The Surficial Geology, Sedimentology and Geochemistry of the Late Glacial Sediments and Paleozoic Bedrock in the Campbellford Area, Ontario, with Special Reference to the Dummer Complex.

by

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ABSTRACT

The Dummer Complex extends 180 km along the Precambrian - Paleozoic contact from Tamworth to Lake Simcoe. It is composed of coarse, angular Paleozoic clasts in discontinuous, pitted, hummocky deposits. Deposits are usually separated by bare or boulder strewn bedrock, but have been found in the southern drumlinized till sheet. Dummer Complex deposits show rough alignment with ice-flow. Eskers cross-cut many of the deposits.

Dummer sediment subfacies are defined on the basis of dominant coarse grain size and lithology, which relate directly to the underlying Paleozoic formation. Three subglacial tills are identified based on the degree of comminution and distance of transport; the immature facies of the Dummer Complex; the mature facies of the drumlinized till sheet and; the submature facies which is transitional.

Carbonate geochemistry was used for till-bedrock correlation in various grain sizes. Of the 3 Paleozoic formations underlying the Dummer Complex, the Gull River Fm. is geochemically distinctive from the Bobcaygeon and Verulam Formations using Ca, Mg, Sr, Cu, Mn, Fe and Na. The Bobcaygeon Fm. and Verulam Fm. can be differentiated using Ca and the Sr/Ca ratio. The immature facies from 1.0 phi and finer is dominated by the non-carbonate, long distance transported component which decreases slightly downice. The submature till facies contains more long distance material than the immature facies. Sr and Mn can be used to correlate the Gull River immature till facies to the underlying bedrock the other subfacies could not be distinguished from each other or their respective source formation. This method proved to be ineffective for sediments with greater than 35% non-carbonate component, due to leaching of elements by the dissolving acid.

The Dummer Complex is produced subglacially, as the compressional ice encounters the permeable Paleozoic carbonates. The increased shear strength of the ice and pore pressures in the carbonates results in the basal ice zones becoming debris ladden. Cleaner ice overrides the basal debris laden dead ice which then acts as the glacier bed. During retreat, the Simcoe lobe stagnates as flow is cut-off by the Algonquin Highlands.

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I wish to dedicate this work to my family, who without their strength and understanding, this would not have been accomplished.

Dedicated with love
to
Johnny and Mom

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1.0 INTRODUCTION

1.1 General Statement

The Dummer Moraine is a late glacial feature found along the Precambrian - Paleozoic contact consisting of discontinuous patches of sediment with very coarse, angular Paleozoic clasts. The Dummer Moraine extends as a broad belt from Lake Simcoe to north - east of Kingston.

In recent years there has been renewed interest in a late Wisconsin glacial feature known as the Dummer Moraine. Schluchter (1979), Gadd (1980), and Terasmae (1980) have addressed the problem of the genesis of the Dummer Moraine and its stratigraphic correlation to other features related to the deglaciation of Southern Ontario. This interest has come to the forefront because of the rapidly increasing understanding of ice dynamics through work on modern glaciers.

The commonly used term for referring to this deposit is the "Dummer Moraine", for purposes of this study the term "moraine" will not be used, as the word itself implies a genetic meaning. Rather, the author will use "Dummer Complex" when referring to the feature in general, and "Dummer Complex sediment" or "Dummer Complex till" when referring to the sediments of which it is composed.

1.2 Previous Work

The Dummer Complex has been studied by a number of workers. Early regional studies by Spencer (1889) and Coleman (1890) refer to the feature but it was during the 1950's and 1960's that most of the work on the complex was done by the Geological Survey of Canada. Gravenor (1957), Mirynech (1962) and Henderson (1966) mapped portions of the Dummer Complex and and interpreted the feature as a recessional end moraine. Chapman and

Putman (1966) in their classic work mentioned the Dummer Complex and some of its most striking characteristics and refer to the Complex as a moraine. The Dummer Complex is also a recognized feature on the Glacial Map of Canada (Prest, 1970).

More recently, Schluchter (1979) did more detailed work on the Dummer Complex in the Norwood area and suggested that the feature could be the result of ice dynamics and not necessarily an end moraine. Terasmae (1980) discusses the Dummer Complex as a major geochronological problem, as extensive work in the area has provided no evidence for the moraine's formation. He suggested that it represents an ice stagnation feature produced as the ice thinned along the Algonquin Highlands during the last stages of deglaciation, was cut off, and thereby down wasted in situ. Gadd (1980) discusses the Dummer Complex and suggests it is not a moraine, but rather a feature produced by its' unique geological setting, referring to the fact that the Dummer Complex lies a short distance from or right along the Precambrian - Paleozoic bedrock contact.

1.3 Purpose

The purpose of this study was to map and investigate the "Dummer Complex" in terms of morphology, sedimentology and its' relationship to other glacial and non-glacial features in the map area.

Specifically the purpose was to map the surficial geology of the west half of the Campbellford NTS sheet at a 1:50,000 scale. To determine the relation between the Dummer Complex and the associated sediments in terms of spacial and stratigraphic position. Investigate the lithology of Dummer sediments and correlate to bedrock geology. Define the sedimentary facies, and facies

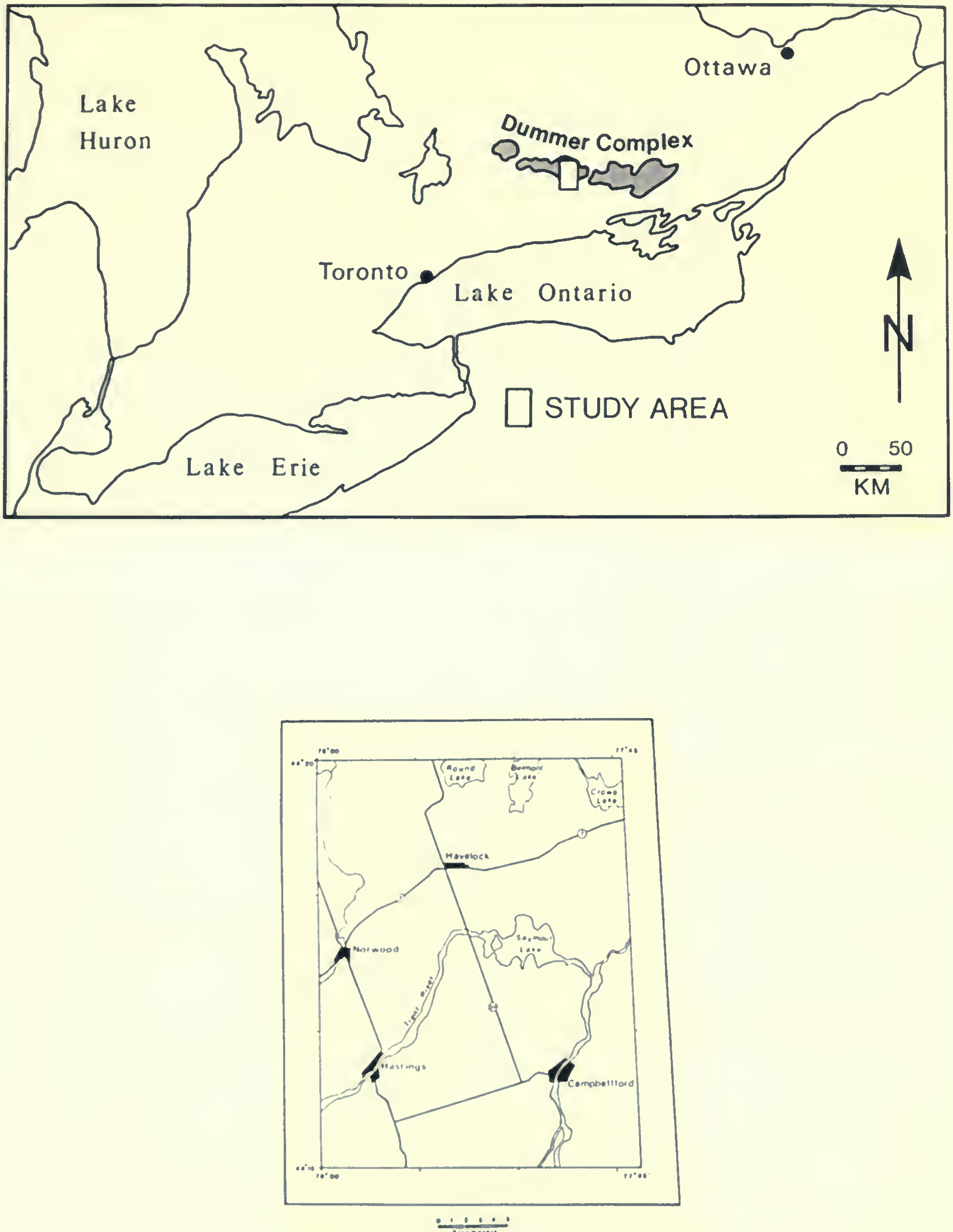


FIGURE 1. Location map of the Dummer Complex and map area. Extent of Dummer Complex from Chapman and Putnam (1966).

associations of the Dummer complex and other related glacial sediments. Geochemically analyze the till and the bedrock to investigate the relationship between grain size and the geochemistry. Propose a depositionary model for the Dummer Complex and associated glacial features.

