DEPOSITIONAL

HISTORY AND PROCESSES

AT BURFORD, ONTARIO

BY

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ABSTRACT

Sediment samples were taken from the exposed facies of two quarries north of Burford Ontario. The samples were then dry sieved and the results were plotted as frequency histograms to show the type and quantity of sediment present. Moreover, measurements of soil tongues, sand lenses and strata depths were recorded to provide a comprehensive understanding of the depositional history and processes.

The above research was then combined with the present day comprehension of the depositional history of southern Ontario. The conclusions reached in this paper are useful, as they contribute and improve the understanding of the depositional history of southern Ontario.

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CHAPTER ONE - INTRODUCTION:

A) RESEARCH OBJECTIVES:

This paper studies the depositional processes and history of an area north of Burford Ontario, (see Chapter 2 for site location). The focus is on the layers of sediment exposed by gravel quarries, and the facies that are present. Depositional processes and history are important to geographers because they help provide a better understanding of the mechanisms that shaped the landscape. Using past research plus personal field studies this paper will attempt an overall description of the depositional processes that were at work at Burford, Ontario.

The first objective is to review the glacial processes that formed the landscape and were responsible for many of the sedimentary deposits that are found in the study area. The second objective is a review of the various pro-glacial lakes that existed and had a significant influences. The third is to investigate the record of glacial meltwaters and the types of deposits that may be associated with them at Burford.

To fulfil these objectives, findings from two test sites (gravel quarries), will be used to provide firsthand evidence of deposition in the Burford area. Exact definitions of the terms used, (diamict, till, etc.), are given in the appendix in order that no conflict of meanings may exist. The study area will be referred to as 'the area north of Burford' or 'Burford'--these terms are used synonymously. SI (Systeme

International) units are used throughout.

REVIEW OF WISCONSINAN GLACIAL RETREAT:

The part of the retreat of the Wisconsinan glacier that is relevant to this paper is the withdrawal of ice from southern Ontario.

Detailed information concerning the recession, is provided by Chapman and Putnam's 'The Physiography of Southern Ontario' (1951 and 1984). As the Wisconsinan glacier began to recede into Ontario there was a splitting of its front into different lobes; "...these first split apart near Orangeville or Waterloo", (MNR--26). The different ice lobes in southern Ontario were the Huron, Georgian Bay and Ontario/Erie lobes. The rift between them widened as the ice receded, see Figure 1. The land that was exposed became known as the "Ontario Island", see Figure 2, (Chapman and Putnam 1984). It was during the time of Glacial Lake Maumee that the Paris Moraine was deposited along the eastern side of the island. According to Karrow et al (1982 p. 37) and Mayewski et al (1981 p. 95) deposition occurred at approximately 14,000 yr BP, Calkin and Feenstra date the deposition to 13400 yr BP (1985 p. 152). The Galt Moraine, a major recessional feature to the east of the Paris Moraine was also deposited around 13400 yr BP, according to Calkin and Feenstra (1985 p. 152). Deposition of both moraines was from the Ontario/Erie lobe, (Chapman & Putnam 1951).

The effects of ice on the landscape were not a factor after the recession of the glacier beyond the Galt Moraine. Glacial meltwaters deposited the majority of deposits in the Burford area.

The main diamict layer formed in the study sites was deposited as an outwash plain during the period of Lake Whittlesey. Early in the history of the lake meltwaters came from both the Georgian Bay and the Ontario/Erie lobes, (Figure 3). The meltwaters broke through the Paris and Galt Moraines to extend a spillway from the glaciers to Lake Whittlesey, creating a channel which continued to discharge water from the glacial lobes after they had receded further and the drainage pattern was changed, (Figure 4). The date given by Karrow et al (1982) for the formation of Lake Whittlesey is approximately 13000 yr BP (p. 37). Mayewski et al (1981, p. 95) also support this view with a date of 13100 +/- 110 yr BP; however, their radiocarbon dates do range from 12800 +/- 200 to 13600 +/-500 yr BP.

From the map given in Chapman and Putnam (1984) and shown in Figure 5, it appears that the deposition of gravels and sands in the main diamict layer of Burford ended at the beginning of Glacial Lake Warren. At this time the drainage of meltwaters followed a more easterly route, east of Brantford, Ontario. The radiocarbon dates for Lake Warren are given by Karrow et al (1982) as approximately 12800 yr BP. Calkin and Feenstra date Lake Warren between 12500 and 12800 yr BP, (1985, p. 152).

It is at this point that the local significance of the Wisconsinan glacier recession ends. The ice, continued to retreat of course; however, beyond the effects of wind blown sediments and a periglacial climate there were no further influences of the glacier or its meltwater at Burford.

REVIEW OF GLACIAL LAKES:

With the receding of the Wisconsinan ice sheet it is not hard to imagine a large amount of meltwater being present. The four glacial lakes which are of the most importance in the Burford area are Maumee, Arkona, Whittlesey and Warren. This section will give a brief discussion of the above lakes with facts given only being those that pertain to the depositional history and processes of Burford.

LAKE MAUMEE:

According to Calkin and Feenstra (1985, p. 152) the earliest proglacial lakes "may have been narrow ice marginal ones". The first relevant one with respect to this study is Lake Maumee which existed between 14000 and 14500 yr BP. Karrow et al (1982, p. 37) date Lake Maumee between 13800 and 14200 yr BP.

Even though Burford would have been under the ice during this period, Lake Maumee is important as it was the first lake to develop because of the rift between the ice lobes of southern Ontario. This pattern may be seen in Figure 6 from Chapman and Putnam (1984), and this pattern prevailed throughout the deposition phase of Burford.

LAKE ARKONA:

Between the times of Lake Maumee and Lake Whittlesey Lake Arkona existed. Karrow et al (1982) date this lake at 13500 yr BP while Calkin and Feenstra (1985) place it between 13600 and 13800 yr BP.

Again the Burford area is still under ice and it is the period when Lake Arkona diminishes to what was called Lake Ypsilanti. During this period the Paris and Galt moraines were deposited, 13500 yr BP and 13400 yr BP respectively (Calkin and Feenstra 1985). Therefore, it was also during this period that the study areas were finally uncovered from ice. It must also be noted that the drainage of the lakes remained the same as it originally began, following the western front of the Ontario/Erie lobe. It may be seen that this pattern persists with the two following lakes, Whittlesey and Warren.

