area west of Highway 6.

East of Acton, as already mentioned, there is a small re-entrant in the Niagara Escarpment. Bedrock relief exceeds 200 feet but the bottom of the partly buried valley there has not yet been reached.

Where the bedrock is exposed or near the surface, many interesting features can be seen. In the vicinity of Rockwood there are several small caves. These have been described by Logan (1863), Panton (1887), Hitchcock (1949), and Weber (1960). The author noticed that several of the caves occur along a straight line trending approximately 325° which seems to trace the trend of a major reef structure in the dolomite. Probably these caves, now separated into segments by erosion, formerly were all one underground system. Local stories of extensive caverns joining Rockwood and Eden Mills have not been verified.

The Rockwood area is even more noted for its magnificent display of potholes, also described by Panton. They have been attributed to torrential meltwaters carrying large boulders that ground out the huge holes in eddies in the stream. One of the larger ones is known as the "Devil's Well" and is on top of a pinnacle of dolomite, a most unlikely spot except under conditions of glaciation. The potholes, caves, and gorges of this district make for fascinating exploration.

Caves, even smaller than those at Rockwood, also occur along the Elora Gorge. Other solution areas in the bedrock have been indicated. Along the Nichol-Guelph Town Line and ¾ mile east of Highway 6 is a sinkhole about 25 feet deep, into which a small stream trickles. Also, several years ago a well on the Ontario Agricultural College campus in Guelph penetrated bedrock, then empty space, then shattered rock; this was thought to indicate an underground cavern.

As in the Hamilton-Galt area to the south, reef structures in the dolomite are common and where exhumed by erosion are evident as steep rock ridges trending more or less north-south. Particularly good examples may be seen east of Moffat, south of Acton near Highway 25, and near Ballinafad.

## PLEISTOCENE GEOLOGY

### DRIFT THICKNESS

Pleistocene deposits vary from zero to about 250 feet in thickness in the Guelph area. The variations are caused mainly by: erosional features of the underlying bedrock surface such as buried valleys, which are filled and concealed by drift, and which result in a thickening of Pleistocene deposits; erosional features of the surface of the drift, such as stream valleys, which cause a thinning of the Pleistocene deposits; and, depositional features such as end moraines, drumlins, and outwash plains of glacial origin, which result in a thickening of the Pleistocene deposits.

A belt of very thin drift, in which there are extensive outcrops of bedrock, extends along the eastern edge of the area from Moffat, in the south, to Acton. Smaller areas of thin drift occur near Ballinafad, in a half-mile-wide belt along the Eramosa River between Everton and Guelph, along the Speed River north of Guelph, along Cox Creek and Swan Creek south of Fergus, and along the valley of the Grand River near Elora and Fergus. In these areas lenses and pockets of drift are seldom more than 10 or 15 feet thick.

In the broad drumlinized till plain between the Paris moraine and the Grand River, drift varies from about 50 feet in thickness in the central portion between Guelph and Fergus to 75 to 150 feet in the southwest near Bloomingdale and West Montrose and in the northeast between Brisbane, Oustic, and Rockwood.

In the major moraine belt of the Paris and Galt moraines, drift varies from 50 to 125 feet in thickness.

The deepest drift occurrences are in the northwest corner of the area near Alma, where several depths near 250 feet have been recorded. Deposits in the re-entrant of the Niagara Escarpment east of Acton are deeper than 170 feet, but bedrock has not been reached.

## GEOMORPHOLOGY

### General

Most of the features of the Guelph area are merely extensions of some of the features of the Galt area to the south (see Karrow 1963a). The regional setting of the features of this area has been described by Chapman and Putnam (1951).

### Till plain

Much of the Guelph area consists of till plain, a large portion of which is drumlinized. There is no sharp boundary between drumlinized and undrumlinized till plain so that distribution of the two can only be given generally.

Till plain (without drumlins) is to be found in a belt extending around the periphery of the Guelph drumlin field to the west and north. Vague traces of ice-motion can be seen as broad flutings in the till surface in the inner portion of the belt nearer the drumlins. These have been indicated on the accompanying geological map and, like the drumlins to the east and south, indicate ice-movement to the northwest out of the Lake Ontario basin.

The outer portion of this till plain is undulating to nearly level, and gives no indication on the surface of the direction of ice-movement. It is interrupted by the terraces of the Grand River but can be found again west of the river extending for a few miles to the terminus of the till sheet that forms it.

Most of the till plain of the area is formed of sandy Wentworth Till. A few square miles of till plain in the northwest corner of the area is underlain by a somewhat different till that extends to the north and west and is derived from the Georgian Bay ice-lobe. Both till plains probably owe their level surface to underlying deposits of glacial till and outwash.

### Drumlins

Over half of the till plain of the area is drumlinized, i.e. formed into streamlined elongate hills by the movement of glacial ice. This is the heart of the Guelph drumlin field. About 200 drumlins of this field occurring in the Hamilton and Galt areas to the south have previously been described (Karrow 1963a).

Over 300 drumlins have been identified in the Guelph area, but many indistinct forms have not been included. Of these, 66 are east of or within the Paris and Galt moraines; the remainder form the main Guelph drumlin field. In some places, the drumlins crowd upon one another so closely that delineating the individual hills is difficult. Proportions vary widely but the drumlins are commonly about ¾ to 1 mile long, ⅓ mile wide, and 50 feet high. The longest drumlins are just west of the City of Guelph, where a few achieve a length of 1½ miles; the smallest are found east of the Galt moraine, having lengths of only ¼ mile.

All the drumlins of the area are composed partly or entirely of sandy Wentworth Till. A few appear to have cores of an older clay or silt till but are veneered by Wentworth Till. Being large massive hills, complete cross-sections through them are seldom exposed. Some drumlins have apparently been truncated by stream erosion but their eroded faces have long since been slumped over and covered by soil and vegetation. Excavation has proceeded well into the centre

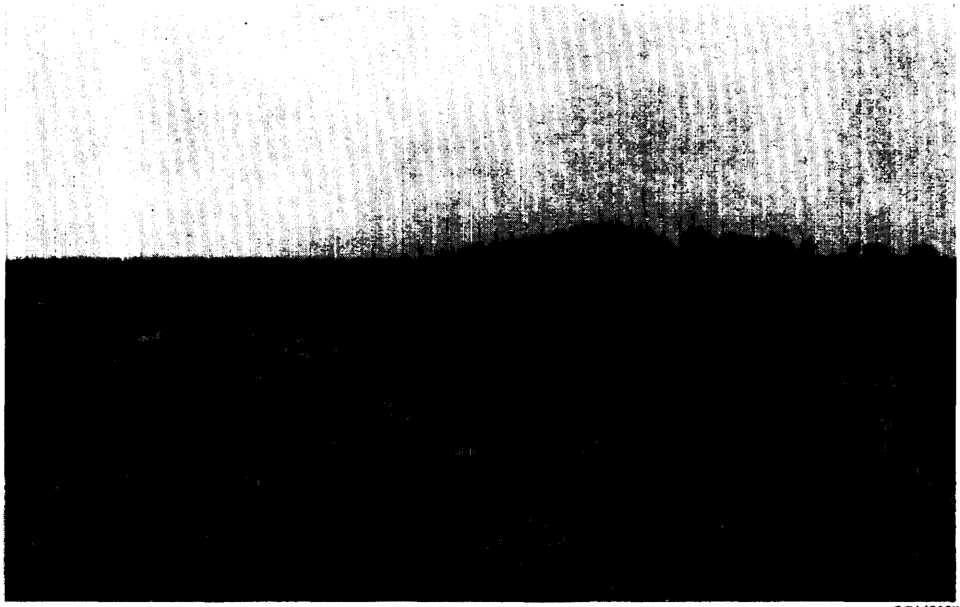

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**Photo 2 — Hummocky topography strewn with boulders; Paris moraine southeast of Arkell.**

of a drumlin in the quarry of the Canadian Gypsum Co. on the southwestern edge of the City of Guelph; although older tills of finer texture occur near the base, the bulk of the drumlin appears to be formed of Wentworth Till with a few sand lenses scattered through the mass. Other deep exposures of drumlins are to be found northeast of Guelph along Highway 24.

The long axes of drumlins indicate the direction of ice-movement. In the Guelph area, these trends vary from almost due west to N45°W, suggestive of the fanning-out of the ice-lobe from the Lake Ontario basin. Adjacent drumlins are not always parallel and a few drumlins are slightly curved. Near Guelph, faint flutings occasionally diverge from the drumlin trends by about 10 degrees. These features may indicate slight changes in direction of ice-movement during the formation of the drumlins, comparable to the formation of crossed striae under conditions of thinning ice.

### Moraines

Parts of several previously-known end moraines have been identified in the area. In addition, there are numerous areas of hummocky topography whose relationship to known moraines is unknown.

Probably the oldest end moraine is the Breslau moraine. Formed of clay till during an earlier ice-advance, it has its strongest development as a till moraine at Maryhill (New Germany) where it rises about 75 feet above the surrounding plains of sandy Wentworth Till. Its flanks and parts of its crest are mantled by the younger sandy till. The Breslau moraine is predominantly a till moraine in the Guelph map-area, in contrast to its more kamey nature in the Galt area to the south. The clay core is exposed intermittently from east of

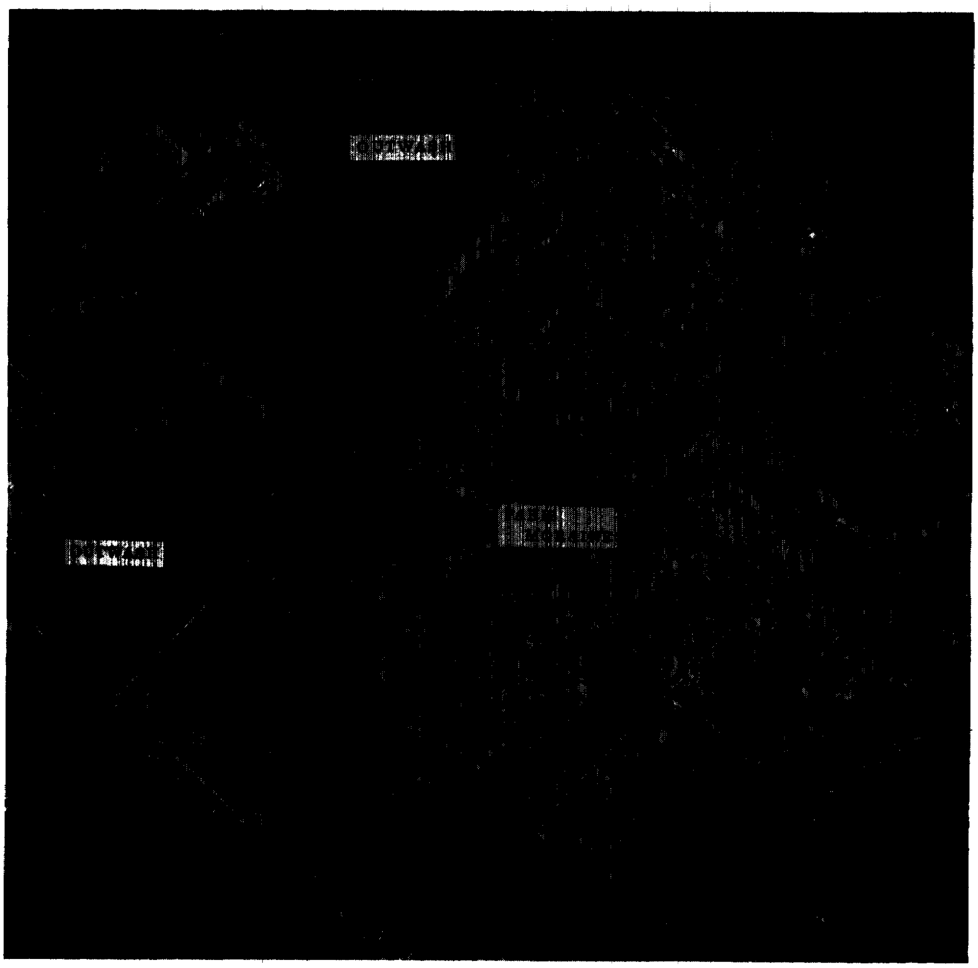

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**Photo 3 — Vertical airphoto of the Paris moraine and outwash plain, southeast of Guelph. (Courtesy Airphoto Division, Canada Department of Energy, Mines, and Resources.)**

Bloomingdale to west of Ariss, and hummocky topography is visible for another 3 miles to the north. The origin of the ice that constructed this moraine is unknown.