1.4 Location

The Dummer Complex trends east-west in a broad belt from Tamworth to the eastern margin of Lake Simcoe, a length of 180 kilometers. It is discontinuous and varies from 6 km. to 24 km. in width, averaging 16 km.

The study area is between 44° 15'N and 44° 13'N latitude and 77° 30' E to 78° 00' E longitude in the Campbellford 31 C/5 NTS map sheet (Fig. 1). Two major highways service the area, the TransCanada Highway # 7 and Provincial Highway # 30. The map area has a well developed road network and 4 major communities; Campbellford, Norwood, Hastings and Havelock. The major water systems are the Trent River and 3 lakes; Round Lake, Belmont Lake and Crowe Lake which are located partially in the map area.

1.5 Present Geological Survey

Mapping of the Quaternary geology of the Campbellford area was initiated in the spring and summer of 1980 for the Ontario Geological Survey mapping program of Trenton - Campbellford map area. Additional field work was done during the summer of 1981.

Field data were obtained from the examination of available natural and man-made exposures and by the use of soil augers. Two sets of aerial photographs

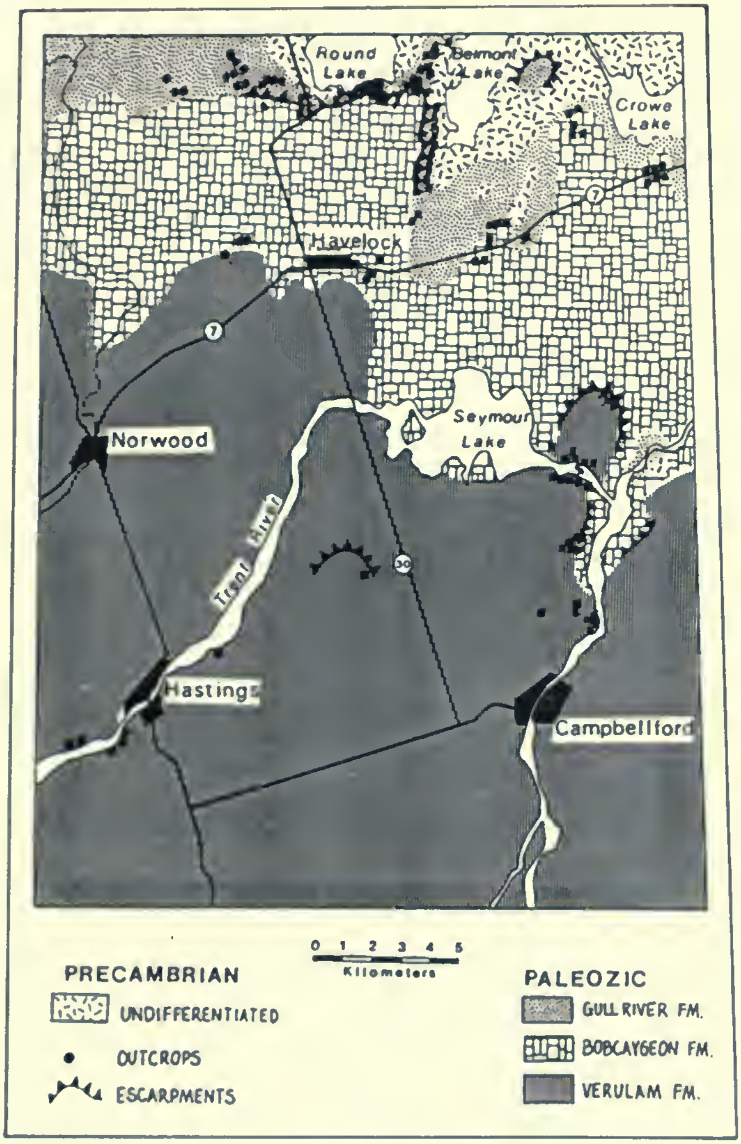


FIGURE 2. Bedrock geology map.

were used for the aerial photography interpretation, the 1:50,000 Federal photographs for regional trends and 1:15,840 photographs for the delineation of surficial geology units.

1.6 Bedrock Geology

A.) Precambrian

Precambrian bedrock underlies 3-7 percent of the map area, primarily in the north-east corner (Fig. 2). There are 2 inliers in the area, a relatively small inlier 1.5 km south of Belmont Lake and the second which is known as the Preneveau inlier which is found on the north side of Hwy. 7, 3 km. south east of Belmont Lake. Although the distribution and extent of the Precambrian bedrock is very limited, it deserves mention as it has special relationship to the Dummer Complex. Dummer sediments have not been found on Precambrian rock except where a Paleozoic outlier is up-ice as for example 1.5 km. east of Belmont Lake. Schluchter (1979) and Gadd (1980) make reference to this specific relationship.

The Precambrian bedrock is composed mainly of granites, granite gneiss, crystalline limestone and other highly metamorphosed rocks, Henderson (1973) estimates surficial sediments cover 30 percent of the Precambrian bedrock surface. In the map area the Precambrian bedrock surface is almost bare with only one till deposit located at the southern end of the Preneveau inlier. The Precambrian surface is quite rugged with a scoured rock-knob topography. The till which is found over the Precambrian bedrock is generally thin, discontinuous and is composed of Precambrian clasts set in a sandy loose matrix.

B.) Paleozoic

The Paleozoic bedrock was mapped by Winder (1955), Carson (1980) and Liberty (1960). Four formations are recognized in the map area, the Shadow Lake, the Gull River, the Bobcaygeon and the Verulam (Fig. 2), ranging in age from the Cambro-Ordovician to the Middle Ordovician.. The Paleozoic rocks terminate in a series of north facing escarpments. The Paleozoic rocks dip gently southwards at 3 degrees.

The major portion of the Dummer overlies the Bobcaygeon and Verulam Formation. There is only one location where the Shadow Lake outcrops and it is north of the Dummer Complex. Therefore, this study concentrates on the other 3 formations. Dunham's (1962) classification for carbonate rocks is used in this study.

i.) Shadow Lake Formation - Carson (1980) describes the Shadow Lake Fm. as consisting of red and green shales, siltstones and sandstones, in beds up to 30 cm. thick.

ii.) Gull River Formation - The Gull River Fm. is divided into 3 members. The Lower Member is a dolomitic feldspathic wacke with a shaley appearance where weathered. This member outcrops 0.5 km. south of Round Lake (Fig. 2). The Middle and Upper Members of the Gull River Fm. are mudstones, generally light to medium grey or dark grey brown with ostracods, stylolites and salt casts characteristic of some beds. The Middle and Upper Members are thick to massively bedded and range from 0.5 - 1.0 m. in thickness, averaging 0.75 m. (Fig. 3).

FIGURE 3. Upper Member of the Gull River Formation 2 km. east of Round Lake.

The results of petrographic investigation of the Gull River mudstones are given in Appendix I. According to Folk's (1962) classification for thin sections the Middle and Upper Members are composed of micrite to dismicrite depending on the amount of spar in the rock. Allochems include bryozoans, crinoids and ostracods with some clastic fragments of quartz and feldspar.

iii.) Bobcaygeon Formation - The Bobcaygeon Fm. overlies the Gull River Fm. This formation is generally grey to brown wackestone and medium to dark grey wackestone to packstone. The Bobcaygeon Fm. also has a facies of light tan grainstone. This formation is highly fossiliferous. Allochems include brachiopods, crinoids peloids, coral fragments and trilobites. Thin section analysis indicates the matrix is highly variable with pseudospar and sparite being most dominant (Appendix I). Stylolite fractures are also very common in this formation. Bedding is medium averaging 20 cm. in thickness.

FIGURE 4. Thin to medium bedded Bobcaygeon Fm. overlying the massive to thickly bedded Gull River Fm. on Hwy. 7, 5km. east of Havelock.

iv.) <u>Verulam Formation</u> - The Verulam Fm., which overlies the Bobcaygeon Fm., is a dark to medium grey coarse grained packstone imbedded with sub-equal beds of mudstone. Fossil allochems are very abundant including trilobites, brachiopods, gastropods, bryozoans, crinoids with concentrated layers of rip-up clasts. Bedding is thin, averaging 3 - 10 cm. thickness (Fig. 5).

FIGURE 5. The Verulam Formation showing thin beds of interbedded packstone and mudstone 3 km. north of Campbellford.

2.0 SURFICIAL GEOLOGY

2.1 Introduction

The Quaternary deposits were mapped according to the procedures used by the Ontario Geological Survey map units. The areal relations of the surficial units are shown in Map 1 (pocket). Each unit is discussed in a generally chronological order from oldest to youngest.

2.2 Campbellford Airfield Deposit

The assumed oldest Quaternary deposit in the map area is commonly known as the "Campbellford Airfield Deposit". It is a deposit 38 m above the surrounding surface and is found on Hwy. 30, 4 km. northwest of Campbellford. It is considered to predate the last ice advance because the drumlins which are related to the last major ice flow, are deflected around the Campbellford Airfield Deposit (Fig. 6). This suggests the Campbellford Airfield Deposit predates the drumlin depositionary period. It is not known how the Campbellford Airfield deposit relates to the regional chronology of southern Ontario except that it appears to be older than the other glacial deposits in the area. The deposit is covered by later Lake Iroquois near shore sands and flanked by the drumlins. The composition of the feature is not known.