LAKE WHITTLESEY:

Lake Whittlesey is by far the most important of the proglacial lakes in terms of the amount of deposition at Burford. Calvin and Feenstra state that this lake is the best-developed in the great lakes region, and "...the inception of lake Whittlesey at about 13000 BP". As noted above in the review of the retreat of the Wisconsinan glacier, the spillway which was developed was very large and prominent. It was between the Paris and Galt Moraine and spilled along the western front of the Ontario/Erie ice lobe into Whittlesey. The delta that developed at this location is now called the Norfolk Delta and/or sand plain. Burford is found between the Paris and Galt moraines at the northern part of the Norfolk sand plains.

There was a second phase of Lake Whittlesey where meltwaters continued to have an influence on the deposition of Burford. The retreat of the Ontario/Erie ice lobe continued such that the spillway shifted with it, as it had done all along with the growth of the Ontario Island; however, there remained an intermitent spillway were the former spillway existed. The continued use of the old spillway allowed meltwaters to continue depositing sediment at Burford.

LAKE WARREN:

Lake Warren appeared around 12800 yr BP, according to Calkin and Feenstra (1985). The beginning of Lake Warren marks the end of the deposition of the majority of sediment in the Burford area. The main diamict layer found at these locations was laid down and the time for the deposition of the upper layers had begun.

The shore line of Lake Warren was at most only 40 m below that of Lake Whittlesey, (Karrow et al 1982). It was a period where local drainage became the prominent force in developing the landscape and the majority of deposits were from wind blown sediments.

There were further glacial lakes of course; however, they were shallow and did not influence deposition in the test area.

REVIEW OF OUTWASH PLAINS:

"Outwash plain" and "sandur" are synonymous in this paper. According to Eyles "there are six different types of principle facies assemblages in gravel and sand dominated braided rivers", three are found in outwash rivers, (Eyles 1985, p. 180). The three types of outwash rivers are Scott-type, Donjek-type and the Platte-type, named after different modern outwash rivers. The Scott-type most resembles the outwash deposits found in Burford.

Ritter (1986, p. 400) defines a sandur as sediment spread into a large plain from debris filled stream channels that display continuous lateral shifting. These braided streams are created by the "simultaneous interaction of a number of factors", (Ritter 1986, p 239). The most important of them are: 1) Erodible banks.

2) Sediment transport and abundant load.

3) Rapid and frequent variations in discharge.

See Figure 7.

The Scott type of sandur given by Eyles (1985, p. 180) is named from the Scott outwash fan in Alaska. Its assemblage typifies the proximal part of this river. Eyles (1985, pg. 176) states that the Scott type is a proximal, gravel-dominated river; the main facies are massive or crudely bedded. The minor facies include gravel stratifications, sands ranging from fine to coarse making up ripples, waves and dunes, and some sand-silt lenses.

CHAPTER 2 - STUDY SITE:

A) SITE LOCATION:

Burford is located in the south western section of southern Ontario. The town is located along Hwy 53 in the western Brant county, Figure 8.

The actual location of the test sites are 1.2 km (Site 1) and 1.4 km (Site 2) from Burford along Maple Ave, measurements beginning at the junction of Maple Ave. and Hwy 53. The first site is on the west side of Maple Ave, 400 m from the road, on the southern side of Whitemans Creek. The second site is on the east side of Maple Ave, 500 m from the road, on the northern side of Whitemans Creek.

Precise locations on the topographical map of Brantford, Ontario are: Site 1, Latitude 43077304, Longitude 80264600; Site 2, Latitude 43077402 and Longitude 80264602.

B) SITE DESCRIPTIONS:

Details that will be discussed at each site will be the appearance of the sites before any field work began, the dimensions of each gravel quarry including the height of the exposures present, and the surrounding landscape features which are important in explaining the depositional processes.

Site 1 is a privately owned quarry that provides gravel for farm uses. The amount of gravel extracted from this site is quite limited; a vegetation cover is able to establish itself on the talus between extractions (Figure 9). As may be seen in the picture of Site 1, most of the cliff face is covered by talus. It was necessary to dig into the talus to expose the cliff face. At least half of the quarry is not used at all today and, as a note of interest, this portion has grown in with shrubs and trees.

The dimensions of Site 1, including the over grown portion, are approximately 4000 m squared; the total height from the floor of the quarry to its top was roughly 8 metres. The portion of the quarry that appears in the photograph in Figure 9 shows the ground surface to the top of the quarry. The width of the Figure--the location of the field work--is 6 metres.

Whitemans Creek is a small creek that runs approximately west to east, emptying into the Grand River. Surface drainage of the area is towards the creek. The topography of the region is generally fairly flat, with a slight downward slope towards the Grand River.

Site 2 is a public owned quarry that provides gravel and sand for the Township of Burford. Compared to Site 1 the amount of gravel extracted is very large; there are daily removals (figure 10). The gravel extraction is quite extensive, so that a large, open cliff face is exposed.

The size of the second quarry is 15.4 Ha with about one third of the area being active at present. The total height of the quarry from the floor to the top of the cliff face is around 9 metres. Figure 10 shows nearly all of the active portion of Site 2.

Like Site 1 the most important feature is Whitemans creek--again the surface drainage of the area is influenced by this body of water. The topographic slope is also towards the Grand River further east.

CHAPTER 3 --- METHODOLOGY:

FIELD ANALYSIS:

The methods used for field study were fairly simple; no instruments were used beyond a tape measure and a compass. Measurements were made of the quarry, the exposed cliff face, individual layers and depositional features. Sediment samples were taken for laboratory analysis and photographs for use as reference. Measurement of the quarry area, given in the site description above, was by pacing at Site 1, and through the Township of Burford for the Site 2. Pacing, of course, only gives an approximation of the actual size of the quarry; however, accuracy here is not of any great importance to the final conclusions.

The cliff face was measured from the top of the quarry down to floor. Individual layers were determined at the same time as the surveying of the cliff face was taking place. Special features such as soil tongues and sand lenses were measured by placing nails at the defining edges of each feature and then measuring between these markers.

Sediment samples for laboratory analysis were taken with a garden trowel, pail, shovel, and a hammer. First, the sites for the sediment samples were chosen at 0.3048 metre intervals in the diamict. The shovel and/or hammer were used to clear the surface sediments away so that materials untouched by weathering were exposed. Special care was taken to ensure that both sand and gravel sediments were extracted in their proper proportions.

LABORATORY ANALYSIS:

The sediment samples were analysed in the laboratory by the dry sieving method:

1. Dry the sample.
2. Weigh sample and record weight.
3. Subdivide the sample, carefully obtaining a fair representation.
4. Weigh the sub-sample and record weight.
5. Select an appropriate set of sieves, coarsest at the top.
6. Place sub-sample in the top sieve.
7. Place the sieve stack on the sieve-shaker.
8. Shake for 10 minutes.
9. Weigh the sediments of each individual sieve and record.