Intermittent tracts of morainic topography can be traced from west of Elora to east of Fergus. They are likely related to the terminus of the Wentworth Till, of which they appear to be formed. Their relationship to the Elmira moraine to the west and the Orangeville moraine to the north is not entirely clear but they seem to form a link between them. The extensive area of hummocky topography east of Fergus is thought to be a southward extension of the Orangeville moraine; the southern portion has been overridden and capped by Wentworth Till and can be traced as buried sands southeastward almost to the Paris moraine.

The best-known end moraines of the area are the Paris and Galt moraines, which together form a moraine belt 4 to 5 miles wide. These moraines enter the area southeast of Guelph and leave it northeast of Acton. The two moraines are so closely associated that they cannot be separated through much of their extent in the area. They are formed mainly of sandy Wentworth Till although kame deposits of gravel and sand are common as well. These moraines are the best examples of morainic topography in the area and contrast sharply with the smooth outwash plain in some areas, such as southeast of Guelph (see Photos 2 and 3). The Paris and Galt moraines were formed by the Ontario ice-lobe during its retreat into the Ontario basin.

Just east of and closely associated with the Galt moraine, are the Moffat moraines, a series of up to four small hummocky ridges formed of Wentworth Till. Because of their location, they must be slightly younger than the Galt moraine, but become indistinguishable from it north of Acton, where they merge into kame deposits.

As noted by Chapman and Putnam (1951) the moraines east of Guelph sometimes partly cover drumlins. This indicates clearly that the moraines were formed after the drumlins.

### Kames

Irregular hummocky accumulations of sand and gravel, called kames, were formed where meltwaters poured off the ice. These ice-contact deposits of stratified drift sometimes grade into esker ridges or, in directions away from a former ice-front position, into outwash.

Kames are abundant in the northern and eastern parts of the map-area and are generally associated with end moraines. Thus, extensive kames occur east of Fergus as a probable extension of the Orangeville moraine. Other substantial kame deposits are situated southeast of Guelph and in a belt from Rockwood to Brisbane in association with the Paris and Galt moraines. Kame gravels near and north of Acton are probably related in part to the presence of the re-entrant in the Niagara Escarpment. Similar concentrations of kames are common in most Escarpment re-entrants north and south of the area.

### Crevasse-fillings

An occurrence of crevasse-fillings, rare in this region, was discovered two miles southwest of Maryhill (New Germany). They consist of short, connected, gravelly, esker-like ridges 15 to 20 feet high having an angular pattern. They are believed to represent deposition of sand and gravel in large crevasses, or cracks, in stagnant ice.

### Eskers

Sinuous sharp-crested ridges of sand and gravel, trending in the general direction of ice-movement, are prominent features of the Guelph area. They originated as the beds of meltwater streams that flowed beneath stagnating glacial ice. As with any stream, there were areas in which erosion was dominant and deposition did not occur; thus esker ridges are intermittent, the separate links being often separated by trough-like depressions along the trace of the meltwater stream. An unusual example of this feature is to be found a mile west of Eramosa where an esker crosses a drumlin; the esker ridge extends away from the drumlin on both sides and the two parts are linked by a stream-cut notch on the crest of the drumlin. This feature has also been recorded in central

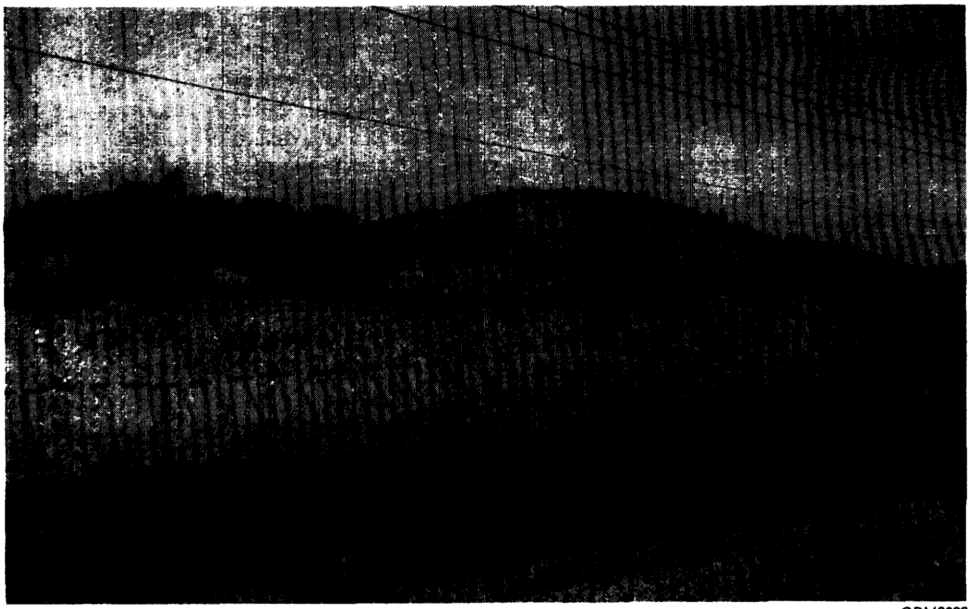

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**Photo 4 — Esker gravel over Wentworth Till; Guelph esker, west edge of Guelph.**

British Columbia (Karrow 1954) and clearly indicates that the drumlins were formed first, with the esker forming later as the ice stagnated and melted.

Three prominent eskers extend obliquely across the Guelph drumlin field from the Eramosa valley to the Grand valley. They can be referred to, from north to south, as the Eramosa, Ariss, and Guelph eskers (see Photo 4). Their length varies from 10 to 12 miles and their height from zero to nearly 50 feet. Although at their heads in the east they are spread laterally over a distance of more than six miles, they converge westward to span just over a mile. This is the reverse of the fanning-out trend of the drumlins and at first seems incongruous. However, the probable explanation is that the meltwaters were deflected westward by the slope of the subglacial land surface; that is, although the central axis of the ice-lobe was directed by ground slope westward toward Elmira, and subglacial meltwater tended to converge toward the low medial line, the ice tended to flow outward from this line, fanning out toward high land to the northwest.

Several smaller eskers may be seen two miles east of Fergus and within the Paris and Galt moraines between Rockwood and the south edge of the area. The four-mile-long esker that follows Swan Creek indicates that the valley, at least in part, dates back to the stagnation of the ice, rather than having been eroded later by meltwater.

### Outwash plains and terraces

During the melting of the glacial ice, vast quantities of sediment-laden meltwater flowed across the area. Their former presence is recorded by the extensive accumulations of sorted and stratified gravel and sand in deposits whose otherwise level surface is marked by channel scars and kettle depressions.

The major true outwash plain in the area is the one in front of the Paris moraine southeast of Guelph (Photo 3). It was apparently fed by meltwaters when the ice stood at the Paris moraine. One prominent source was a stream that cut a deep notch in the front of the Paris moraine; this meltwater valley is about 1¼ miles northeast of Arkell and was pictured by Taylor (1913, Fig. 10). The outwash plain extends southward into the Galt area as an enlarged spillway along the Speed River.

Most outwash deposits are narrowly-confined along the major river valleys such as the Grand, along underfit streams such as Cox Creek, or in depressions between drumlins. These narrow ribbon-like masses of outwash have been called spillway deposits by Chapman and Putnam and are the equivalent of what is called valley train in other regions of higher relief.

The general pattern of the spillway deposits is a series of winding concentric arcs trending southwesterly across the area, probably representing successive positions of the retreating ice-front. Modern streams occupy portions of these channels (e.g. Grand River northeast of Elora, Swan Creek, Cox Creek, Hopewell Creek, and the Eramosa River). Other portions of the old channels are now abandoned and are often occupied by swamps and bogs. Although the spillways influenced the early development of drainage in the area, they often followed paths different from the present streams. Thus meltwater drainage at one time originating east of Birge Mills crossed the present Speed River valley and followed a bedrock-floored valley to the present Cox Creek valley, probably entering the Grand River near Inverhaugh.

Outwash fans, as noted in the Galt area, occur along the Galt and Paris moraines and in all cases indicate ice-flow from the southeast because the meltwater channels suggest flow to the northwest. A notable fan at Oustic has an ice-contact face around its periphery indicating formation while ice stood to the southeast.

Because the Guelph area is near the interlobate line between the Ontario, Georgian Bay, and Huron ice-lobes, it is not easy to differentiate outwash from these various sources. It appears however, that most of the outwash features of this area were derived from the melting of the Ontario lobe. Some outwash, perhaps derived in part from the Georgian Bay lobe, or even the Lake Simcoe lobe, entered the area from the north along the Eramosa River valley. Further contributions were received along the way from the Ontario ice-lobe. For a time the retreating ice covered part of the present channel southwest of Eden Mills and meltwaters followed a parallel course two miles to the northwest in a valley now followed by Highway 7 northeast of Guelph; following retreat of the ice to the Paris moraine, the present channel was occupied.

Probably most stream terraces higher than modern flood plains date back to the wasting of the ice-sheet. When the transition from meltwater sources to rainfall sources took place, the local postglacial history of the stream valleys began; no criteria for distinguishing terraces of the two origins have been noted.

**Swamps and bogs**

There are numerous depressions in the area in which organic accumulations of peat and muck are to be found. All gradations of the sequence from open water, through marsh, to peat bog and swamp can be found.

Organic terrain occurs in poorly-drained situations; in areas of bedrock exposure south of Acton; in ice-block depressions (kettles) in the morainic areas; in abandoned meltwater channels such as the upper Eramosa valley or valleys southeast of Fergus.

## STRATIGRAPHY

### General

The nature and sequence of deposits in the area have been studied in numerous man-made and natural exposures, such as quarries, excavations, road cuts, and stream banks. Several distinctive till sheets have been identified, and by study of their vertical and horizontal distribution, some idea of their origin and time sequence has been obtained.

Stratigraphic sections, from which the sequence of superimposed deposits can be interpreted, are not abundant in the area. Generally, any particular exposure shows only part of the sequence, and it is necessary to correlate various strata from section to section to include all the significant events of the history. Interpretation of the history of the Guelph area has been greatly enhanced by earlier studies in the Galt area to the south and by current studies (1966) in the Conestogo area to the west. As is so often true, the solutions to many of the problems of the area lie beyond its borders.

FORMATIONS AND EVENTS

| STAGE | FORMATION OR EVENT | LITHOLOGY |
|---|---|---|
| Recent: | alluvium | gravel, sand, mud |
| | marsh and bog deposits | muck, peat, marl |
| Wisconsinan, Late: | outwash | gravel and sand |
| | kames | gravel and sand |
| | WENTWORTH TILL | sandy till |
| | Northern till | clayey sand till |
| | kames and outwash | gravel and sand |
| | Middle till | clay till |
| | CATFISH CREEK TILL | sandy till |

### Grand River sections

Only along the banks of the Grand River are there significant exposures of Pleistocene deposits. A few sections are exposed in the meandering stretch of the river, between Bloomingdale and Conestogo (see Photo 5). These sections are illustrated in Figure 2 and described in Appendix A to this report.