3.3 Drumlinized Basal Till

The basal till which comprises the drumlins and now referred to as "drumlin till" is considered to be the oldest deposit of the last ice advance (Mirynech, 1962).

There are over 364 drumlins in the map area, concentrated in the southern half of the area. The drumlins are situated south of the Norwood esker and

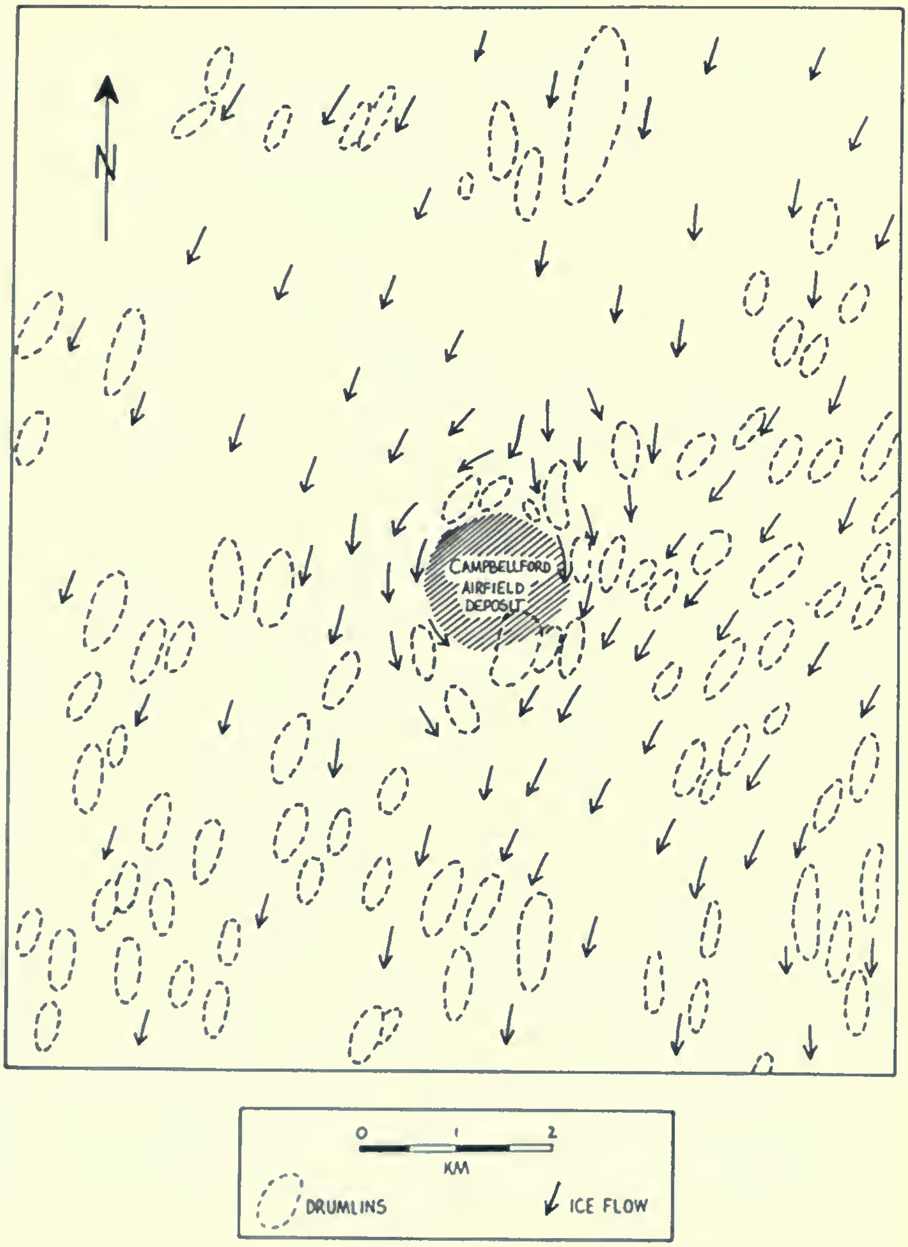


FIGURE 6. Drumlin orientation and assumed flow lines in the Campbellford Airfield Deposit area.

south and southeast the Trent River (Fig. 7). Many of the drumlins are very well developed, reaching heights of over 38 m. in the area between Hastings and Campbellford. The drumlins indicate a southwestwards ice-flow direction.

The till which makes up the drumlins is brown-grey, sandy-silty with sub-angular to subrounded clasts and has a **fissile** matrix. This till is also found between the drumlins in the southern part of the map area where the drumlins are more dense.

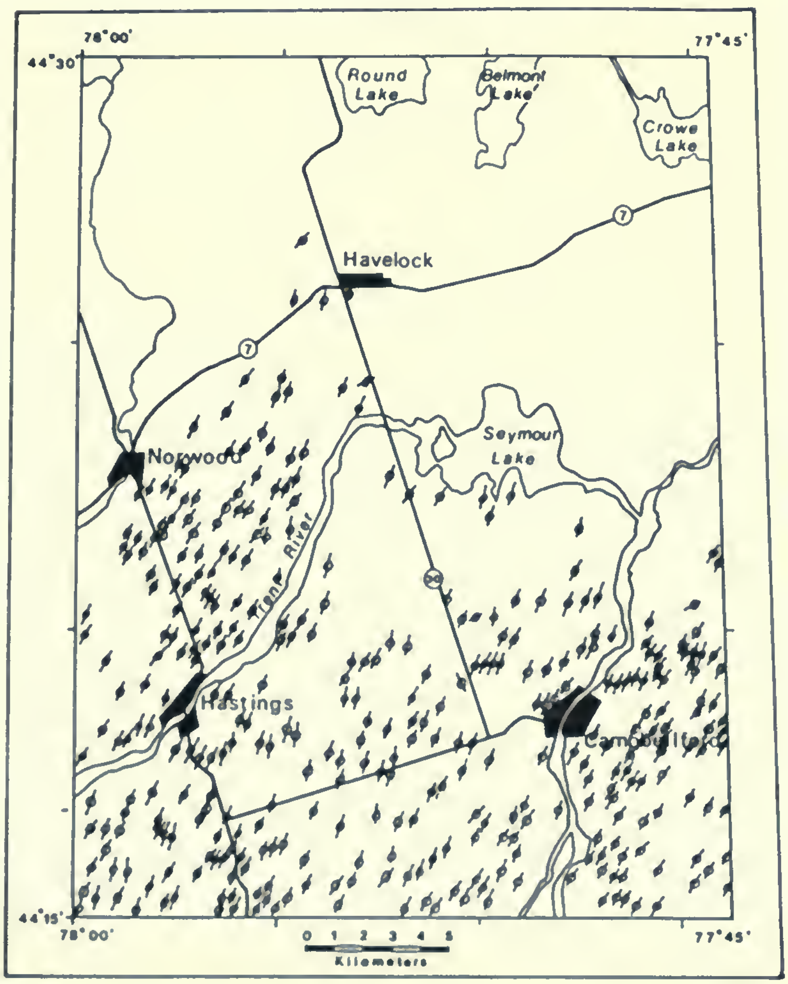
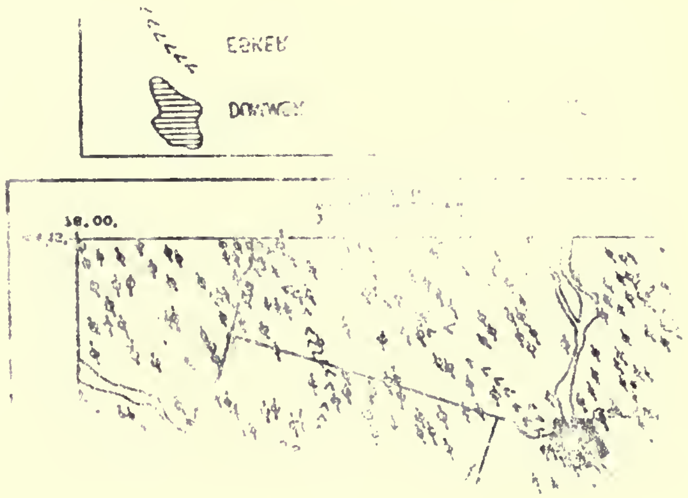


FIGURE 7. Drumlin location and orientations.

2.4 Dummer Complex

The Dummer Complex consists of pitted, hummocky deposits ranging from 1 to 10 meters in thickness, but averaging 3 to 5 meters (Fig. 8). Deposits are located on Paleozoic carbonate bedrock in discontinuous patches separated by expanses of bare to boulder strewn rock plains. Even the mapped deposits of Dummer sediment are often thin and discontinuous with bedrock exposed between hummocks. The Dummer Complex deposits mapped appear to be roughly aligned in the direction of ice flow as determined by the drumlins (Fig. 9).