The results of the dry sieving were then graphed into frequency histograms and cumulative frequency grain-size curves--as in Chorley, (1984).

CHAPTER 4 - RESULTS:

FIELD ANALYSIS:

At Site 1 the exposed portion of the quarry faced to the north; therefore, it would be reasonably protected from weathering--especially from the prevailing south-westerly winds. First impressions of the cliff face suggested that there were two very distinct strata ('A' & 'B'); however, under closer scrutiny it was found that the top stratum was made up of several layers which were not as well defined. For their location please refer to Figure 9.

Layer 1 has a clay/silt content with some clasts present. Layer 2 is quite similiar, but there is an increase in the amount of stratification. In Layer 2, this is better defined and the layer is quite compacted. The increased stratification of Layer 2 may be seen quite well in Figure 11; the layer shows up as a lighter shade of grey. Also there are a few clasts present; however, their frequency decreases compared to Layer 1. Layer 3 of stratum 'A' is quite unusual. It is the boundary between strata 'A' and 'B', (Figure 12). Layer 3 is a reddish brown in colour and has a higher moisture content than the other layers. The sediments will clump together, suggesting a clay/silt content; and the clasts found within the matrix are similar to those found in stratum 'B'. The depth of this layer is also quite variable, being at its greatest in the soil tongues. Layer 3 also has the attribute of wedging and staining into strata 'B'. Which simply means the components of Layer 3 are leaching into the lower strata uniformily, except at the soil tongue regions, where the downward leaching is in a wedge shape and thicker.

The most striking feature of stratum 'A' are the soil tongues. As may be seen in Figures 9, 11, & 12 the shape and size of the tongues varies across the exposed face. The sediment found in them is a silt, but there are a also few clasts present. The contact between the sediments of the soil tongue and Layer 2 is quite distinct in all instances. The soil tongues also had a tendency to be directed towards Whitemans Creek. They are interpreted as the remnants of channel cuts.

In all of the layers of stratum 'A' there are various size clasts of various sizes found within the matrix. All of the clasts are rounded or smoothed, except where frost shattering has occurred. Often with shattered examples the clast was intact until handled, at which time it broke into pieces.

The presence of the larger clasts in stratum 'A' would likely be due to the action of frost forcing them up from stratum 'B' towards the surface. There is also the possibility, however, that the clasts may have been deposited there from ice floes.

Thicknesses of the different layers of stratum 'A' are: Layer 1 = 0.256 m; Layer 2 = 0.106 m; Layer 3 =0.089m; Soil tongue height = 0.305 m, width = 0.368 m.

Again, it is stressed that the size and shape of the soil tongues are quite variable. The depth measurement for each of the soil tongues is fairly consistent, especially with the best developed examples.

Stratum 'B', Site 1, is a very large diamict layer that is quite loosely compacted; its depth is 7.03 m from the quarry floor to stratum 'A'. There is a large amount of gravel in this layer but it has a sand matrix, and clasts are supported by the sand. There are some distinctly stratified layers, and others without apparent structure. There was a little variation in the size of the gravel/clasts with in the stratified layers. In all instances the clasts are rounded and smooth. The sand grains are also a block shaped rather than a sharp jagged form.

Within the diamict there are sand lenses of different sizes, all of which are slightly stratified and clast filled at their lower ends. This feature may be seen in Figure 13 of Site 2.

Site 2 also has two distinctly different deposits--again referred to as 'A' & 'B'. This time the 'A' stratum is not as well defined; however, the diamict layer (stratum 'B') is very well exposed.

Stratum 'A' characteristics are similar to that of Site 1. The depths of Layers 1 and 2 are 0.165 m and 0.203 m respectively. It may be seen that Layer 1 at Site 2 is less distinctive than at Site 1, but Layer 2 is similar to Site 1's

Layer 2.

Layer 3 is very comparable to that of Site 1, measuring 0.092 m.

The soil tongues at Site 2 are not as distinctive as those at Site 1. They are generally smaller and less frequent; It must be noted that this second test site is further from Whitemans Creek than the first site. The intrusion of Layer 3 into the stratum 'B', both by wedging and staining, is also less than at Site 1.

Stratum 'B', Site 2 is very well exposed because of the current quarrying operations. This diamict, like that at Site 1, is stratified, matrix supported, consisting of gravels and sands, and has plenty of sand lenses. The exposed depth of the diamict Layer is 8.458 m, from the floor of the quarry to the base of stratum 'A'.

LABORATORY ANALYSIS:

In the laboratory, sediment samples were dry sieved, as described above. Only gravel and sand could be analyzed by this method. Therefore, sieving was limited to the diamict layers of Sites 1 and 2. For both test locations the results of the sieving were similar.

Site 1 results of the sieving process produced a histogram with a high concentration of fine gravels and coarser sands, and a decreasing amount of finer sands, (Figure 14). The gravels are very high in the phi -3 range as there are an abundance of larger gravels.

Site 2 had a similar histogram. However, there was less coarse sand and more medium size sand, (Figure 14). The results of the gravel were similar to that of Site 1. Since both sites had similiar results only one stratigraphy was drawn, it may be seen in Figure 15.

Also graphed were cumulative frequency grain-size curves for both test sites. In these curves it may be seen that there is a slight difference in the grain sizes between the two sites; however, the shape of the distributions are similar, (Figure 16).

CHAPTER 5 - DISCUSSION:

In comparing the histograms and the cumulative frequency graphs, and by the description given it may be confidently stated that the study areas are deposited from the same conditions. Therefore, stratums 'A' and 'B' will be discussed on a general level pertaining to both sites.

STRATUM 'A':

The first layer at the top of the cliff face consists of a sandy loam with a few small pebbles. Grubb (1973, p. 9), states that the Horizon 'A' is "mostly loamy sand except at Brantford where the profiles are siltier." Brantford is lies ten to fifteen kilometres from Burford, and according to Chapman and Putnam's physiographic map (1951), Brantford is also in a sand plain similar and linked to the Norfolk sand plain. Chapman and Putman (pg. 153) further describe the Norfolk sand plain as being a "wedge shaped with a broad, curved base along the shore of Lake Erie and tapers northward to a point at Brantford on the Grand River."

These authors continue by claiming that the type of depositional process for these sands and silts was that of a delta for the deglacial lakes Whittlesey and Warren. It was pointed out earlier, however, that the beaches of those two glacial lakes did not extend as far north as Burford; therefore, the deposits at the study sites are not those of the delta mentioned by Chapman and Putnam.