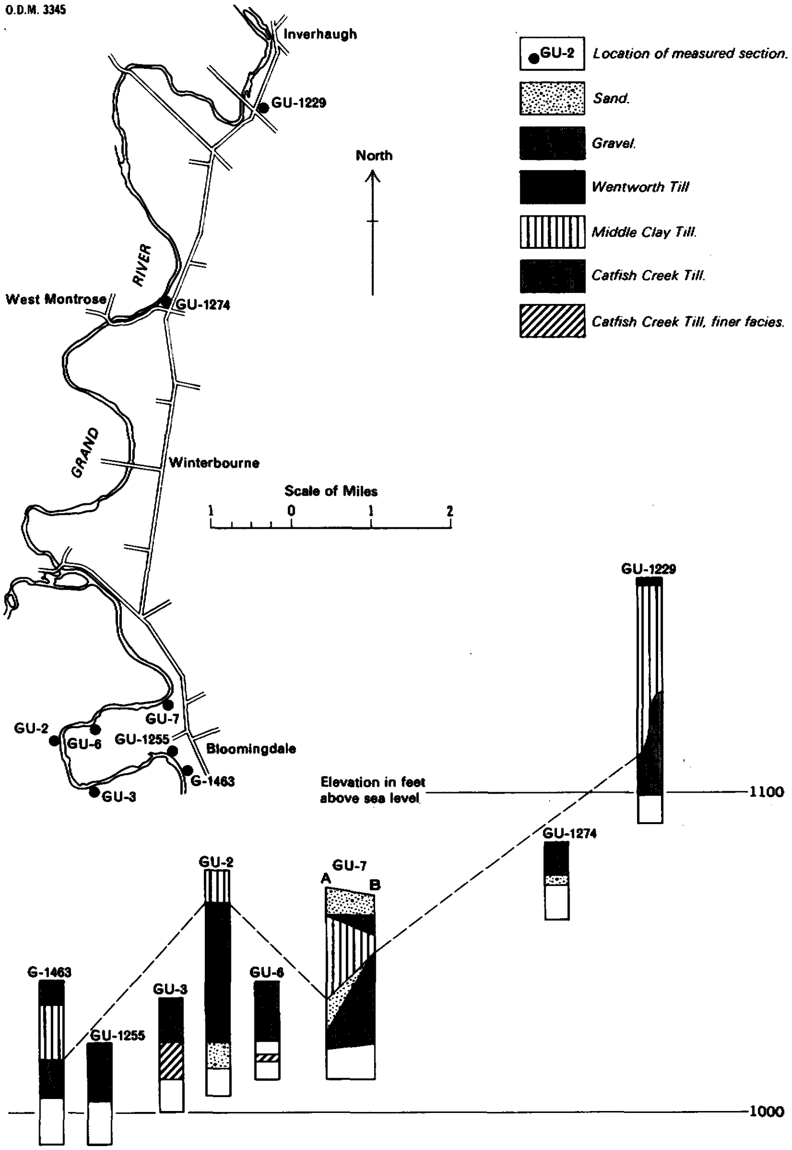


Figure 2 — Grand River stratigraphic sections.

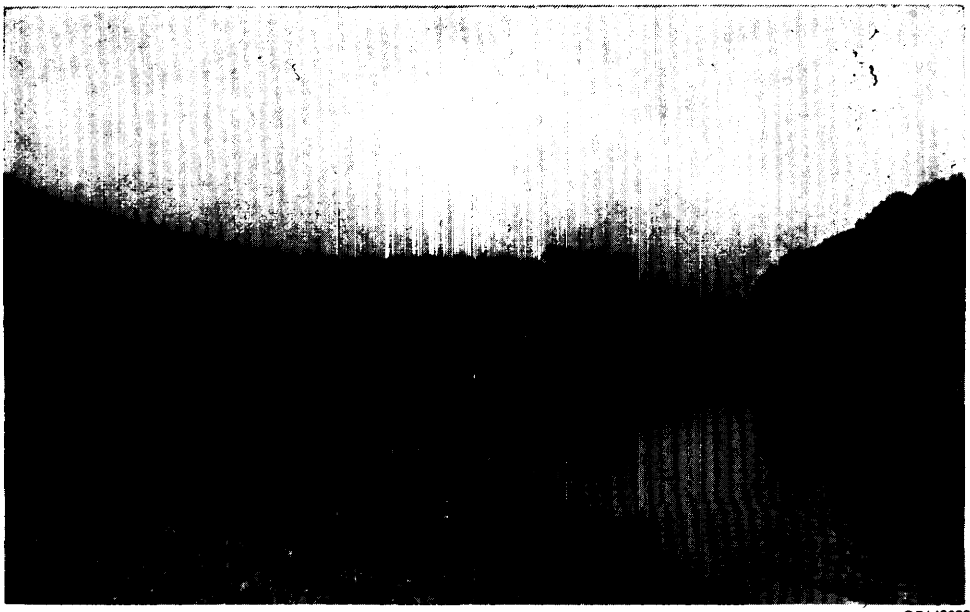
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**Photo 5 — Grand River Section GU-7, exposing Middle clay till and sandy Catfish Creek Till; Grand River north of Bloomingdale.**

The Grand River sections expose two older tills correlated with the sandy Catfish Creek Drift (of Tazewell age) and the clayey Port Stanley Drift (of Cary age). These tills lie stratigraphically below a younger sandy till (Wentworth Till) not generally exposed in the river banks but present on the upland surface back from the Grand River.

In many places along the smaller streams tributary to the Grand River, two or all three of the tills are exposed in road cuts, rather than the valley walls. This is true of Swan Creek, Cox Creek, and Hopewell Creek. Indeed, most of the occurrences of the older tills have been identified in such situations.

### Catfish Creek Till

The oldest recognized traceable stratigraphic unit in the area is a stony, silty, sand till. It is exposed in the lower parts of the banks of the Grand River and along valleys tributary to it in the west half of the area. Except for a very few places where possibly older units occur, the base of this unit is not exposed and its total thickness therefore cannot be measured. Exposed thicknesses in excess of 40 feet have been seen however (e.g. section GU-2 in Figure 2) and it appears to be generally a relatively thick till sheet with an irregular surface. It commonly contains sandy and gravelly stringers and bands.

This till can usually be identified in the field by its texture, hardness, grey-buff to olive colour, stratigraphic position below a clay till, and occurrence at lower elevations. Analyses (see Appendix B for individual sample results and the accompanying table for a comparative summary of till analyses) of 11

## SUMMARY OF TILL ANALYSES

### RANGES AND AVERAGES

| | Size analyses | | | | Pebble counts | | | | | Carbonate analyses | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples | Clay percent | Silt percent | Sand percent | No. of Samples | Limestone percent | Dolomite percent | Chert percent | Crystallines percent | No. of Samples | Calcite percent | Dolomite percent | Ratio of Calcite to Dolomite |
| Northern till | 2 | 33-33, 33 | 24-35, 30 | 32-43, 37 | 2 | 12-25, 19 | 63-82, 73 | 0-1, 1 | 4-8, 6 | 2 | 10.7-15.2, 13 | 18.6-25.2, 21.9 | 0.4-0.8, 0.6 |
| Wentworth Till | 25 | 12-33, 18 | 22-47, 33 | 31-61, 49 | 23 | 6-67, 22 | 17-91, 69 | 0-2, 1 | 0-11, 4 | 24 | 7.5-19.0, 10.6 | 13.8-33.4, 25.1 | 0.3-1.1, 0.6 |
| Middle till | 16 | 39-79, 52 | 14-45, 27 | 7-37, 21 | 14 | 2-55, 26 | 32-83, 64 | 0-3, 1 | 0-12, 6 | 16 | 7.8-30.8, 21.3 | 7.0-21.4, 13.2 | 0.6-4.3, 1.9 |
| Catfish Creek Till | 11 | 11-24, 19 | 26-48, 35 | 35-52, 46 | 9 | 13-30, 21 | 59-80, 71 | 0-3, 1 | 1-10, 6 | 11 | 11.5-21.6, 16.1 | 23.0-35.7, 28.3 | 0.3-0.8, 0.6 |
| finer facies | 4 | 31-42, 36 | 25-53, 36 | 16-34, 28 | 1 | 24 | 64 | 0 | 6 | 4 | 15.5-21.0, 18.3 | 10.7-21.2, 16.8 | 0.7-1.8, 1.2 |

samples yielded an average textural composition of 19 percent clay, 35 percent silt, and 46 percent sand; pebble lithology of 9 samples averaged 21 percent limestone, 71 percent dolomite, 1 percent chert, and 6 percent crystallines (Precambrian). Carbonate analyses on matrix (<200 mesh) of 11 till samples yielded averages of 16.1 percent calcite, 28.3 percent dolomite, and a calcite-dolomite ratio of 0.6. The preferred orientation of pebbles in the till (till fabric) was measured at several localities and indicated a variation in the trend of ice-flow from just west of north, to northeast.

Four samples of unusually fine-grained till associated with this unit but usually underlying typical Catfish Creek Till had an average textural composition of 36 percent clay, 36 percent silt, 28 percent sand, and an average carbonate content of 18.3 percent calcite, 16.8 percent dolomite, and a calcite-dolomite ratio of 1.2. These atypical occurrences may represent either local contamination of the till by the overriding of older deposits or, perhaps more likely, exposures of older tills. Similar occurrences were noted in the Galt map-area near Kitchener and not far from those noted above.

The identification of this till as Catfish Creek Till rests on its lithology, general continuity and comparable stratigraphic position as traced from Paris to Kitchener, and its northerly fabric, features similar to those in its type-area of exposure south of London, Ontario, as described by de Vries and Dreimanis (1960). It is considered to correlate with the Tazewell substage of the standard Midwest sequence or early Woodfordian of Frye and Willman (1960) of Illinois.

#### Middle till

A till, varying in texture from clayey silt to clay, occupies an intermediate stratigraphic position between two sandy tills along the Grand valley and its tributaries in the west half of the area. This fine-grained till overlies Catfish Creek Till and underlies the sandy Wentworth Till. Where the Wentworth Till is thin (particularly west of the Grand River) this till occurs in the hill slopes and valleys. The core of the overridden Breslau moraine is composed of the same till. Fine-grained till, low in pebbles, occurs also in many places under Wentworth Till and intervening ablation deposits in the east half of the map-area to the northwest of the Eramosa valley. All these occurrences are grouped together as an informally-named "middle till" unit.

The full thickness of this unit is seldom observed in an exposure except where the full thickness of this unit is rather thin. The maximum thickness observed was 25 to 30 feet, but in many places it is less than 10 feet thick. At GU-1229, southwest of Inverhaugh, (see Figure 2) it apparently varied from 30 to 52 feet because of an uneven surface on the underlying Catfish Creek Till; postglacial erosion along the Grand valley has reduced the formerly thick till mass to a few feet on the valley side. Similar conditions exist at GU-7, near Bloomingdale, where an erosional channel in the Catfish Creek Till caused a thickening of the clay till from 6 feet on the flank of the channel to 25 feet over the channel.

Analytical results on samples from the Guelph area have yielded an average textural composition of 52 percent clay, 26 percent silt, and 21 percent sand (16 samples); pebbles in the till are 26 percent limestone, 64 percent dolomite, 1 percent chert, and 6 percent crystallines (14 samples). Analysis of 16 samples of till matrix yielded 21.3 percent calcite, 13.2 percent dolomite, and a calcite-dolomite ratio of 1.9.