FIGURE 8. Characteristic pitted, hummocky topography of the Dummer Complex, 6 km. west of Havelock.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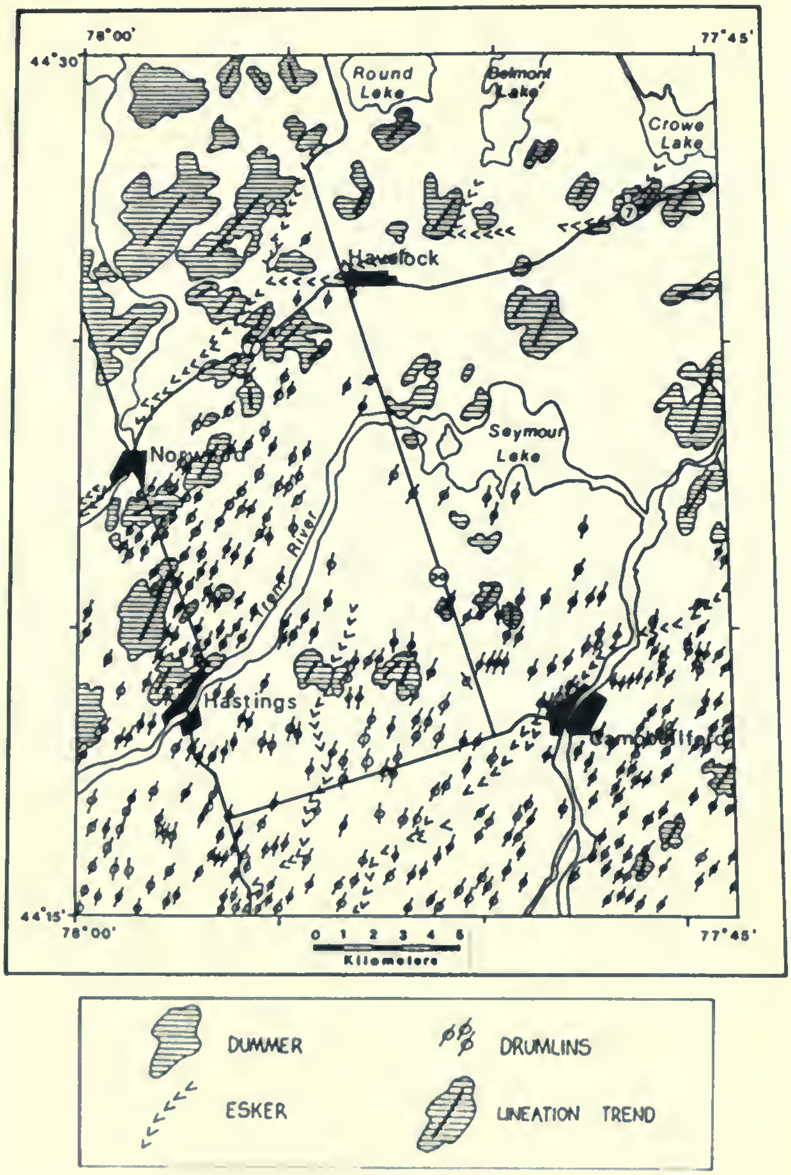


FIGURE 9. Relation of Dummer Complex deposits, drumlins and eskers.

The Dummer Complex sediments are characterized by the predominance of large, very angular Paleozoic clasts, often as large as 50 cm. to 1 meter in diameter (Fig. 10). The diamicton is matrix supported and massive, with no apparent clast orientation. The matrix is sandy-silty, brown-grey with weak to well developed fissility.

FIGURE 10. Dummer Complex sediment 6 km. west of Round Lake.

Dummer deposits predominate in the area north of the Norwood esker and Trent River in the Burntwood Point Bay area, becoming less common towards the south. The most southerly deposit occurs 6.4 km. south-east of Campbellford in a drumlinized area. This is one of several areas where Dummer deposits are within an area of drumlins and in some places Dummer sediments are completely surrounded by drumlins (Fig. 9). However, even though Dummer patches and drumlins are found in very close proximity, the sediments have not been found in the Campbellford area and in adjoining eastern areas (Leyland, 1984).

2.5 Ice-Contact Deposits

A hummocky belt of ice-contact sediment 1.6 km. wide and 5 km. long is situated on Hwy. 30 north of Havelock. The deposit was initially mapped as a Dummer Complex deposit because of its topographical expression, but detailed examination revealed a complex association of rapidly changing sediments of basal till, and ice-contact sands and gravels. The deposit has been mapped as a kame - moraine.

Eskers comprise the other ice-contact deposits in the area. The Norwood esker is the largest and best developed. Tributaries from Crowe Lake, Belmont and Round Lake join near Havelock to form a large braided esker complex trending southwest parallel to Hwy. 7. The surface of the Norwood esker is pitted in the area between Havelock and Norwood (Fig. 11 and 12).

Two other eskers are found in the map area. The larger of the two runs through Campbellford southwestwards and the other is 6.5 km. west of it.

FIGURE 11. Aerial photograph of the Norwood esker complex. The south side of the esker has been modified by Lake Iroquois.

FIGURE 12. Norwood esker showing pitted surface.

2.6 Glaciofluvial Outwash

Outwash deposits are related to the esker systems of the area. Extensive outwash deposits are found along the flanks of the Norwood esker. Two outwash fans are mapped, one associated with an area of Dummer Complex in the northwest corner of the map area and the other south-east of Hastings in a drumlinized area.

2.7 Glaciolacustrine Deposits

a.) Shoreline - Well developed beach deposits are found in the southern portion of the map area. The best developed beach, assumed to be related to glacial Lake Iroquois (Johnston, 1916; Coleman, 1937) is found at an elevation of 197 m asl at Hermiston Lake and rises to 212 m asl by Healey Falls (Fig. 13). Other beach deposits are found in the area, but their correlation is difficult because the deposits are not well developed. The shoreline development in the area north of the Trent River is not definitive, suggesting the lake abutted the ice margin along its northern shore. Minor shore deposits found in the Campbellford area are at lower elevations than Lake Iroquois and are correlated with the lower stages of glacial Lake Iroquois as defined by Mirynech (1962).

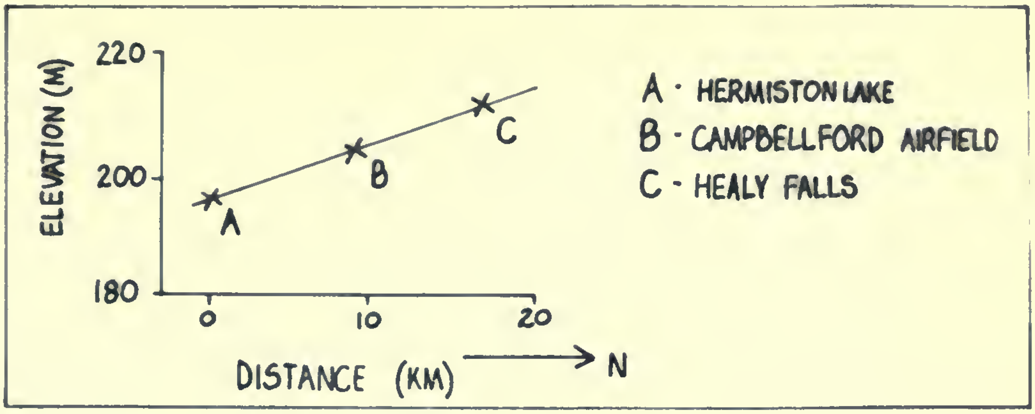
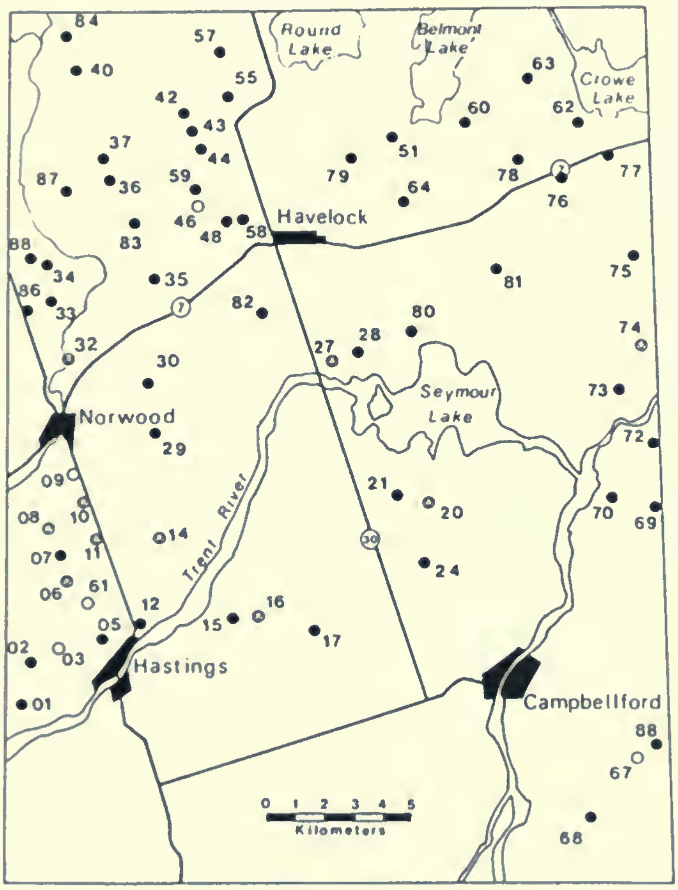


FIGURE 13. Differential uplift of the Iroquois strandline, at 9.4 meters per 10 kilometers.

b.) <u>Glaciolacustrine</u> - Littoral and basinal deposits

Extensive areas of sand occur southwest of Campbellford up to Round Lake and beyond the map area. The origin of the sands is unknown and it may have been deposited as littoral sand or glaciofluvial outwash sands. No attempt was made in this study to define the specific origin of the sands.