It is suggested that stratum 'A' was deposited under low water velocity conditions with slightly different velocities causing the different layers examined.

Grubb (1973, p. 10) describes Layer 2 in the Brantford locality as being "0 to 20 cm thick, very dark greyish brown (10YR3/2m) loam, medium granular or platy; friable; common very fine to fine roots; pebbles rare; sharp even boundary; no HCL reaction." This description does not completely fit the layer found in the Burford area as the matrix of Layer 3 is not loam but clay, and there are clasts present.

Layer 3 in Burford is divided into two horizons in the Grubb study of soil tongues. As described above, Layer 3 divides the two stratum. This upper layer of Layer 3 may be seen in Figure 12, and is found between the dark brown layer and the pocket knife. Grubb (1973 p. 10) describes this horizon as being "brown to dark brown (7.5YR4/2m) loam, with streaks of bleached (10YR7/1m) quartz grains along the surfaces of structural units; fine to medium platy; firm; few, very fine roots; clear, slightly wavy lower boundary no HCL reaction." This section of Layer 3 at Burford does have similar characteristics with the exception that there are a few clasts present.

The lower horizon of Layer 3--in the Grubb study--is similar to the Burford Layer 3 observed at the study sites. Grubb (1973, p. 11) describes this horizon as a "dark reddish brown (5YR3/3m) gravelly, coarse sandy loam; fine sub-angular blocky; friable; few, very fine roots; lower boundary clear to diffuse and very irregular with shallow to deep tongues extending into the under lying horizon; numerous pebbles, mainly weathered and very friable; weak HCL reaction." According to Grubb and Bunting (1976, p. 250) Layer 3 "formed in situ is are of pedogenic origin [which] is indicated by the active weathering of carbonate pebbles and the deposition of clay. Yehle (1954) states that Layer 3 "results from the localization of soil forming processes." Grubb (1973, p. 81) further suggests that "the existence of a blanket of fine material overlying a course gravel deposit would tend to hold water at the interface and initiate a weathering front."

In the soil tongues there are pockets of sediment that differ significantly from the Layers 2 and 3. These pockets are clay and/or silt deposits with a low frequency of pebbles present. One of these pockets may be viewed in Figure 12--to the left of the knife. Grubb and Bunting decide, agreeing with Yehle, that these pockets of sediment are silt deposited in a fluvial channel.

Since there is no deformation of the sediment above the clasts found in stratum 'A', then it is suggested that the clasts here were deposited by ice floes.

STRATUM 'B':

The diamict layer or stratum 'B' is entirely sand and gravel deposited in a massive layer with local, poorly differentiated stratification.

The Ministry of Natural Resources (1981, p. 9) states that "the sand and gravel were deposited in an outwash plain on the west side of the Paris Moraine." This outwash plain also existed on the east side of the Paris Moraine, west of the Galt Moraine. The Ministry of Natural Resources reports (1981 p. 10) that there is a 60% stone content with numerous sand lenses, and that the total face height is 14 metres, six of which are below the water table and under water (1981, p. 15).

The results of the laboratory work for this paper certainly support these findings with respect to the proportions and size of gravel and sand present.

A notable feature is the leaching of Layer 3, in stratum 'A' down into the diamict below. This leaching is continuous across the top of stratum 'B', but it is especially concentrated below the fluvial channels in the diamict layer, resulting in the formation of soil tongues. Due to the easy movement of water through the diamict it is logical that fine sediments may pass from the stratum above. The weathering front between the two strata provided an increased water holding capacity--the leaching of this weathering front would be concentrated in the fluvial channels--thus the formation of the soil tongues, (Figure 17).

The soil tongues described by Grubb and Bunting are located further east at Brantford and Freelton. The soil tongues at Brantford trend "towards the nearby Grand River and it is suggested that they form part of an integrated drainage system...." Also the tongues described by Grubb and Bunting are larger and deeper than those found at Burford. The Burford tongues, as noted above, trend towards Whitemans Creek. This actuality supports the conjecture that these soil tongues are in fact channel cuts forming a part of an integrated drainage system. The different sizes of the soil tongues reported in the two studies may be a result of the different scales of the Grand River and Whitemans Creek. There is also a difference in the frequency of soil tongues between Site 1 and Site 2. Site 1 has more soil tongues, but the same reddish layer separates stratum 'A' from that of 'B' in both instances.

CHAPTER 6 - CONCLUSION:

To conclude, a chronological description of the sequence of deposition will be given for the study area.

As stated above the relevant information with respect to the retreat of the Wisconsin glacier begins when the ice sheet divided into different ice lobes to form the Ontario Island. The relavent lobes which concern Burford were the Gorgian Bay and Ontario/Erie.

The Georgian Bay lobe is important because of all of the sediment that is eroded from it, and because of the large amounts of meltwater that flowed from its front. The meltwater from the Georgian Bay lobe flowed along the Ontario/Erie front creating the deglacial lakes, Maumee, Arkona, Whittlesey, and Warren.

The Ontario/Erie lobe is important in the deposition of the Burford area as it is the ice lobe that directly covered the study area. No deposition could have occurred until the lobe retreated away from the study sites. The Paris and Galt moraines were both deposited by the Ontario/Erie ice lobe as it was in situ. This fact is important as the development of these moraines led to a topography that encouraged a spillway to develop between them, spilling into the area north of Burford.

The most important era of deposition in Burford was the time of Lakes Whittlesey and Warren, around 13000 and 12000 years before the present. The main diamict layer--stratum 'B'-

-was deposited under spillway or outwash plain conditions. Meltwaters from the Georgian Bay and Ontario/Erie lobes flowed along the Ontario/Erie ice front and between the Paris and Galt moraines into Lake Whittlesey, forming a delta to the south of Burford. The test locations north of Burford are too high in elevation to have been a part of the delta that makes up the Norfolk sand plains.

Lake Warren also was a time of outwash plain deposits, and it likely marked the end of such deposition at Burford. The Ontario/Erie lobe had further retreated and most of the meltwater was flowing to the east around the Brantford--Grand River locality. There was, however, a remnant of the spillway discharge still flowing between the Paris and Galt moraines. This 'old' spillway marked the beginning of the end of the outwash plain, and was the beginning of Layer 3 development. During this period local drainage would start and new channel cuts would form (Grubb and Bunting 1976).