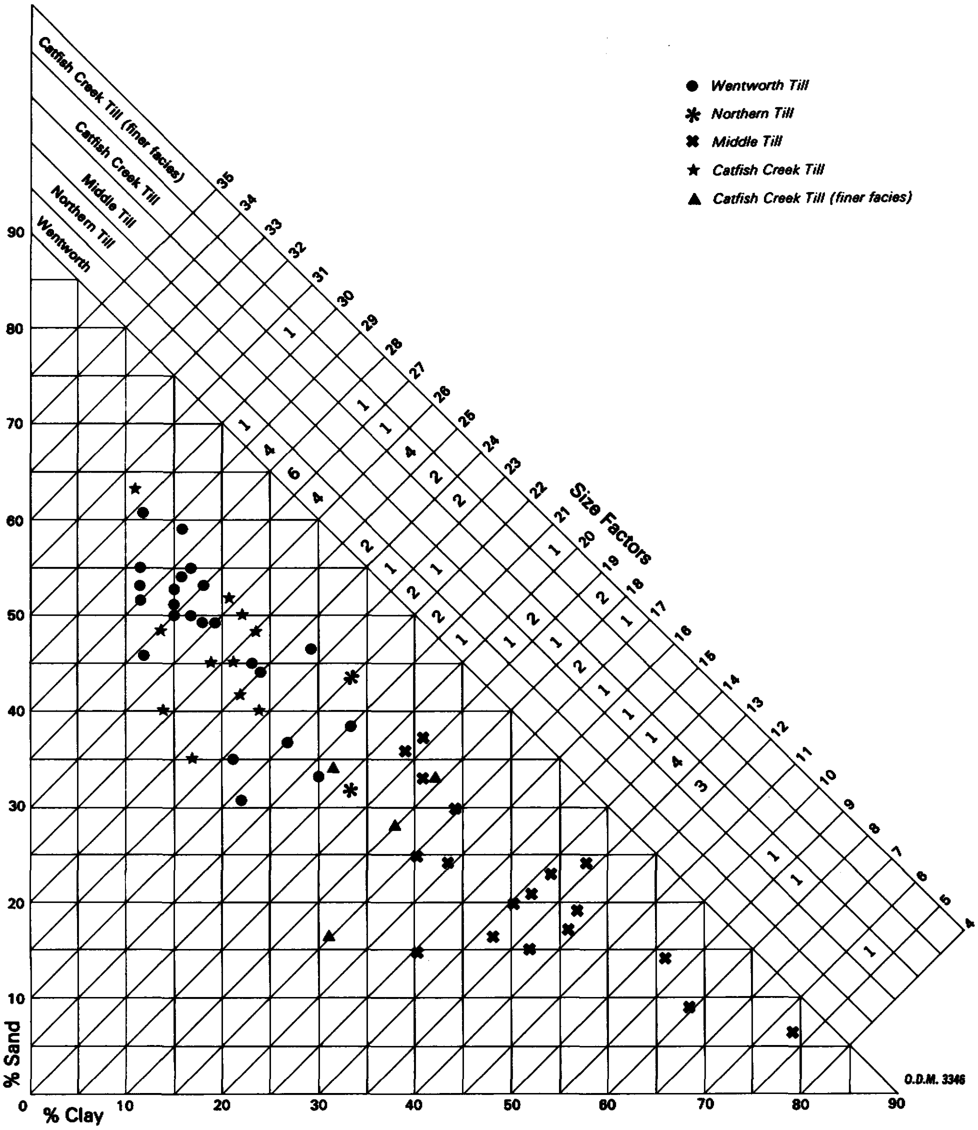


**Figure 3 — Mechanical analyses of tills.**

Uncertainty about the origin of this till has increased with further field work after its initial recognition in the Galt map-area near Kitchener in 1958. Its stratigraphic position led the author to suggest it was merely the northward extension of the Port Stanley Drift of Dreimanis south of London and of Karrow along the Nith River. The widespread occurrence of lithologically similar tills farther west and north, where it is believed the Huron and Georgian Bay ice-lobes were active, has suggested a source other than the Ontario ice-lobe. Generally low pebble contents make fabric determinations difficult, and scant surface exposure precludes studying evidence of direction of ice-movement from surface features. Additional studies such as detailed mineralogical analysis, microfabric analysis, and more extensive mapping could shed light on the problem. Until the source of the till becomes more definitely known, no formal name will be applied to it; if it can be established that it is part of the Port Stanley Drift, the name Port Stanley can be applied to it; if it becomes established that it was deposited by ice coming from the north or west, a new stratigraphic name will be necessary. At any rate, on the basis of sequence, it is believed to be Cary in age, i.e. about the same age as the Port Stanley Drift.

In the vicinity of Guelph, there are a few places where finer tills occur below the Wentworth Till and may represent the southeastward extension of the middle till unit. Analyses for two of these localities are given in Appendix B under stations GU-249 (Canadian Gypsum quarry) and GU-595 (Elizabeth Street, west of Metcalf). Deep excavations in the Guelph district may well expose more of these older tills.

### Wentworth Till

The youngest till sheet in the area is a sandy to silty sand till, usually buff in colour, and often bouldery or stony (Photo 6). It can often be distinguished from the Catfish Creek Till on the basis of colour; the Wentworth Till tends to a more pinkish tint of buff colour, relative to the olive-buff of the Catfish Creek. Stratigraphic position is the most reliable distinction; Catfish Creek Till is usually found low down in valleys and under a clayey till, and in contrast the Wentworth occurs above a clay till in the upper portion of valley walls and is exposed extensively at the surface between valleys. Wentworth Till is the surface till over most of the Guelph sheet; it forms the streamline hills of the Guelph drumlin field and the hummocky topography of the Galt, Paris, and Moffat end moraines. Drumlins, flutings, and striae indicate that this till sheet was deposited by ice flowing westward out of the Lake Ontario basin. Its westward and northward limits apparently lie beyond the map-area except for the portion northwest of Elora and Fergus. It has been possible to locate a fairly definite boundary for this till extending from the west edge of the area east to Highway 6, parallel to the Grand River and about 2 miles northwest of it. East of Highway 6 the boundary has been placed partly on small differences in till lithology, and partly by arbitrary extrapolation, and extended through a region of level swampy ground with poor exposure. To the west, the till border is associated with weak morainic topography; to the east there is no belt of morainic topography evident and till lithology is somewhat variable and atypical.

The thickness of the till is very variable and can, in a general way, be related to its surface topography. Thus, its thickness probably ranges between

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**Photo 6 — Large erratic of Precambrian gneiss, estimated to weigh 60 tons, on Paris moraine near Rockwood.**

50 and 100 feet in drumlins and end moraines but is much less in low areas, such as between drumlins. Near the limit of its westward extent, along the west edge of the area, it is a thin sheet about 5 feet thick overlying outwash sand and gravel or clay till. It is thin and patchy, and even absent, in the southeastern corner of the area, leaving bedrock extensively exposed over an area of several square miles.

Analyses of 25 samples of Wentworth Till yielded an average textural composition of 18 percent clay, 33 percent silt, and 49 percent sand; 23 pebble counts averaged 22 percent limestone, 69 percent dolomite, 1 percent chert, and 4 percent crystallines. Carbonate analyses of 24 samples of till matrix yielded average values of 10.6 percent calcite, 25.1 percent dolomite, and an average calcite-dolomite ratio of 0.6. Similar results were obtained on sand-sized material in the till by Dell (1959); complete mineral analyses have been reported by Dell for this till. Some additional analyses are also reported by Dreimanis (1961). Two samples near the east edge of the area have an unusually high percentage of limestone pebbles, no doubt reflecting the relatively short distance over which the ice had crossed dolomite bedrock west of the Niagara Escarpment. The coarsest textures occur along the Paris-Galt moraine belt and the finest occur near the northwestern periphery of the till sheet; stratified lake silts were seen to underlie the till near the eastern edge of Fergus and probably explain, in part at least, this finer texture. The siltier texture near Fergus greatly complicated the task of distinguishing Wentworth from tills derived from the north.

In numerous places in the east part of the area, the Wentworth Till has a bright red colour (Figure 4). These localities are obviously associated with re-entrants in the Niagara Escarpment near Campbellville (in the Hamilton map-

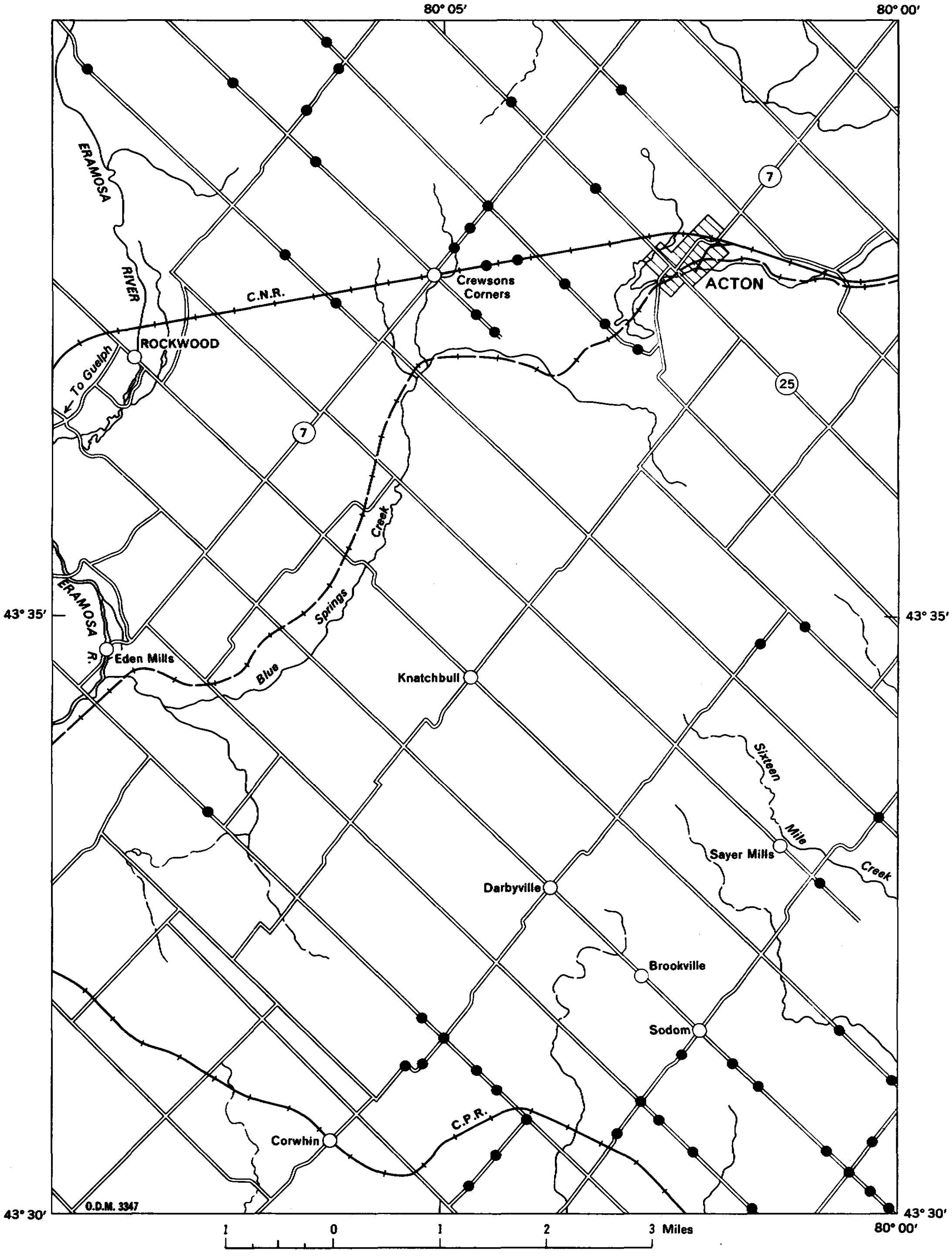


Figure 4 — Occurrences of red till.

area) and near Acton. Probably glacial erosion of the soft Queenston red shale was concentrated along these valleys, yielding unusually red till.