Silt and clay deposits are found east and south of Campbellford, where deep water sediments were deposited between the drumlins. Two areas of lacustrine deposits have been mapped south of Hastings which do not appear to be related to any specific major post glacial lake level. These deposits consist of massive to laminated silt and clay found in local depressions and are correlated to the Schomberg ponds described by Gravenor (1957).



TILL FACIES

● Immature Dummer
⊙ Submature Dummer
○ Mature Drumlins

FIGURE 14. Sample location map.

2.8 Older Alluvium

A good exposure of what has been mapped as older alluvium is found 3 km. west of Hasting on the north side of the Trent River. The deposit consists of well rounded clast supported imbricated cobble gravel. The specific origin of these local deposits is not clearly understood, but they appear to be related to the Trent Waterway system.

2.9 Organic Deposits

Peat deposits are found primarily in the northern portion of the map area. Overall they are of minor importance and distribution. The organic deposits are generally less than 2 meters in thickness.

2.10 Quaternary History

The surficial sediments in the map area are all of late Wisconsin age. The only evidence of older deposits is the deflection of drumlins around the feature upon which the Campbellford Airfield was built, commonly known as the Campbellford Airfield deposit.

The last ice advance flowed southeastwards depositing drumlins in the southern portion of the map area. These drumlins are part of the larger Peterbrough drumlin field which Gravenor (1957) attributed to deposition by the Simcoe Lobe.

As the Simcoe Lobe retreated north of the Oak Ridges Moraine, numerous local pondings developed, collectively known as the Schomberg Ponds (Gravenor, 1957). Speculation on the nature of the retreat of the Simcoe lobe has been expressed and Terasmae (1980) suggested that as "the Lake Simcoe lobe thinned over the Algonquin Highlands, large masses of ice became stagnant to the lee of these highlands and the melt-out of englacial debris resulted in the ...Dummer Moraine."

Lake Iroquois came into being with the retreat of the Simcoe Lobe. Glaciolacustrine sands are found between and over Dummer Complex deposits in the Belmont Lake - Crowe Lake area. This relationship has also been reported by Mirynech (1962), Leyland (1984) and Henderson (2973) in adjoining eastern and northern areas. It seems that deposition of the Dummer occured prior to the Lake Iroquois stage dated 12,500 B.P. Lake Iroquois drained shortly after 12,000 B.P. (Karrow, et. al., 1975; Terasmae, 1980) with several lower lake stages developing for short periods of time (Mirynech, 1962).

3.0 SEDIMENTOLOGY

3.1 Introduction

Sedimentological characteristics of the Dummer Complex and other glacial deposits were examined. Properties studied included structure, texture, bedding, dominant coarse grain size, pebble lithology and roundness. The purpose was to characterize the sedimentological properties of the Dummer Complex and thereby define the till facies; then to determine the relationship of the till facies.

3.2 Field Methods

Dummer sediments are found in roadside sections where rapid slumping make fresh exposures difficult to locate. Samples were collected 30 cm. to 70 cm. into the face of the exposure, as it was generally not manually possible to excavate any deeper. This resulted in the collection of samples which have probably been affected by soil forming processes. It is considered unlikely that even if deeper excavation were possible, unaltered samples could be collected because of the coarse characteristics of the sediment. The degree of alteration is unknown. A total of 71 locations were sampled (Fig. 14).

At each sampling location a sediment matrix sample was taken as well as a separate random pebble collection of approximately 100 clasts ranging from 1 cm. to 6 cm. in diameter.

B. Laboratory Methods

Pebble Counts - Pebble collections from Dummer deposits and from the basal till of the drumlins were washed and cracked to expose unweathered surfaces. The clasts were then categorized according to lithology and roundness.

i.) Lithology

Pebbles were first divided into 2 groups, the Precambrian clasts and the Paleozoic clasts. The Precambrian clasts included granites, gneisses and gabbros. Many of the pebbles, particularly the gneisses, were very friable and broken into a number of fragments. In those situations where the pieces were identifiable as belonging to one clast, they were counted one pebble.

The Paleozoic clasts were subdivided into formations. The clasts included mudstones, feldspathic wackes, wackestones, packstones and some grainstones of the Gull River, Bobcaygeon and Verulam Formations. Analysis of fresh and weathered surfaces of bedrock outcrops provided information for identifing pebble lithologies (Table 1).

Identification of the clasts as to their formation was difficult because of the variety of lithologies found in each formation. Particular difficulty occured in differentiating the wackestone of the Bobcaygeon Formation from the wackestone of the Verulam Formation. This is because the boundary defining the Bobcaygeon and Verulam is based on bedding characteristics (Carson, 1980). The Verulam Fm. is identified when the beds of wackestone are of sub-equal thickness to the beds of mudstone, and the lithological change from primarily a wackestone in the Verulam Fm. is gradational. In situations where the clast could not be specifically defined as either Bobcaygeon or Verulam, preference was given to the underlying bedrock formation.

	Rock Type	Lithology	Color	Friability	Texture	Surface Texture	Allo-chems	Dist. Charact.
Precambrian	variable	variable	variable	high	cryst.	smooth	absent	hardness
Gull River	mudstone	micrite	lt. grey-lt. brown	low	fine	smooth	few	lith.&color
	feldspathic-wacke	micrite with non-carbonate grains	red-green	high	fine	smooth	v.few-absent	rock type & color
Bobcaygeon	wackestone	sparite	pinkish	medium	fine-medium	smooth - mod.	mod. abundant	color
	grainstone	carbonate grains	med.grey	medium	cryst.	mod.rough	frag.	rock type
Verulam	packstone	packed sparite	med.grey	medium	coarse cryst.	rough	v. abund.	allochem
		micrite	v. dark grey	medium	fine cryst.	smooth	few	oxidized zones

Table 1 Identifying Characteristics for Pebble Classification

FIGURE 15. Photographs of the Gull River, Bobcaygeon and Verulam immature subfacies.

ii.) Roundness

Roundness was determined using Folk's (1968) visual roundness chart for all the samples after the clasts were identified. Five categories were recognized; very angular, angular, sub-angular, sub-rounded, and rounded.

iii.) Till Matrix Grain Size Analysis

Sediment samples were first soaked and then wet sieved using deionized water. Samples were then dried and sieved at 1/2 phi intervals between 2.25 ø and 4.00 ø. The silt and clay fraction was retained for geochemical analysis.

3.3 Sedimentology Results

Field observations of glacial sediments led to the recognition of three gradational till facies. The 3 facies are referred to as the immature, submature and mature till facies related to the Dummer Complex, the drumlinized basal till and a transitional sediment.

A.) Immature Facies

The immature facies which covers most of the map area is generally associated with the classic Dummer Complex. The coarse fraction is dominated by large, angular clasts of Paleozoic bedrock. The size of the clasts range from over 2 meters in diameter to less than 5 cm. the average being dependant on the bedding patterns of the source bedrock (Fig. 15). The immature till which is dominated by the Gull River Fm. is generally boulder dominated with the average being 0.5 - 1.0 m. in diameter. The immature till on the Bobcaygeon Fm. is dominated by cobble sized clast, averaging 0.25 - .50 m. in diameter, while the immature

till on the Verulam Fm. is characterized by pebble sized clasts. The size and angularity of the coarse component of this facies is the most prominent characteristic.

The matrix is sandy-silty with an average sand content of 42.55 percent and mud content of 20.63 percent (Table 2). The color is generally grey-brown with an overall loose structure and poor to well developed fissility.

Sedimentological characteristics of the immature till facies as observed in the field are given in Table 3.

	Pebble	Sand	Mud	Sand/Mud Ratio
57 Igr	32.54	50.77	16.69	3.04
55 Ibb	26.70	49.30	24.00	2.05
48 Ibb	34.16	40.67	25.17	1.62
44 Ibb	39.66	34.27	26.07	1.31
43 Ibb	30.75	42.24	27.01	1.56
36 Ibb	69.21	21.91	8.88	2.47
35 Ibb	40.49	37.53	21.98	1.71
34 Ivr	43.00	30.03	26.97	1.11
30 Ivr	27.05	49.87	23.08	1.16
05 Ivr	24.68	68.89	6.43	10.71
means	36.82	42.55	20.63	2.77

Table 2. Grain size analysis by weight percent of the immature till facies.

Morphological	Sedimentological
- Situated on Paleozoic bedrock	- Very coarse
- Down-ice of Precambrian contact	- Dominant clast size varies with bedrock
- Hummocky and pitted	- Clasts angular
- Down-ice lineations	- No bedding or stratification
- Discontinuous patches	- No observed pebble fabric
- Close proximity with drumlins and eskers	- Matrix shows weak fissility
- Average height 3-5m	

Table 3. Morphological and sedimentological characteristics of the immature till facies.

Field observations suggest a good correlation between the boulder - cobble size fraction of the immature till facies to the underlying Paleozoic bedrock formations. The immature till facies was subdivided according to the underlying formation.

i.) Pebble Counts:

Pebble counts on clasts collected from the immature till facies sites are given in Table 4. Of the 48 locations, 10 were on the Gull River Fm. 20 from the Bobcaygeon Fm. and 18 from the Verulam Fm. In most situations the clasts are primarily derived from the underlying formation, except at those locations which are located, slightly down ice from the contact between two formations.