The further reduction of the 'old' spillway led to decrease in flow in the channels on the outwash plains. This endorsed deposition of the finer sediments that today fill in the channels--above the soil tongues. Grubb and Bunting (1971) considered two possible depositional processes for the sediments found in the channels in stratum 'B'. These processes are loess and fluvial deposits. This paper supports a combination of the two, based on the small number of pebbles and fine gravel found in this deposit; if wind blown sediments were entirely responsible for infilling the channels then it is doubtful that any pebbles/gravels would be present, (Figure 12).

The deposit above the diamict--stratum 'A'--is also attributed to the lessened meltwater drainage, being made up of clays/silts and sand. Gravel in stratum 'A' is surprisingly large given the suggested depositional environment. Reasons for this may be frost upheaval of gravel from the lower diamict, or erosion of higher portions of the outwash plain into the lower regions.

These conclusions summarize of the depositional history and processes involved at Burford, Ontario. The main diamict layer of gravels and sands is interprited with confidence, while there are some difficulties in explaining the deposits above it. In speaking with officials of the Township of Burford it was learned that beneath the diamict layer there is a deposit which was referred to as a 'blue' clay. Unfortunately this 'blue' clay is about 6 metres beneath the water table and was not accessible at the study areas. Perhaps the deposition of this layer is tied to the Ontario/Erie ice lobe--being a till and not blue clay. Further study, however, is necessary to provide the answer.

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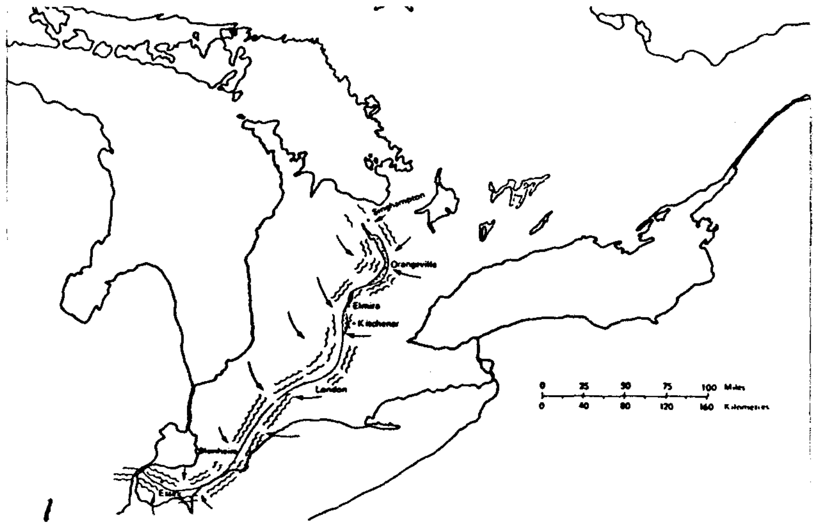
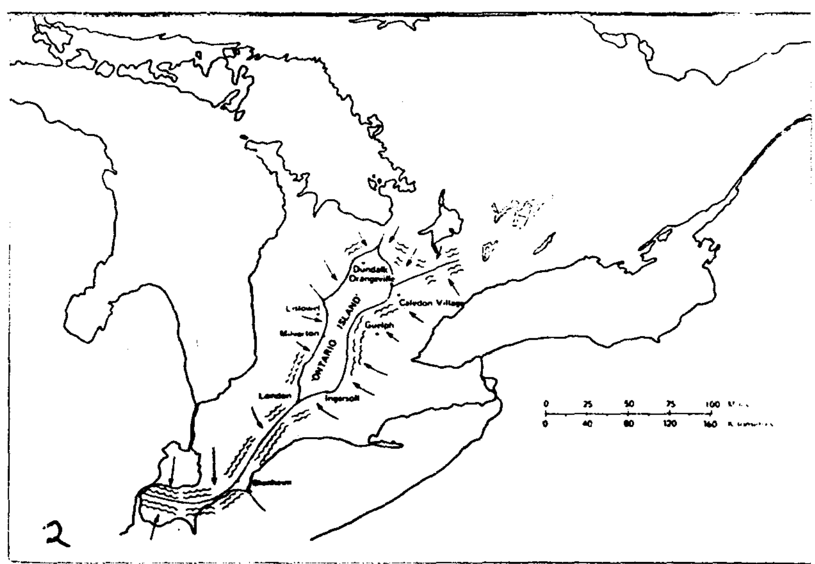
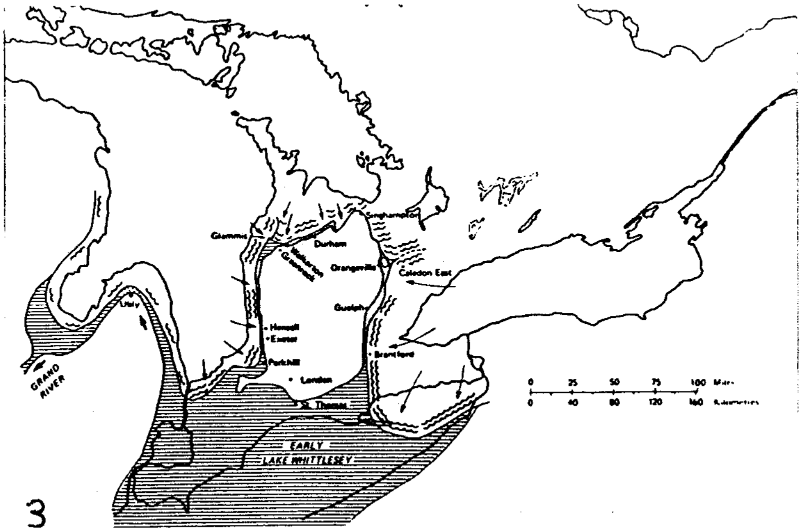




<u>FIGURE #1</u>: Shows the rift that separated the different ice lobes in southern Ontario, it was responsible for shaping the topography of southern Ontario. (Chapman & Putnam 1984)
<u>FIGURE #2</u>: Shows the separation of the ice lobes and the early development of the Ontario land island. (Chapman & Putnam 1984)