The Wentworth Till is probably of Port Huron age or perhaps slightly older; a radiocarbon date at the base of a kettle bog in the Galt moraine indicates an age somewhat greater than 12,000 years (Karrow 1963a). The Paris and Galt moraines have been correlated with the Port Huron (or Mankato advance) by Chapman and Putnam (1951). More regional study of till sheets, moraines, and related glacial lake stages, is needed to confirm this assignment.

#### Northern till

East of Alma and north of Fergus is an area of about 6 or 7 square miles over which is exposed till that apparently overlies the middle clay till, has a coarser texture than the clay till, but is usually finer-textured than Wentworth Till. It is typically more deeply weathered than Wentworth and has a darker, more brownish colour; in the soil profile, ivory-coloured weathered dolomite pebbles contrast sharply with the brown matrix. The generally level topography in the area concerned, and the deeper weathering, hindered efforts to determine the relationships of this till to others, previously described. In 1963 the preliminary map of the Guelph area was issued without any boundary between this till and the Wentworth. Further study of the problem, together with information from outside the area, has made it possible to locate a boundary, as described (p.20) under "Wentworth Till". As mentioned previously, east of Highway 6 the boundary is particularly uncertain and it may swing farther southeast than shown, extending perhaps down to the Grand River near the Shand Dam.

Because of the limited extent of this till, no formal name is proposed for it at this time. It is believed to have been deposited by the Georgian Bay lobe flowing in a direction somewhat east of south. Because the Georgian Bay lobe crossed rocks having lithology similar to those crossed by the Ontario lobe (in particular, extensive areas of Silurian dolomite and Ordovician limestone and shale), the lithology of the northern till is similar to the Wentworth. Analyses at two localities average 33 percent clay, 30 percent silt, and 37 percent sand; pebble lithology is 19 percent limestone, 73 percent dolomite, 1 percent chert, and 6 percent crystallines; till matrix averages 13 percent calcite and 21.9 percent dolomite, with a calcite-dolomite ratio of 0.6.

The age of this till is uncertain. It certainly appears to be younger than the middle clay till but its relationship to the Wentworth is in doubt. No exposure was seen of the northern and Wentworth tills superimposed but on the basis of rather slight field evidence it is thought to be older than Wentworth. There is no evidence that it extends much farther south than the area of its surface exposure. The elaboration of the history of this till sheet must await extensive field work to the west and north of the Guelph area.

#### Ablation deposits

Ablation deposits, that is sediments deposited by glacial meltwaters, are abundant in the Guelph area. Because of limited exposure, little is known of ablation deposits associated with the earlier ice-advances; only in two exposures were stratified sand and gravel seen below the Catfish Creek Till (GU-2 and GU-1274). Between the Catfish Creek and middle clay till a channel fill of sand and gravel occurs in GU-7, but in all other exposures the two tills are in direct contact with no stratified sediments between them.

Commonly, however, between the middle and Wentworth tills there is an abundance of sand and gravel. It is usual to find kame and outwash deposits below the Wentworth Till. Such deposits are particularly evident in the north central part of the area, in the northeast along the front edge of the Paris moraine, and in the southwest along the Grand Valley. In the former two districts the deposits are of a kamey character, but in the latter appear to be outwash. The present topography of the overlying till appears to reflect, in large part, the surface of the ablation deposits; it is irregular where kamey, and level where it is outwash.

Ablation deposits laid down during the retreat of the Wentworth ice are the most obvious and account for perhaps 20 percent of the area of the map sheet. Kame gravels, formed in contact with glacial ice, are particularly abundant north and west of Acton, where they are associated with the Paris and Galt moraines. As already noted, till texture tends to be coarser in the moraine belt and the distinction between poorly-sorted kame gravel and coarse till is often arbitrary. Kames are also abundant east of Fergus. Scattered kame deposits occur west of Elora. The elongated ridges known as eskers contain kame-like stratified sand and gravel that has been usually sorted and rounded to a greater extend than ordinary kame gravels. The three most prominent ones, the Eramosa, Ariss, and Guelph eskers have already been described.

Carbonate analyses of some of the sands have been reported by Chapman and Dell (1963). Deposits of sand and gravel with level surface and relatively uniform bedding were formed by meltwaters flowing out beyond the ice. These deposits, referred to as outwash, or where relatively confined to narrow low areas as spillway deposits, are concentrated along the Eramosa, Speed, and Grand valleys and in a complex, interconnecting network of channels through the Guelph drumlin field. These deposits are usually well sorted and rounded.

### Pond deposits

Small areas of stratified silt, with some clay and sand, are scattered through the centre of the area in a north-south belt. They represent sedimentation in small temporary ponds that, in most cases, filled residual depressions between drumlins. The largest deposit is 6 miles southeast of Guelph in the Paris-Galt moraine complex. Pond sediments are often encountered as well beneath swamps and bogs.

### Alluvial deposits

Alluvial deposits of stratified gravel, sand, and silt, border most of the streams of the area. The transition from glacial meltwaters to pluvial waters must have been gradual and it is very difficult to distinguish between stream terrace deposits of the two origins. High terraces are probably of glacial origin; low terraces are postglacial and recent in age.

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**Photo 7 — Vertical airphoto of gravel terraces along Grand River south of Inverhaugh. (Courtesy Ontario Dept. Lands and Forests.)**

Extensive alluvial terraces occur along the portion of the Grand River between Inverhaugh and Bloomingdale where meanders are present. (see Photo 7). Inside each meander there are extensive slip-off slopes mantled with gravel deposited as the river enlarged its meanders. These lower terrace gravels are usually less than 10 feet thick.

Recent alluvium is to be found on the modern floodplains of most permanent streams in the area. It consists of stratified silt, sand, and gravel, with an admixture of varying quantities of wood and finer organic matter. Molluscan remains are uncommon in alluvium of either young or old terraces. Recent alluvium tends to have a thickness approximating the depth of the channel of the depositing stream.

### Swamp and bog deposits

There are numerous areas, mostly small, underlain by accumulations of plant material referred to as swamps or bogs, depending on the type of vegetation and the degree of decomposition of the plant fibre. Swamps are wooded wet areas with shallow accumulations of decomposed muck. Some swamps occur in the southeast corner of the map-area, where bedrock is close to the surface and impedes drainage.

More common, however, are the long narrow boggy areas. These are deeper accumulations having a depth of about 3 to 10 feet, and occur along abandoned glacial meltwater channels. The most prominent example extends along the Eramosa valley from Brisbane to Everton. Numerous smaller channel bogs occur in association with the pond and spillway deposits, scattered through the Guelph drumlin field.

The deepest bogs, some probably exceeding a depth of 20 feet, are those located in kettle holes. They are most common along the Galt and Paris end moraines. Many are too small in area to be shown on the accompanying geological map. Below the peat and muck, there may be stratified sand, silt, and clay, deposited in an initial pond stage before vegetation filled the depression. A layer of marl is sometimes present as well.

### Historical geology

Although there is abundant evidence of Early Wisconsinan glacial events to the south in the vicinity of Paris and London, and to the east at Toronto, no deposits older than early Late Wisconsinan are known in the Guelph area. No doubt such Early Wisconsinan deposits do occur in the area but erosion has not yet exposed them where they lie buried; they most likely exist at depth where drift is thickest along the western edge of the area.

The Late Wisconsinan glaciation is well represented in the area by three major till sheets. The first of these, the Catfish Creek of Tazewell age, records a major glacial advance that has been recognized at many places throughout the area covered by the Erie lobe in Ontario and Ohio. At its maximum extent it reached almost to the Ohio River about 18,000 years ago (Goldthwait *et al.* 1965) and overwhelmed all of southern Ontario by a regional flow from the north or northeast. This flow direction is indicated by the preferred orientation of pebbles in the Catfish Creek Till in the Guelph area. All subsequent glacial events and deposits can be related to the fluctuating retreat of this ice-sheet.

Moderating climate melted the ice-edge back an unknown but considerable distance, probably exposing a substantial portion of southwestern Ontario. The meltwater was dammed up in large glacial lakes in which were deposited lake clay and silt. These fine sediments were overridden by the subsequent glacial advance to form the clayey Port Stanley Till of Cary age. Most, if not all, of the area of southwestern Ontario exposed by the preceding retreat was again ice-covered. The middle clay till of the Guelph area was probably deposited by this advance but it is not known whether by the Ontario, Georgian Bay, or Huron lobes. Retreat following this advance allowed development of the earlier glacial lakes of the Erie basin such as Maumee and Whittlesey; these did not extend far enough eastward, or high enough, to affect the Guelph area.

An advance of the Georgian Bay lobe affected the northwestern corner of the area at about this time, perhaps slightly preceding the last (Wentworth) advance of the Ontario lobe across the area.

Not long after, the youngest till sheet of the area was laid down by a re-advance of the Ontario lobe. This advance covered all but the northwest corner of the area, laying down the Wentworth Till. The area covered by this till indicates that a sub-lobe of the Ontario lobe formed a projection of the ice-front that was confined by higher ground of the Waterloo moraine to the southwest and the regional slope upward to the north. The difference in elevation between the areas of higher ground and the low axis of the sub-lobe was about 150 feet (allowing for the tilting of the land by isostatic rebound following deglaciation). Eskers and kames indicate at least partial stagnation of the ice during its retreat. Pauses in the retreat of the ice-edge, and perhaps slight readvances, are represented by the massive Paris and Galt moraines; the Galt moraine was formed more than 12,000 years ago (Karrow 1963a). Retreat of the Wentworth ice allowed the area to become permanently icefree. The next younger ice-advance, which deposited the Halton Till to the southeast, barely reached the crest of the Niagara Escarpment and did not enter the Guelph area; the Acton district may have received meltwaters and glaciofluvial gravels from this advance.

Meltwaters from the retreating Wentworth ice spread gravels along channels established in residual depressions in the till surface. As the streams became fed by rain instead of meltwater, and their sediment load decreased, valleys such as the Grand were cut down through the various till layers. Undrained or poorly-drained depressions collected silt and sand, and marl, and later grew bog vegetation.

The dissection of the area by streams is still in an early stage of development. Most of the area retains, relatively unmodified, the strong imprint of glaciation.

## ECONOMIC GEOLOGY

### General

The Pleistocene deposits of the area are important as major sources of ground water and sand and gravel, and are a base for roads and foundations. Small to moderate quantities of usable clay and peat are also available in the area though not at present exploited.

The glacial history has had a strong influence on the nature of the soils of the area; agriculture is the most important industry in the area dependent on geological materials. Three of the five soil-forming factors (parent material, topography or drainage, and time) are geological in nature and a strong correlation can be made between the geology and the soils.

### Clay

There is no exploitation of the clay in the area for ceramic purposes. Stone-free lake deposits are of very limited extent and are likely to be too silty or lean.