Contours of the pebble counts are shown in (Fig. 16). Maps were constructed for the 3 Paleozoic formations, but not for the Precambrian component because of the low percentages in the samples. The average percentages of the Precambrian component is given in Table 5.

Sample Number	Bedrock Fm.	% Lithology PC	GR	BB	VR	Dominant Lithology	% Other Clasts	% Dominant Lithology	
51	GR-Im	1.0	99.0	-	-	GR	1.0	99.0	
57	GR-Im	22.0	78.0	-	-	GR	22.0	78.0	
60	GR-Im	-	100.0	-	-	GR	-	100.0	n = 10
62	GR-Im	-	100.0	-	-	GR	-	100.0	
63	GR-Im	-	100.0	-	-	GR	-	100.0	Gull River
77	BB-Im	2.7	52.7	44.6	-	GR	47.3	52.7	
78	BB-Im	6.2	61.1	32.7	-	GR	38.9	61.1	subfacies
79	BB-Im	1.0	92.4	6.6	-	GR	7.6	92.4	
81	BB-Im	5.6	62.1	32.3	-	GR	37.9	62.1	
84	GR-Im	4.6	95.4	-	-	GR	4.6	95.4	
	mean	4.3	84.1	11.6					
28	BB-Im	-	-	100.0	-	BB	-	100.0	
36	BB-Im	-	-	100.0	-	BB	-	100.0	
37	BB-Im	2.0	10.8	87.2	-	BB	12.8	87.2	n = 20
40	BB-Im	6.9	11.5	81.6	-	BB	18.4	81.6	
42	BB-Im	4.7	30.7	64.6	-	BB	35.4	64.6	Bobcaygeon Sub-
43	BB-Im	-	-	100.0	-	BB	-	100.0	facies
44	BB-Im	-	-	100.0	-	BB	-	100.0	
55	BB-Im	1.8	11.5	86.7	-	BB	13.3	86.7	
58	BB-Im	0.9	4.6	94.4	-	BB	5.6	94.4	
59	BB-Im	1.2	4.2	94.5	-	BB	5.5	94.5	
70	BB-Im	2.7	0.9	96.4	-	BB	3.6	96.4	
72	BB-Im	1.0	-	99.0	-	BB	1.0	99.0	
73	BB-Im	0.8	9.9	89.3	-	BB	10.7	89.3	
75	BB-Im	-	-	100.0	-	BB	-	100.0	
76	BB-Im	1.0	1.0	98.0	-	BB	2.0	98.0	
80	BB-Im	5.3	-	94.7	-	BB	5.3	94.7	
82	VR-Im	10.4	3.8	65.1	20.7	BB	34.9	65.1	
48	VR-Im	2.4	3.6	48.8	45.2	BB	51.2	48.8	
86	VR-Im	0.9	3.5	92.0	3.5	BB	8.0	92.0	
87	BB-Im	4.0	1.0	95.0	-	BB	5.0	95.0	
	mean	2.3	4.8	89.4	3.5				
01	VR-Im	-	-	18.1	81.9	VR	18.1	81.9	
02	VR-Im	-	-	6.1	93.9	VR	6.1	93.9	
05	VR-Im	-	-	-	100.0	VR	-	100.0	
07	VR-Im	1.6	-	2.5	95.9	VR	4.1	95.9	
12	VR-Im	1.8	0.9	1.8	95.4	VR	4.6	95.4	
15	VR-Im	-	-	6.4	93.6	VR	6.4	93.6	n = 18
17	VR-Im	-	-	-	100.0	VR	-	100.0	
21	VR-Im	3.0	10.0	6.0	81.0	VR	18.0	81.0	Verulam Sub-
24	VR-Im	0.6	1.9	16.6	80.9	VR	19.1	80.9	facies
29	VR-Im	0.7	11.9	12.6	74.8	VR	25.2	74.8	
30	VR-Im	1.1	1.1	22.3	75.5	VR	24.5	75.5	
33	VR-Im	1.7	-	4.2	94.1	VR	5.9	94.1	
34	VR-Im	8.0	10.7	9.8	71.4	VR	28.6	71.4	
66	VR-Im	1.6	-	6.4	92.0	VR	8.0	92.0	
68	VR-Im	1.0	-	1.0	98.0	VR	2.0	98.0	
69	VR-Im	1.9	-	0.9	97.2	VR	2.8	97.2	
83	VR-Im	-	2.1	43.7	54.2	VR	45.8	54.2	
88	VR-Im	-	-	1.7	98.3	VR	1.7	98.2	
	mean	1.3	2.1	8.9	87.7				

Table 4. Pebble counts of the Gull River, Bobcaygeon and Verulam immature till subfacies.

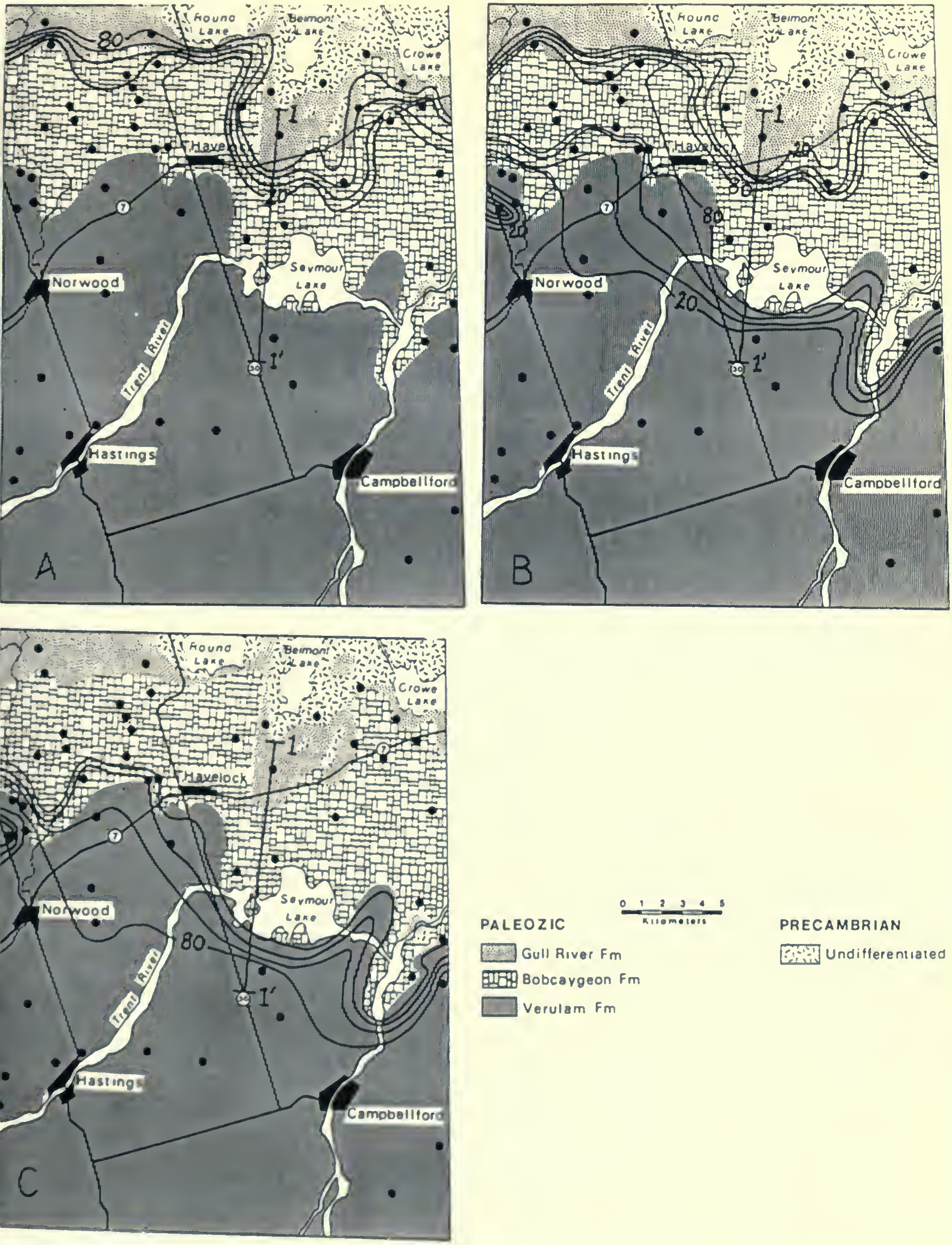


FIGURE 16. Isopleths of the Gull River, Bobcaygeon and Verulam Formations in the immature till facies. Contour interval is 20 percent.

Immature Till Subfacies	Average Precambrian Component (%)
Igr	4.3
Ibb	2.3
Ivr	1.3

Table 5. The average Precambrian component in percent for the 3 immature till facies; Igr - Immature Gull River facies, Ibb - Immature Bobcaygeon facies - Ivr - Immature Verulam facies.

The pebble contours from the immature facies follow formational contacts. In those areas where few samples were collected the contours were drawn to follow the formational contacts as supported by the areas where sample locations are abundant. A cross section of isopleths and bedrock geology is illustrated in Fig. 17.