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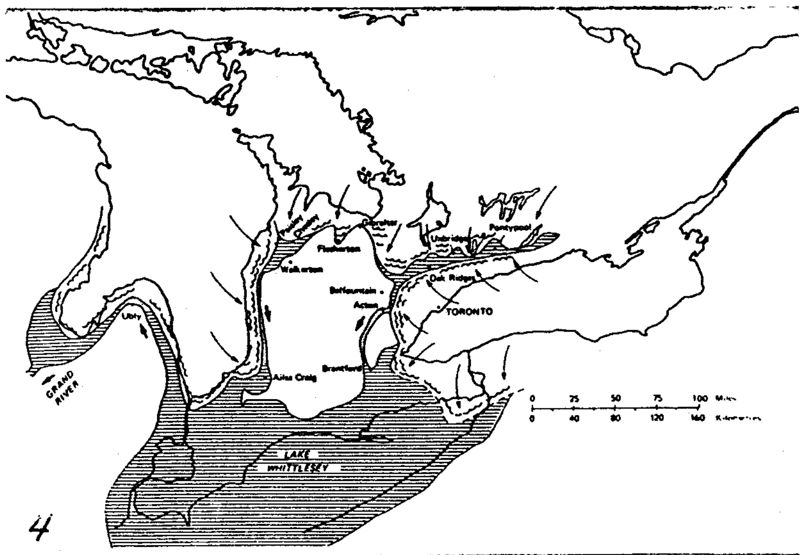

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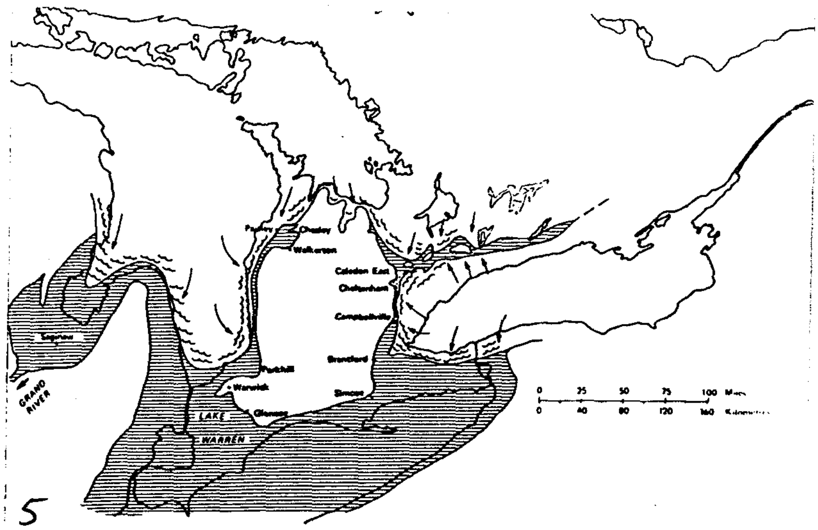
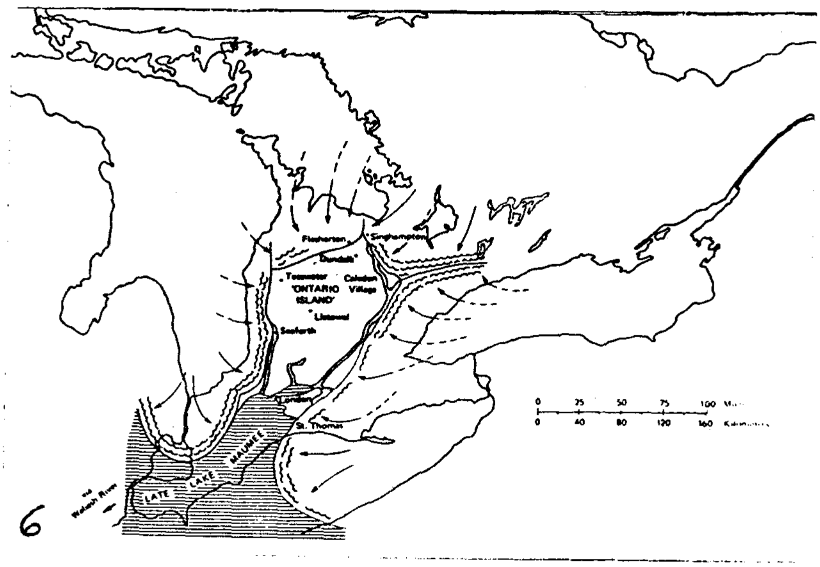
<u>FIGURE #3</u>: Demonstrates how the meltwaters came from the Georgian Bay and Ontario/Erie ice lobes. (Chapman & Putnam 1984)
<u>FIGURE #4</u>: Demonstrates a later time period where the spillway has changed with the ice recession, and the old spillway becomes intermittent. (Chapman & Putnam 1984)





<u>FIGURE #5</u>: This map depicts the end of the deposition by glacial meltwater. The shift in the deglacial drainage away from the Burford area marked the beginning of Lake Warren. (Chapman & Putnam 1984)

<u>FIGURE #6</u>: Depicts the drainage pattern in the Ontario island that helped shaped the topography of southern Ontario.

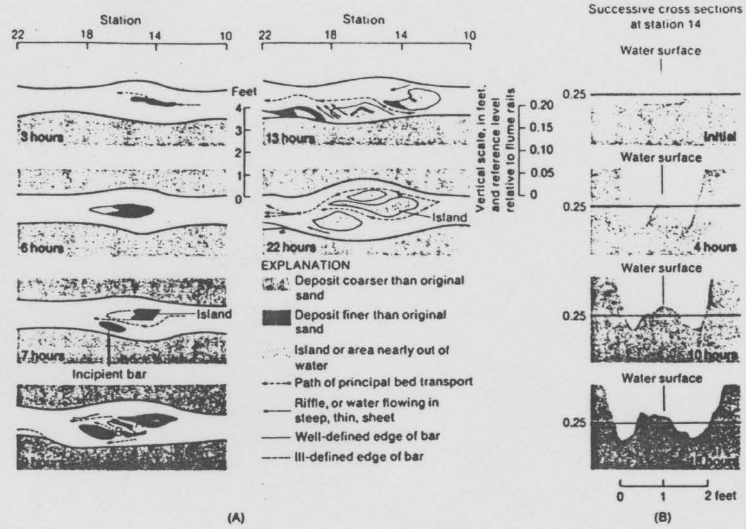


Figure [redacted] 7
Stages in the development of a braid in a flume channel.
(A) Sequential development of the pattern at various times. (B) Cross sections at one station along the flume (From Leopold and Wolman 1957)