The middle clay till often has a high enough clay content to be useful and was exploited many years ago in pits to the west of the area (Baker 1906). In some places near Kitchener (south of the area) varved clays are interbedded with

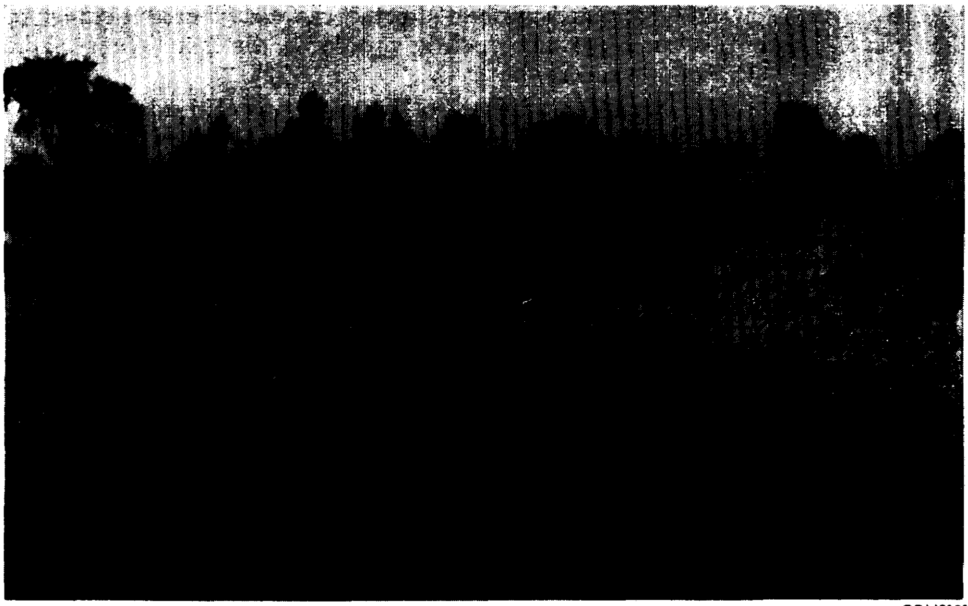

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Photo 8 — Gravel pit in Speed River spillway gravel, two miles southwest of Eramosa.

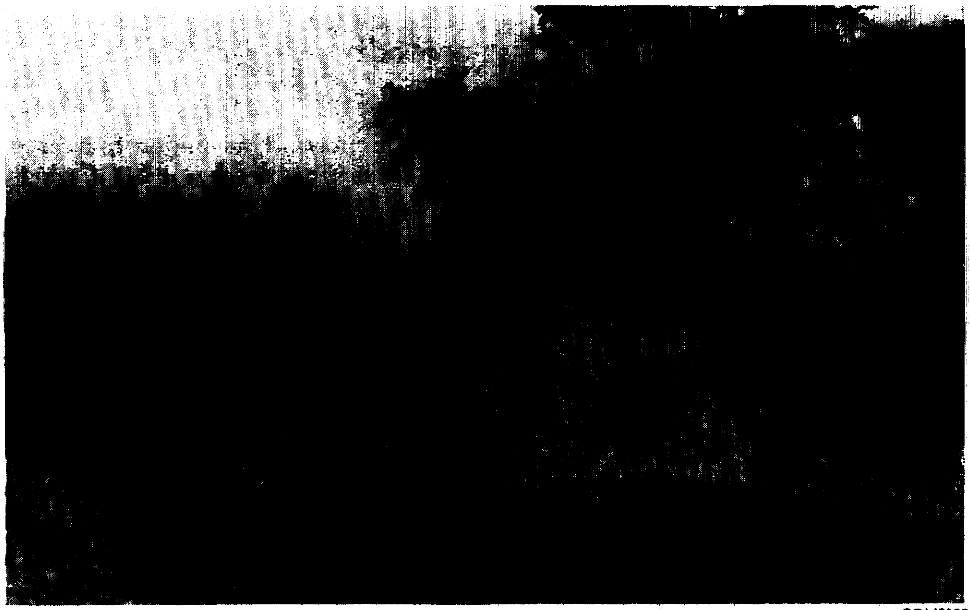

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Photo 9 — Gravel pit in Guelph esker, north of Highway 7.

the till but this feature was not observed in the Guelph map sheet. The chief problem with the till, of course, is the removal of grits and pebbles.

### Sand and gravel

Outwash constitutes the highest quality and most-exploited source of gravel in the area with the larger pits clustered in the vicinity of Guelph and Kitchener. The Eramosa, Speed, and Grand rivers are flanked by important gravel terraces that are the sites for many pits (see Photo 8). A number of pits, mostly small, are also scattered along the outwash network in the Guelph drumlin field.

Kames and eskers are also important sources of gravel although, because of their uneven and variable quality, they are less prized. Most of the Guelph esker has been removed by gravel pit operation near Guelph (see Photo 9); 50 years ago it was a flourishing source with substantial reserves (Ledoux 1918). Almost all eskers in the area have served at least as small temporary sources of gravel for farm lanes and township roads. Production from these many smaller pits is not recorded.

The extensive kame deposits near Acton are probably the least desirable in the area because of the presence of so much siltstone and shale from Ordovician bedrock to the east. In contrast, gravels derived from the Silurian dolomites are relatively free of these undesirable constituents. Most of the gravels west of the Galt moraine are of this good type. Chert is never present in troublesome quantities and is more often almost completely absent.

In all, more than 175 active or abandoned pits were noted in the area. Undoubtedly, large quantities of good sand and gravel await future exploitation. A recent study of the sand and gravel industry by Hewitt and Karrow (1963) included some of the operations in this area.

### Water supply

Pleistocene deposits are the direct source of most of the ground water utilized in the area, although no doubt large quantities pass a relatively short distance through these from their bedrock source.

Guelph derives most of its water supply from springs in gravels and bedrock near Arkell. It has been reported that substantial quantities of water are lost from the Eramosa River between Rockwood and Eden Mills, presumably flowing into solution-widened joints in the bedrock floor of the riverbed. The presence of caves supports the idea of large bedrock sources in the area east of Guelph.

Permeable deposits, capable of serving as aquifers, include the outwash and river deposits. Infiltration is greatest in these deposits and in the hummocky tracts of end moraine. Large buried masses of sand and gravel occur east of Fergus but the relatively high relief probably causes a low water table. Other buried sand and gravel deposits underlie the Wentworth Till west of the Grand River but their extent and thickness have not been adequately determined.

Buried valleys, such as have been found at Guelph and Fergus are good potential aquifers if filled with gravel or sand. Where the Fergus valley intersects the present Grand River gorge on the south side, the ground is soft and springy, suggesting just such a permeable, water-bearing filling.

## Guelph area

The chief problem with water quality in the area is the hardness caused by an abundance of dissolved carbonate of lime from the bedrock and glacial deposits.

### Peat

Peat occurs in numerous small deposits throughout most of the area. The largest single deposit is that along the Eramosa valley northeast of Everton. These deposits should yield peat for horticultural purposes. There is no exploitation of these deposits at present except occasionally as a byproduct of construction activities.

### Engineering geology

The Guelph map-area has few engineering problems. The largest urban centre, Guelph, lies on bedrock, Wentworth Till, or outwash deposits. The recently-constructed Victoria Street bridge over the Eramosa River has its south abutment on rock on the south side of the Guelph buried valley and its north abutment on the sediments filling the valley; what effect this may have in the way of differential settlement remains to be seen.

Highway construction encounters two problems in the area: crossing organic deposits; and the necessity for deep cuts in the drumlins and end moraines. Both are readily dealt with by standard engineering practices.

Glacial till was used for construction of the Shand earth dam east of Fergus (Legget 1942). Other conservation dams are planned near West Montrose on the Grand River and along the Speed River north of Guelph. Here too, glacial till will provide the main construction material. Engineering properties of the middle clay till at Kitchener, just south of the area, have been recently described by Christensen (1963).

# APPENDIX A

## Descriptions of Measured Sections

**(For locations see map)**

### GRAND RIVER SECTIONS

**All measurements in feet**

**GU-2 section**

0–3 clayey soil.
3–10 brown clay till; few stones, reworked stratification (middle till).
10–54 stony, silty, sand till. Lower 2 feet sandier. (Catfish Creek Till).
54–62 stratified, fine, grey-buff sand and yellow medium sand.
62–71 slump to Grand River.

**GU-3 section**

0–6 buff, fine, sandy loose till (Catfish Creek Till).
6–7 kamey brown sand with pebbles.
7–9 grey-buff till as above.
9–14 grey-buff and grey till as above (Catfish Creek Till).
14–22 dark grey, sandy, silt till; moderately stony and dense. Boulders at top. (Catfish Creek Till, finer facies).
22–26 mostly slump with some exposures of same till.
26–36 slump to Grand River.

**GU-6 section**

0–19 fine to coarse subrounded gravel.
19–23 slump.
23–25 grey, sandy, silt till (Catfish Creek Till, finer facies).
25–31 slump to Grand River.

**GU-7A section**

0–9 medium, stratified, buff sand with fine gravel stringers.
9–34 purple and grey, clayey silt to silt till; many buff lenses of fine wet sand. (middle till).
34–44 stratified, fine, yellow sand, silty sand, and medium sand.
44–47 medium to coarse subangular gravel.
47–50 silty, grey-buff, sand till (Catfish Creek Till).
50–60 slump to Grand River.

**GU-7B section** (short distance east of A)

0–6 stratified, fine sand.
6–12 stratified, fine to coarse, subrounded gravel.
12–18 brown clay till; interbedded fine greenish silty sand. (middle till).
18–46 stony, silty sand till (Catfish Creek Till).
46–58 slump to Grand River.

## Guelph area

**GU-1229 section**

0–2 buff, silty, sand till (Wentworth Till).
2–3 creamy, fine silty sand.
3–35 red-brown, clayey, silty till (middle till).
35–68 olive, stony, sandy till. Upper 20 feet is partly covered by clay till whose lower contact slopes down toward Grand River. (Catfish Creek Till).
68–77 slump and 4-foot modern alluvial terrace to Grand River.

**GU-1255 section**

0–18 stony, buff, sand till (Catfish Creek Till).
18–32 slump to Grand River.

**GU-1274 section**

0–10 buff, sandy, silty till (Catfish Creek Till).
10–13 stratified, kamey coarse sand and some gravel.
13–24 slump to river.

**G-1463 section**

0–8 gravel.
8–25 brown clay till (middle till).
25–37 brown silty sandy till (Catfish Creek Till).
37–52 slump to Grand River.

### OTHER SECTIONS

**GU-2501A section**

0–2 soil.
2–4 buff, stratified silt and fine sand.
4–10 fine to medium gravel.
10–16 buff, stratified silt and fine sand.
16–17 stratified medium sand.
17–19 coarse sand and fine gravel containing balls of underlying silt till.
19–19½ blocky silt till (middle till).
19½–25 buff, sandy, stony till (Catfish Creek Till). To creek level.

**GU-2501B section** (40 feet south of A)

0–1 soil
1–4 fine to medium gravel.
4–12 buff stratified fine silt, sand, and clay.
12–13 medium sand.
13–16 blocky silt till (middle till).
16–23 buff sandy, stony till (Catfish Creek Till). To Creek level.