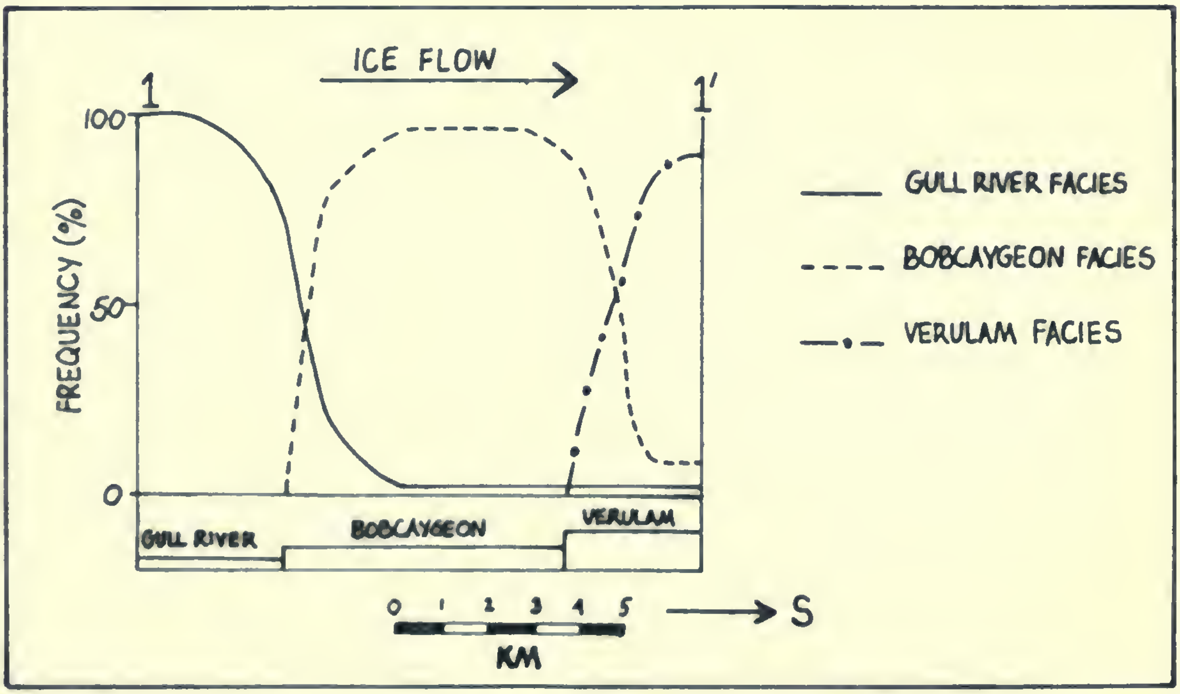


FIGURE 17. Cross-section isopleths and bedrock.

The rapid increase of a particular formational constituent is directly related to the underlying bedrock. The immature facies reflects the underlying formation in the pebble size range within 1 to 3 kilometers from the contact. This relationship between the immature facies and the underlying bedrock was used for bedrock identification in those areas where outcrops were absent.

ii.)` Roundness

The immature facies is dominated by angular to subangular clasts. The dominant roundness class is angular for all 3 subfacies, averaging 60.7% for the Gull River, 64.2% for the Bobcaygeon and 70.1% for the Verulam. Rounded and subrounded clasts are not common (Table 6). The percentage of rounded clasts was an average 0.5 and the subrounded clasts averaged 3.1 percent. The degree of rounding appeared to be related to the clast lithology as illustrated by sample 57. This sample is dominated by the Lower Member of the Gull River Fm. which is very soft and highly friable.

B. Submature till facies

The submature till facies is found at the southern margins of the area dominated by Dummer deposits and at the northern margin of the area dominated by drumlins. Nine locations have been mapped in the area (Fig. 14). The morphology of the deposits is hummocky and indistinguishable from deposits of the immature till facies. Sites of submature and immature facies can be found together in the same deposit, for example sites 15,16 and 6, 7.

Sample	Till Facies	Number Counted	Very Angular	Roundness Angular	Sub-Angular	Sub-Rounded	Rounded	Dominant Roundness Class
51	Igr	104	9.6	30.8	54.8	3.8	1.0	SA
60	Igr	110	24.5	75.5	-	-	-	A
62	Igr	121	45.5	54.5	-	-	-	A
63	Igr	119	7.6	49.6	35.3	5.9	1.7	A
64	Igr	124	8.1	37.9	34.7	12.9	6.5	A
77	Igr	110	18.2	70.0	8.2	0.9	2.7	[illegible]
78	Igr	113	11.5	71.7	14.2	2.6	-	[illegible]
79	Igr	107	8.6	67.6	20.0	3.8	-	A
81	Igr	124	23.4	72.6	4.0	-	-	A
84	Igr	108	10.2	76.8	13.0	-	-	A
*57	Igr	109	-	7.3	43.1	47.7	1.8	SR
n=10		mean	16.7	60.7	22.7	3.0	1.4	A
28	Ibb	114	13.2	86.8	-	-	-	A
36	Ibb	100	12.0	85.0	3.0	-	-	A
37	Ibb	102	6.9	58.8	24.5	9.8	-	A
40	Ibb	87	27.6	51.7	12.6	4.6	-	A
42	Ibb	127	7.1	59.8	18.9	11.0	3.1	A
43	Ibb	166	6.0	73.5	20.5	-	-	A
44	Ibb	191	8.9	64.9	24.6	1.6	-	A
48	Ibb	84	-	84.5	11.9	3.6	-	A
55	Ibb	113	-	24.8	73.5	1.8	-	SA
58	Ibb	108	13.9	69.4	16.7	-	-	A
59	Ibb	165	6.1	43.0	31.5	16.4	3.0	A
70	Ibb	110	2.7	28.2	50.9	16.4	1.8	SA
72	Ibb	101	6.9	88.1	4.0	1.0	-	A
73	Ibb	121	0.8	38.0	44.6	15.7	0.8	SA
75	Ibb	106	13.2	80.2	6.6	-	-	A
76	Ibb	103	5.8	78.6	14.6	1.0	-	A
80	Ibb	114	7.9	74.6	17.5	-	-	A
82	Ibb	106	8.5	50 9	23.6	9.4	8.5	A
86	Ibb	113	6.2	82.3	4.4	6.2	0.9	A
87	Ibb	101	8.9	61.4	25.7	4.0	-	A
n=20		mean	8.1	64.2	21.5	5.1	0.9	A
01	Ivr	116	3.4	80.2	16.4	-	-	A
02	Ivr	115	15.7	75.7	8.7	-	-	A
05	Ivr	114	9.6	76.3	12.3	1.8	-	A
07	Ivr	121	19.0	77.7	1.6	1.6	-	A
12	Ivr	110	13.6	63.6	14.5	8.2	-	A
15	Ivr	110	31.8	66.4	1.8	-	-	A
17	Ivr	129	19.4	79.8	0.8	-	-	A
21	Ivr	100	10.0	63.0	16.0	10.0	-	A
24	Ivr	157	3.8	89.2	5.7	1.3	-	A
29	Ivr	135	2.2	63.0	28.9	5.9	-	A
30	Ivr	94	1.1	51.1	40.4	5.3	2.1	A
33	Ivr	118	5.1	84.7	10.2	-	-	A
34	Ivr	112	2.7	64.3	15.2	13.4	4.5	A
46	Ivr	125	-	64.8	21.6	12.0	1.6	A
68	Ivr	102	1.0	57.8	31.4	8.8	1.0	A
69	Ivr	107	10.3	79.4	9.3	0.9	-	A
83	Ivr	96	28.1	54.2	16.7	1.0	-	A
n=17		mean	10.4	70.1	14.8	4.1	0.5	A

Table 6. Pebble roundness results for the immature till facies.

The sediments of the submature till facies are less stoney than the immature till facies but are considerably more so than those of the mature till which comprises the drumlins. The sediment is brown-grey and has a sandy-silty matrix ranging from 40 to 50 percent sand and 15 to 38 percent mud, with a dense to loose structure. The matrix shows well developed fissility and there is no apparent stratification. The submature till facies varies in sedimentological characteristics and is characterized by its variability. It is recognizably not immature or mature till facies but has characteristics that are transitional between these two facies.

Pebble counts and roundness determinations are shown in Table 7. Most samples lie on the Verulam Fm. except for site 74 which is on the Bobcaygeon Fm. The average percentage of Precambrian clasts is 4.7. The dominant roundness class is angular to subangular and the average amount of subrounded and rounded clasts is only 14.8% compared to 75% for the immature facies and 41.5 for the mature facies.

C.) Mature Till Facies

The mature till facies comprises the drumlinized areas regionally, and shows all the characteristics of a lodgement till. The matrix is silty-sandy, and massive. Clasts are sub-rounded to sub-angular and have an orientated fabric (Mirynech, 1962). The till appears to be overconsolidated and shows well developed fissility.

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Pebble lithology and roundness determinations were done on five samples (Table 8). The samples were all collected from drumlins on the Verulam Fm. The average content of Precambrian clasts was 7.6 percent, the Gull River Fm. clasts constituted 5.5, the Bobcaygeon Fm. 65.2 and the Verulam Fm. 20.9 percent. The pebble population is dominated by the Bobcaygeon Fm. clasts unlike the immature and submature till facies, suggesting longer distance transport.