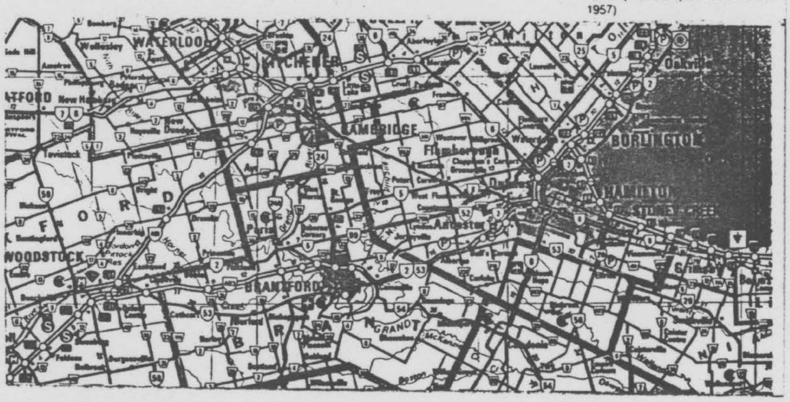
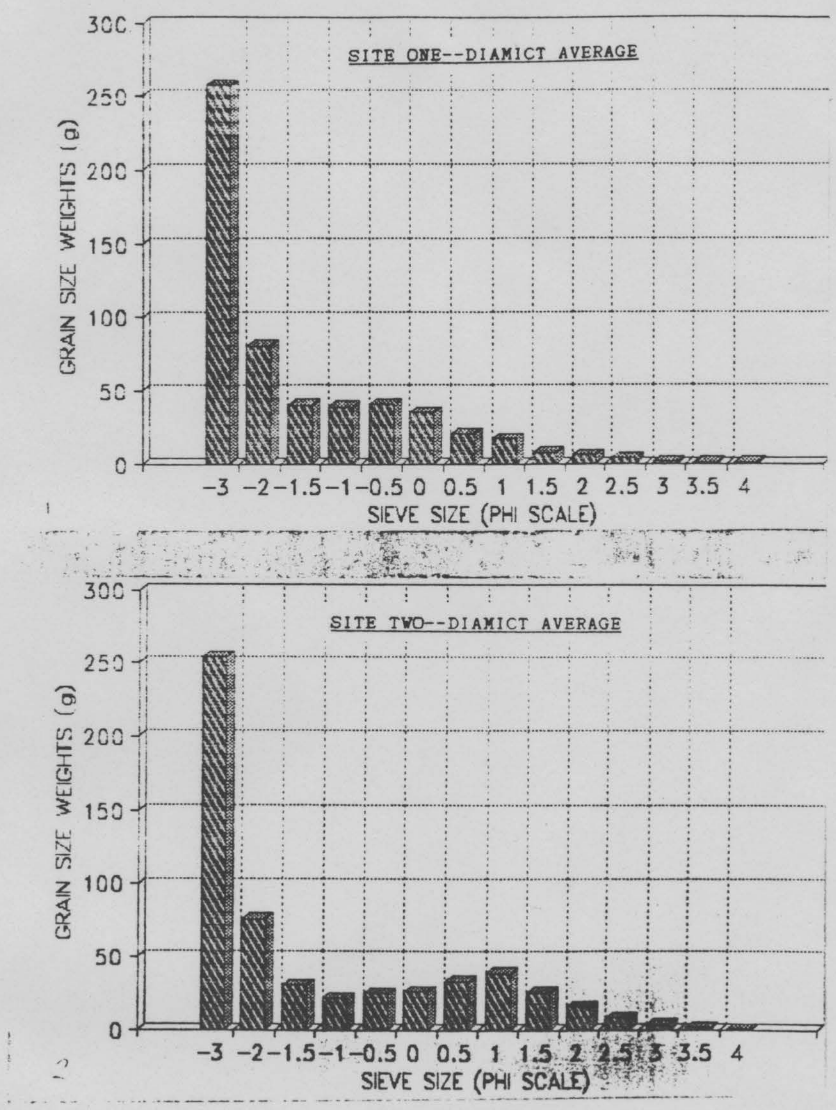


FIGURE #8: Map provides the location of study area with respect to southern Ontario. The town of Burford is circled in red.

FIGURE #9: Picture shows study Site 1, note the shovel in lower right corner for scale.
FIGURE #10: Picture shows study Site 2.

FIGURE #11: Layer 2, in stratum 'A', is the light grey layer. Notice the increased stratification of Layer 2 compared to Layer 1 above, this may be due to agricultural tillage.
FIGURE #12: A typical soil tongue found at Site 1. Layer 3 may be seen here as the dark, red between Strata 'A' and 'B'. Notice the clasts to the right of the knife, and just below the red marker. Clasts suggest a fluvial deposition rather than a loess deposit.

FIGURE #13: A sand lense found at Site 2. Notice the difference from top of the lense to the bottom in the depositional content. Size of sand lenses varied; and help support outwash plain concept. This feature was also present at Site 1.



<u>FIGURE #14</u>: Site 1 and 2 histograms of stratum 'B' show the relation of sediment sizes with respect to each other. Both cases display a large amount of gravel tapering down to fine sands.