**GU-2524 section**

0–4 brown sandy stony silt till (northern till).
4–10 cream coloured sandy till (Catfish Creek Till)

# APPENDIX B — TILL ANALYSES

| Symbols | Notes: |
|---|---|
| Md — median diameter<br>W — Wentworth Till<br>n — northern till<br>m — middle clay till<br>CC — Catfish Creek Till<br>CCf — Catfish Creek Till, finer facies | 1. clay-silt boundary = 0.004mm.<br>silt-sand boundary = 0.062mm.<br>2. pebble counts on pebbles 1 to 2 in. diameter<br>3. carbonate analysis on till matrix passing 200 mesh sieve, using Chittick apparatus. |

| Size Analyses | | | | | | Pebble Counts | | | | Carbonate Analyses | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality | Till | Clay % | Silt % | Sand % | Md. mm. | Limestone % | Dolomite % | Chert % | Crystallines % | Calcite % | Dolomite % | Total % | Ratio of Calcite to Dolomite |
| GU–2A | m | 68 | 23 | 9 | 0.0016 | 16 | 65 | 1 | 7 | 25.6 | 10.1 | 35.7 | 2.5 |
| –2B | CC | 21 | 27 | 52 | 0.052 | 27 | 59 | 2 | 10 | 17.0 | 30.0 | 47.0 | 0.6 |
| –3 | CCf | 42 | 25 | 33 | 0.0062 | — | — | — | — | 16.8 | 14.1 | 30.9 | 1.2 |
| –4 | m? | 41 | 26 | 33 | 0.0071 | 28 | 68 | 1 | 2 | 23.4 | 11.6 | 35.0 | 2.0 |
| –6 | CCf | 38 | 34 | 28 | 0.008 | — | — | — | — | 19.8 | 10.7 | 30.5 | 1.8 |
| –7A | m | 52 | 33 | 15 | 0.0038 | — | — | — | — | 26.0 | 14.1 | 40.1 | 1.8 |
| –7B | CC | 21 | 34 | 45 | 0.047 | — | — | — | — | 18.2 | 23.0 | 41.2 | 0.8 |
| –8 | CCf | 32 | 34 | 34 | 0.016 | — | — | — | — | 21.0 | 21.2 | 42.2 | 1.0 |
| –55 | W | 15 | 35 | 50 | 0.062 | 6 | 81 | 0 | 0 | 15.8 | 32.2 | 48.0 | 0.5 |
| –69 | W | 18 | 33 | 49 | 0.061 | 18 | 75 | 1 | 5 | 15.2 | 33.4 | 48.6 | 0.5 |
| –113 | CC | 22 | 28 | 50 | 0.065 | 30 | 62 | 0 | 8 | 15.2 | 23.2 | 38.4 | 0.7 |
| –113 | m | 56 | 27 | 17 | 0.003 | 31 | 59 | 3 | 5 | 18.4 | 12.6 | 31.0 | 1.5 |
| –118 | W | 18 | 29 | 53 | 0.074 | 21 | 70 | 1 | 5 | 17.1 | 28.2 | 45.3 | 0.6 |
| –178 | m | 79 | 14 | 7 | 0.0005 | 25 | 67 | 1 | 7 | 30.8 | 7.1 | 37.9 | 4.3 |
| –200 | W | 19 | 32 | 49 | 0.063 | 26 | 70 | 1 | 4 | 15.3 | 28.2 | 43.5 | 0.5 |
| –217A | m | 48 | 35 | 17 | 0.0046 | 25 | 67 | 0 | 2 | 23.0 | 18.4 | 41.4 | 1.3 |
| –217B | CC | 11 | 26 | 63 | 0.120 | 22 | 72 | 1 | 3 | 11.5 | 33.6 | 45.1 | 0.3 |
| –249A | ? | 26 | 38 | 36 | 0.021 | — | — | — | — | 15.3 | 28.5 | 43.8 | 0.5 |
| –249B | m? | 43 | 33 | 24 | 0.0052 | — | — | — | — | 19.8 | 9.2 | 29.0 | 2.2 |
| –255 | W | 16 | 30 | 54 | 0.075 | 20 | 76 | 0 | 3 | 14.4 | 29.7 | 44.1 | 0.5 |
| –295 | W | 21 | 44 | 35 | 0.042 | 25 | 67 | 0 | 2 | 19.0 | 27.1 | 46.1 | 0.7 |
| –451 | W | 12 | 27 | 61 | 0.120 | 8 | 91 | 0 | 1 | 10.6 | 29.9 | 40.5 | 0.3 |
| –465 | W | 12 | 27 | 61 | 0.120 | 7 | 89 | 0 | 4 | 18.1 | 25.3 | 43.4 | 0.7 |

## APPENDIX B — TILL ANALYSES (continued)

| Locality | Till | Size Analyses: Clay % | Silt % | Sand % | Md. mm. | Pebble Counts: Limestone % | Dolomite % | Chert % | Crystallines % | Carbonate Analyses: Calcite % | Dolomite % | Total % | Calcite / Dolomite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -595 | m? | 50 | 30 | 20 | 0.0041 | — | — | — | — | 15.2 | 9.7 | 24.9 | 1.6 |
| -622 | W | 15 | 34 | 51 | 0.068 | — | — | — | — | 9.4 | 18.4 | 27.8 | 0.5 |
| -662 | W | — | — | — | — | 67 | 18 | 0 | 9 | — | — | — | — |
| -708 | W | 12 | 36 | 52 | 0.077 | 13 | 80 | 1 | 2 | 13.1 | 28.4 | 41.5 | 0.5 |
| -786 | W | 12 | 27 | 61 | 0.125 | 25 | 71 | 0 | 2 | 15.8 | 19.5 | 35.3 | 0.8 |
| -913 | W | 12 | 33 | 55 | 0.070 | 64 | 17 | 0 | 11 | 16.6 | 21.2 | 37.8 | 0.8 |
| -1078 | W | 17 | 28 | 55 | 0.080 | 8 | 84 | 0 | 2 | 13.5 | 28.4 | 41.9 | 0.4 |
| -1086 | m | 41 | 22 | 37 | 0.009 | 55 | 32 | 0 | 9 | 30.0 | 7.0 | 37.0 | 4.3 |
| -1113 | W | 12 | 35 | 53 | 0.075 | 15 | 77 | 0 | 4 | 7.5 | 18.7 | 26.2 | 0.4 |
| -1147 | W | 17 | 33 | 50 | 0.064 | 24 | 73 | 0 | 3 | 9.7 | 31.4 | 41.1 | 0.3 |
| -1162 | CC | 17 | 48 | 35 | 0.025 | 16 | 73 | 1 | 3 | 14.4 | 28.4 | 42.8 | 0.5 |
| -1195 | m | 58 | 18 | 24 | 0.0028 | 32 | 68 | 0 | 0 | 19.0 | 11.6 | 30.6 | 1.6 |
| -1213 | W | 22 | 47 | 31 | 0.018 | 19 | 69 | 1 | 8 | 15.9 | 17.0 | 32.9 | 0.9 |
| -1222 | m | 40 | 35 | 25 | 0.007 | 27 | 60 | 1 | 6 | 18.6 | 16.1 | 34.7 | 1.2 |
| -1229 | m | 66 | 20 | 14 | 0.0012 | 28 | 65 | 1 | 5 | 19.6 | 14.7 | 34.3 | 1.3 |
| -1229 | CC | 14 | 46 | 40 | 0.032 | 28 | 62 | 0 | 7 | 13.7 | 26.1 | 39.8 | 0.5 |
| -1235 | W | 27 | 36 | 37 | 0.024 | 17 | 73 | 1 | 6 | 14.8 | 26.7 | 41.5 | 0.6 |
| -1268A | m | 54 | 23 | 23 | 0.003 | 2 | 82 | 0 | 6 | 7.8 | 13.8 | 21.6 | 0.6 |
| -1268B | CCf | 31 | 53 | 16 | 0.013 | 24 | 64 | 0 | 6 | 15.5 | 21.2 | 36.7 | 0.7 |
| -1536 | W | 29 | 22 | 47 | 0.045 | 28 | 53 | 1 | 7 | 13.7 | 17.9 | 31.6 | 0.8 |
| -1544A | m | 44 | 26 | 30 | 0.0069 | 11 | 83 | 0 | 3 | 13.5 | 20.4 | 33.9 | 0.7 |
| -1544B | CC | 13 | 39 | 48 | 0.055 | 16 | 80 | 3 | 1 | 15.0 | 30.1 | 45.1 | 0.5 |
| -1545 | W | 16 | 25 | 59 | 0.105 | 20 | 69 | 1 | 6 | 12.0 | 29.9 | 41.9 | 0.4 |
| -1657 | W | 15 | 32 | 53 | 0.074 | 22 | 70 | 2 | 3 | 9.1 | 28.8 | 37.9 | 0.3 |
| -1810 | m | 40 | 45 | 15 | 0.0048 | 29 | 63 | 0 | 5 | 20.3 | 8.7 | 29.0 | 2.3 |
| -1991 | W | 23 | 32 | 45 | 0.042 | 15 | 77 | 0 | 2 | 14.9 | 13.8 | 28.7 | 1.1 |
| -2147A | W? | 33 | 29 | 38 | 0.020 | — | — | — | — | 15.9 | 20.0 | 35.9 | 0.8 |
| -2147B | m | 57 | 24 | 19 | 0.0028 | — | — | — | — | 22.1 | 13.5 | 35.6 | 1.6 |
| -2147C | CC | 24 | 36 | 40 | 0.030 | — | — | — | — | 18.7 | 25.5 | 44.2 | 0.7 |
| -2153 | m | 52 | 27 | 21 | 0.0038 | 29 | 58 | 1 | 12 | 24.3 | 9.9 | 34.2 | 2.5 |
| -2153 | CC | 22 | 36 | 42 | 0.033 | 13 | 80 | 0 | 6 | 16.9 | 25.5 | 42.4 | 0.7 |
| -2221 | W | 24 | 32 | 44 | 0.040 | 25 | 67 | 1 | 3 | 17.0 | 28.4 | 45.4 | 0.6 |
| -2495 | n | 33 | 35 | 32 | 0.012 | 25 | 63 | 0 | 8 | 15.2 | 18.6 | 33.8 | 0.8 |
| -2501A | CC | 19 | 36 | 45 | 0.045 | 18 | 71 | 1 | 9 | 15.1 | 30.2 | 45.3 | 0.5 |
| -2501B | m? | 39 | 25 | 36 | 0.013 | 26 | 64 | 0 | 9 | 18.5 | 21.4 | 39.9 | 0.9 |
| -2524A | n | 33 | 24 | 43 | 0.030 | 12 | 82 | 1 | 4 | 10.7 | 25.2 | 39.9 | 0.4 |
| -2524B | CC | 23 | 29 | 48 | 0.060 | 15 | 77 | 0 | 7 | 21.6 | 35.7 | 57.3 | 0.6 |
| -2536 | W | 30 | 37 | 33 | 0.015 | 22 | 74 | 0 | 4 | 17.1 | 21.6 | 38.7 | 0.8 |
| -2587 | W | 12 | 42 | 46 | 0.050 | — | — | — | — | — | — | — | — |