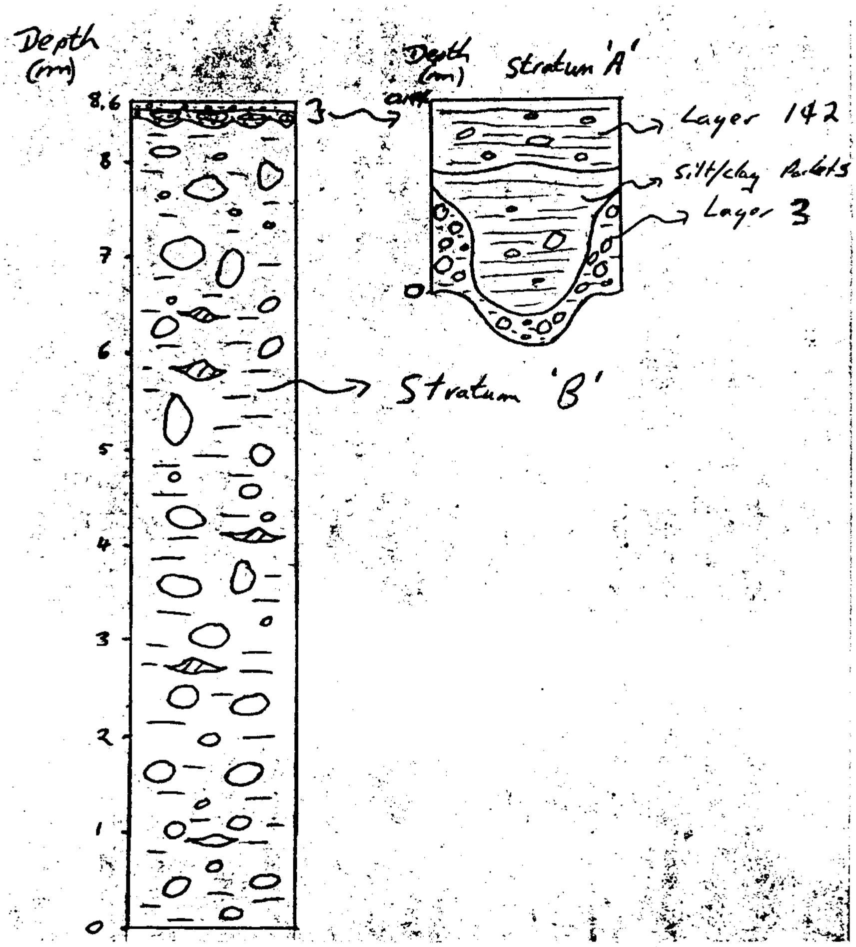


FIGURE #15: The stratigraphy shown is drawn to scale, with 2 cm equivalent to 1 m. The difference in the sizes of stratum 'A' and 'B' is quite evident; and the depth of stratum 'B' is only that exposed by quarrying practices. The importance of the outwash plain mechanisms is certainly shown to be quite prominent.

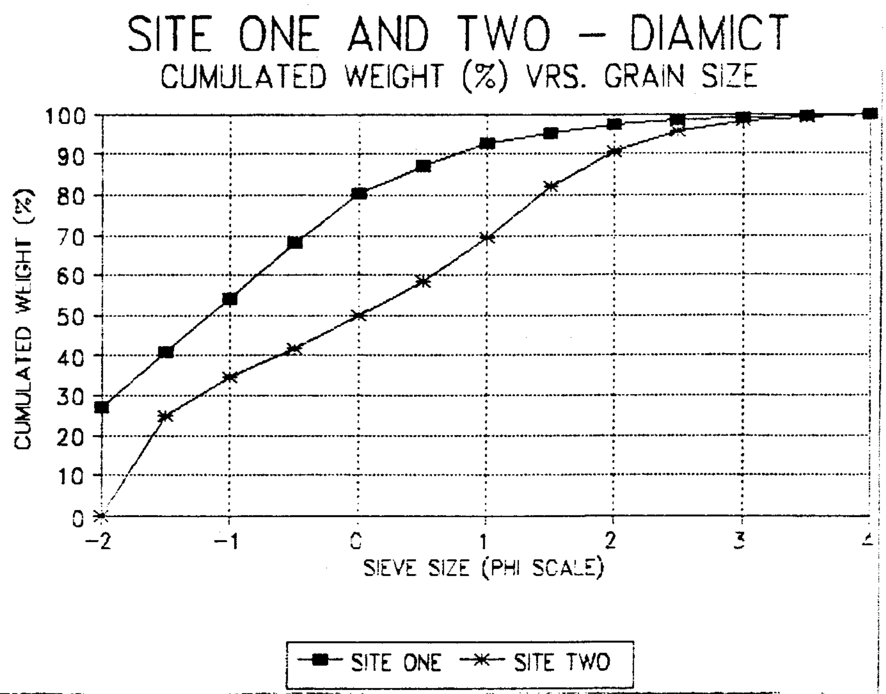


FIGURE #16: Cumulative frequencies for both Sites 1 and 2. Other than the slight dip in Site 2 in the medium sized sands both curves are similar.

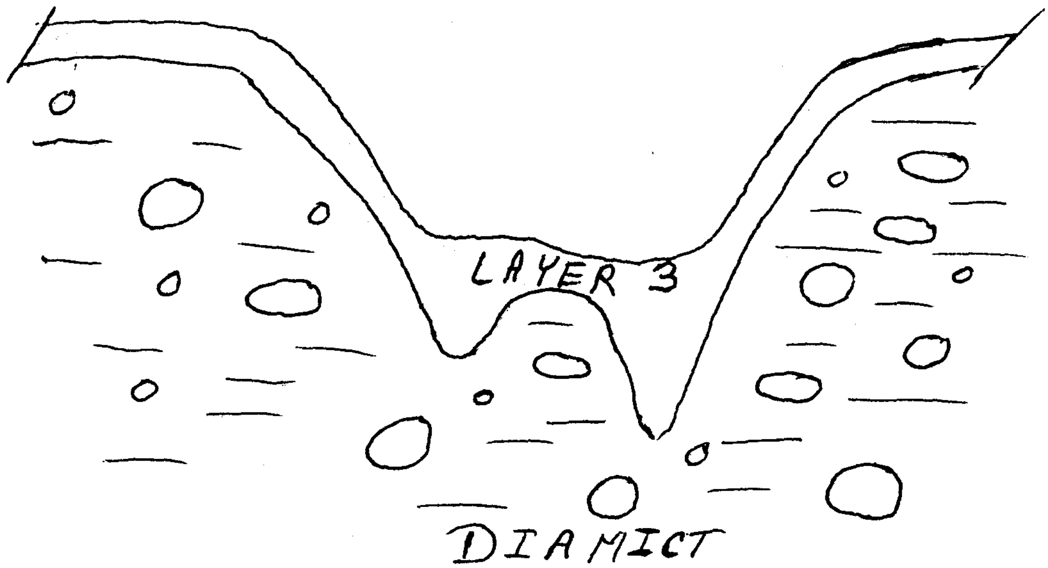


FIGURE #17: Soil tongues developed because of the channel cuts in the diamict. Layer 3 is the weathering layer following the outwash plain deposition. The leaching of Layer 3 is concentrated in the bottom of the channel cut due to the increased and sustained amount of water present. This increased amount of water causes extended leaching and thus the formation of the soil tongues.

APPENDIX (Symbols and abbreviations)

moraine: a depositional feature whose form is independent of the subjacent topography and that is constructed by thy accumulation of drift, most of which is ice-deposited.

diamict: any poorly-sorted gravel-sand-mud admixture regardless of origin.

till: sediment originating directly from glacial ice and typically is a non-stratified mass of unsorted debris that contains angular particles composed of a wide variety of rock types.

loess: a homogeneous unstratified silt, up to 100 m thick, which is highly porous and has the capacity to maintain vertical or nearly vertical slopes.

yr BP: abbreviation for 'years before the present'.

delta: a depositional plain formed by a river at its mouth, where the sediment accumulation results in an irregular pro-gradation of shoreline.

sandur/outwash plain:
large plains of sediment which was deposited by the continuous lateral shifting of a debris filled stream channels.

braided stream:
a river channel that divides into a network of branches and the growth and stabilization of intervening islands.

talus: refers to the accumulated debris eroded from a cliff face and deposited at the base of the cliff face.

clast: refers to any sediment larger than sand.