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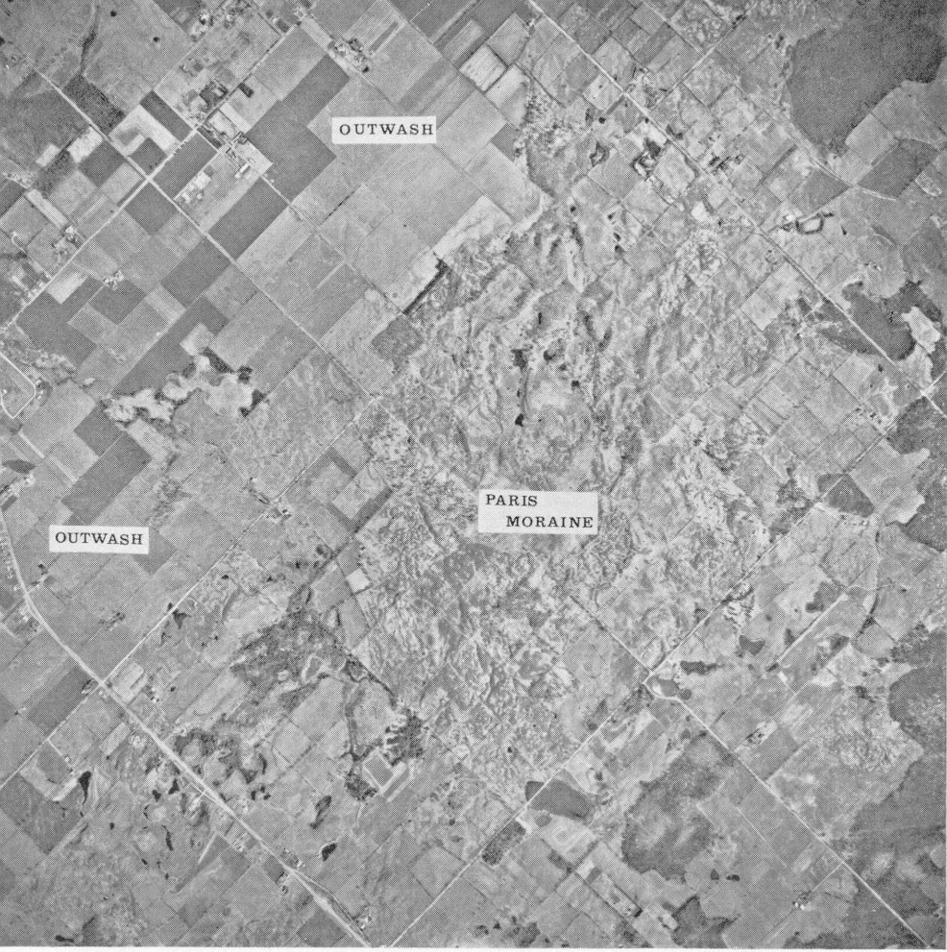
# INDEX

## Guelph Area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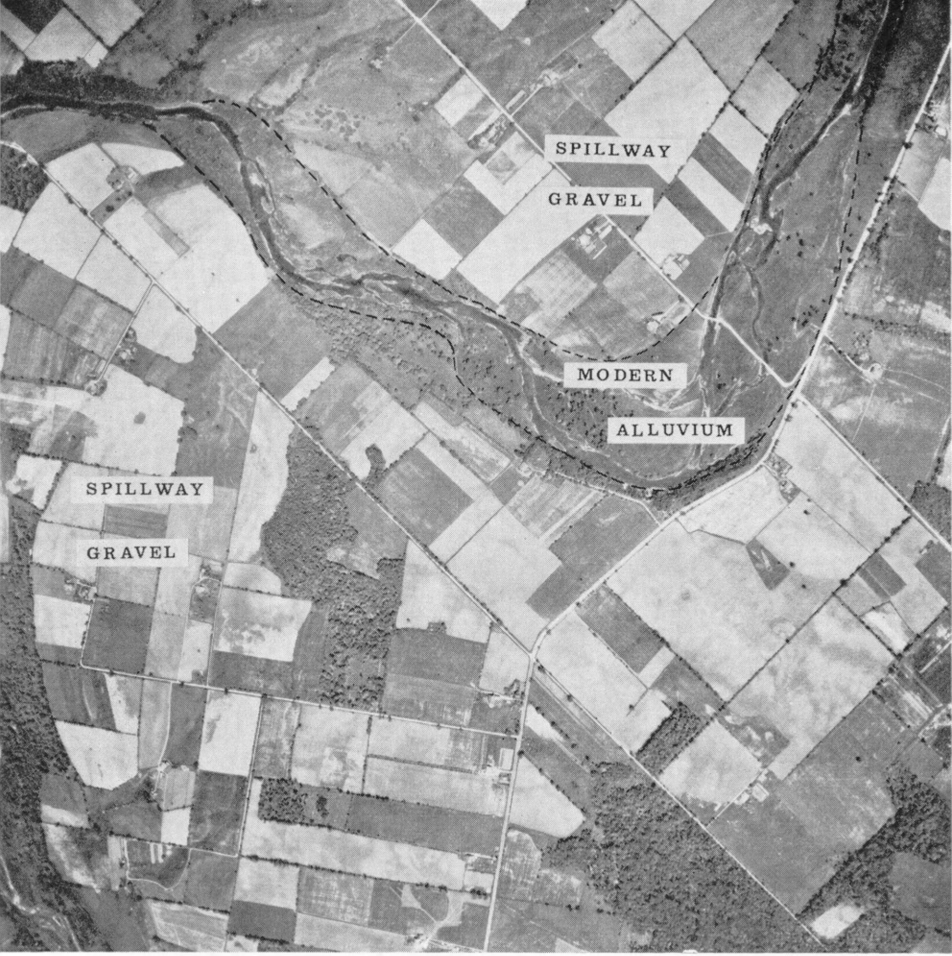
PARIS
MORAINE


ESKER GRAVEL
TILL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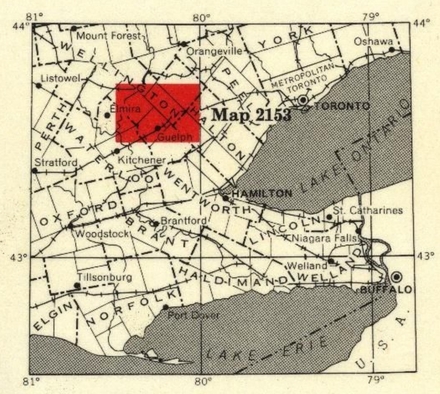
GRAVEL
MODERN
ALLUVIUM
SPILLWAY
GRAVEL

ODM810

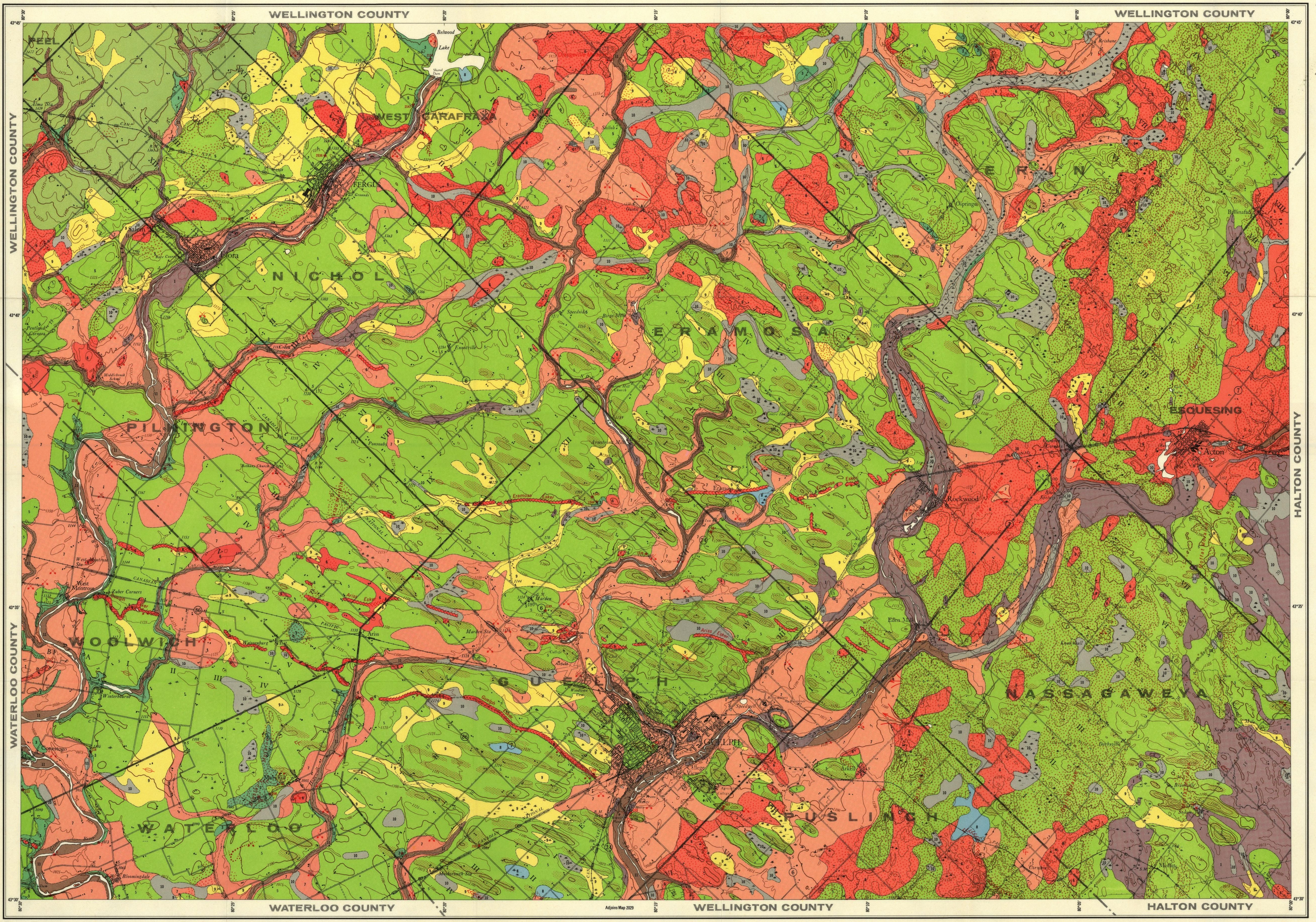
ONTARIO
DEPARTMENT OF MINES

HON. RENE BRUNELLE, *Minister of Mines*
D. P. Douglass, *Deputy Minister* J. E. Thomson, *Director, Geological Branch*

Map 2153
GUELPH AREA
Pleistocene Geology




Scale 1 inch to 50 miles




## LEGEND

CENOZOIC
PLEISTOCENE
RECENT

| | |
|---|---|
| 11 | *Modern alluvium: Gravel, sand, silt.* |
| 10 | *Swamps and bogs: Peat, muck, marl.* |

WISCONSINAN

| | |
|---|---|
| 9 | *Lacustrine, kame, and outwash sand.* |
| 8 | *Pond deposits: Silt and clay.* |
| 7 | *Outwash gravel.* |
| 6 | *Kames and eskers: Sand and gravel.* |
| 5 | *WENTWORTH TILL: Buff or pink sandy till.* |
| 4 | *Northern till: Clayey sand till.* |
| 3 | *Middle till: Brown clay till.* |
| 2 | *CATFISH CREEK TILL*: Olive, stony, silty, sand till.* |

PALEOZOIC
SILURIAN
ALBEMARLE GROUP

| | |
|---|---|
| 1 | *Guelph Formation: Dolomite. Amabel Formation: Dolomite.* |

**Exposed only in river banks under the Middle till and not shown separately.*

*Paleozoic formations are covered by thin, patchy soil.*

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

## SYMBOLS

*County boundary.*
*Township boundary.*
*Topographic contours.*
*Glacial striae.*
*Glacial fluting.*
*Outwash fan.*
*Hummocky topography.*
*Drumlin.*
*Esker.*
*Crevasse filling.*
*Geological boundary, position interpreted.*
*Quarry.*
*Sand, gravel pit.*
*Sample locality; (see report).*

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

## SOURCES OF INFORMATION

*Geology by P. F. Karrow and assistants, 1961, 1962, 1963.*

*Cartography by B. Jackson and R. M. Robertson, Ontario Department of Mines, 1967.*

*Topography directly from map 40 P/9 (East and West sheets) of the National Topographic System.*

# Map 2153
# Pleistocene Geology of the GUELPH 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

## NOTES

*For additional information refer to the following sources:*

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

*Bedrock geology: Paleozoic Geology of the Brantford Area, Ontario, J. F. Caley; Geological Survey of Canada, memoir 226, 1941.*

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*Magnetic declination in the map area approximately 6°W., 1963.*