Sample		% Lithology				Roundness				
Number	n=	PC	GR	BB	VR	VA	A	SA	SR	R
03	103	9.7	7.8	77.7	4.9	1.0	11.7	24.3	29.1	33.9
09	125	5.6	3.2	47.2	44.0	-	51.2	37.6	10.4	0.8
61	137	9.5	5.1	68.6	16.8	-	3.8	41.4	36.1	18.8
65	118	5.9	5.9	45.8	38.1	0.8	29.7	38.1	18.6	8.5
67	111	7.2	5.4	86.5	0.9	-	10.8	37.8	43.2	8.1
	mean	7.6	5.5	65.2	20.9	0.4	21.4	35.8	27.5	14.0

Table 8. Pebble counts and roundness determinations for the mature till facies.

2.4 Discussion

The immature till facies which comprises most of the Dummer is distinctive and easily recognizable even though it overlies three Paleozoic bedrock formations of varying lithological and structural characteristics.

The most striking feature of the immature facies is the abundance of the coarse fraction and angularity of the clasts and the morphology of the deposits. This is even more striking when compared to the till comprising the drumlins which lie in very close association with patches of the Dummer Complex.

Pebble counts of the three till facies are shown in Fig. 18. The sample sites all lie on the Verulam Fm. and are from approximably the same area. The pebble fraction of the immature till is dominated by the underlying bedrock type to the vertual exclusion of other lithologies. The mature till has less of the local component and a correspondingly high percentage of long distance transported clasts. The lithology of the submature facies is intermediate between the two other facies.

FIGURE 18. Histograms of percent lithology for the immature, submature and mature till facies.

Roundness determinations for the three till facies also show a trend (Fig. 19). The immature facies is dominated by the angular class, while the submature facies is angular to subangular and the mature facies is subangular to subrounded. Table 9 outlines the characteristics of the three facies.

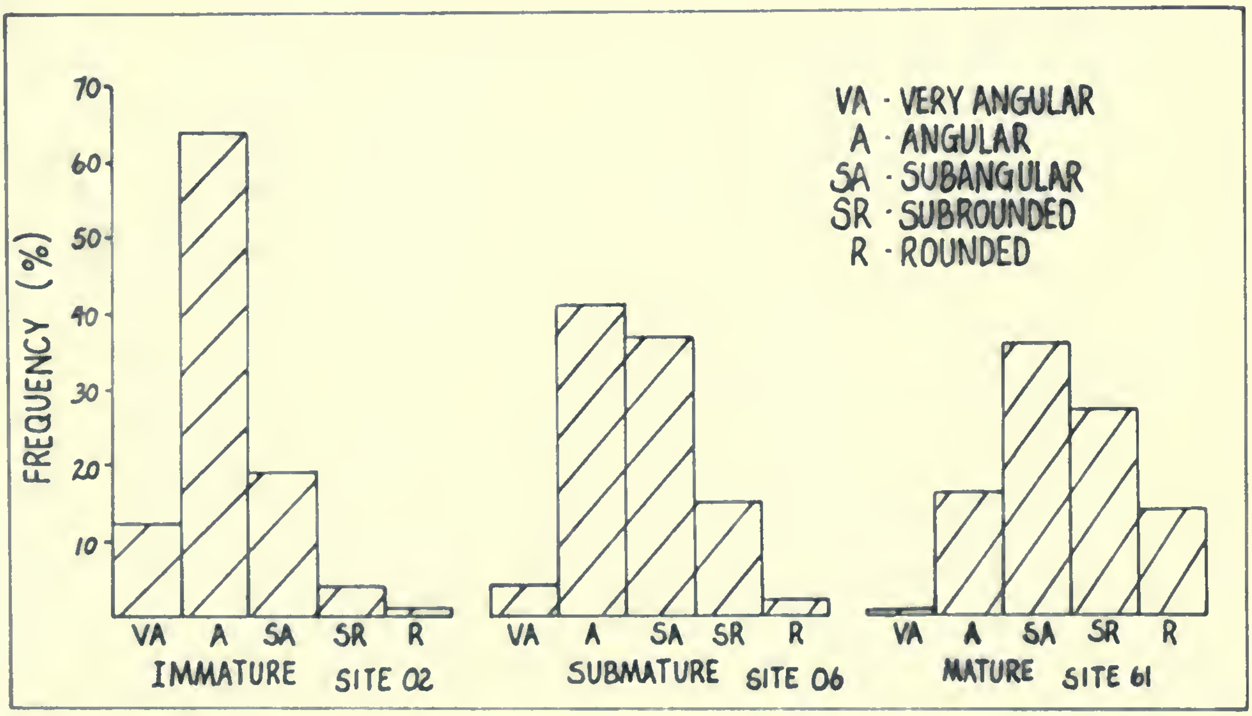

FIGURE 19. Roundness in percent for the immature, submature and mature till facies.

	Immature	Submature	Mature
Morphology	Hummocky	Hummocky - Rounded	Rounded
Lineation	Roughly	Weak - strong	Strong
Dominant grain size	Clast	Clast - Matrix	Matrix
Structure	Loose	Loose - Dense	Dense
Stratification	None	None	None
Matrix	Silty - Sandy	Silty - Sandy	Silty - Sandy
Orientated Fabric	Non decernable	Non decernable - Weak	Well developed
Pebble Lithology	Local	Primarily local	Long distance and local
Fissility	Well developed	Well developed	Well developed
Roundness	Very Angular - Angular	Angular - Sub-Angular	Sub-angular to Sub-rounded

Table 9. Sedimentological characteristics of the immature, submature and mature till facies.

3.5 Conclusions

Three till facies are recognized in the map area; an immature facies which comprises the Dummer Complex, a submature facies which is mapped with the Dummer Complex but has properties of both other two facies, and a mature till facies which comprises the drumlinized area.

The Dummer Complex is of predominantly one till which is composed of coarse, angular clasts in a silty-sandy matrix. The coarse fraction consists primarily of clasts of the underlying Paleozoic bedrock formation. On the basis of dominant lithology, which is the underlying formation, three subfacies of the immature facies are recognized. The immature subfacies differ in lithology and the size of the dominant coarse fraction, relating to bedrock bedding patterns. The immature facies matrix which is grey-brown, silty-sandy with fissility and massive appears to remain relatively constant. The Dummer Complex deposits show rough alignment with the ice flow direction.

The mature till facies comprises the drumlinized till sheet and has all the characteristics of lodgement till. This till appears consistant regionally and has undergone long distance transport.

The submature till facies, although indistinguishable morphologically from the Dummer Complex has characteristics of the immature and mature till facies. The submature till facies has a greater amount of rounding than the immature facies and much less than the mature facies. Clast lithology shows a dominance of local bedrock clasts but less than the immature till facies.

The three till facies appear to be in a continuum related to ice transport. The immature facies shows little to no transport, the submature a variable amount and the mature till facies reflects long distance ice transport. The exclusion of the immature and mature till facies suggests the processes were mutually exclusive and contemporaneous.

4.0 GEOCHEMISTRY

4.1 Introduction

The close association of the dominant lithology in the Dummer sediments to the underlying Paleozoic carbonate bedrock formations, was illustrated in the previous chapters. To see if this relationship also holds for the finer grain sizes samples were analyzed geochemically.

A selective leach technique for carbonates developed by Brand and Veizer (1980), was used in an attempt to recognize geochemical signatures for the Gull River, Bobcaygeon and Verulam Formations in the map area. (Leyland-Mihychuk and Brand, 1982). The aim of the geochemical study was to (1) establish geochemical signatures of the three Paleozoic formations, and to (2) correlate these geochemical signatures to the sediments comprising the Dummer Complex in various grain sizes if possible and thereby (3) gain some indication of the processes of erosion, transport and deposition of the glacier during the formation of the Dummer Complex.

There have been numerous attempts to correlate till to bedrock in order to determine provenance (Warren and Delavault, 1961; May and Dreimanis, 1973; Shilts, 1973; Stea and Fowler, 1979). These studies used bulk rock methods on a particular grain size range, usually the mud fraction. This approach has certain inherent disadvantages, such as the masking of various elements due to their concentration in certain rock types, as the lithology of the Dummer sediments is directly related to the Paleozoic carbonate bedrock it would be advantageous to remove the Precambrian fraction thereby making correlation of the

carbonate fraction of the till to the carbonate bedrock much more direct.

4.2 Method

Bedrock and till samples were analyzed chemically in the same way. The till samples were pretreated in the following manner.

The till samples were first wet sieved on a 63 mesh stainless steel screen using deionized water. The coarse fraction was dry sieved at 1/2 phi intervals from -0.05 phi to 4.00 phi and the silt and clay fraction retained. The individual sieved fractions were then powdered. Bedrock samples were cleaned and then powdered manually.

The powdered samples were oven dried and cooled in a dessicator after which 0.5 gram of sample was leached with 18 ml of (5% v/v) HCl for 5 hours (Brand and Veizer, 1980). The insoluble residue was washed and weighed. The sample solutions were analyzed on a Varian 1475 atomic absorption spectrophotometer with HP. 85 control. The samples were analyzed for Ca, Mg, Sr, Na, Fe, Al, Cu, Mn, Zn, Ba and Ni.

Intially the 2.0 and 4.0 phi fractions were analyzed on 3 selected till samples. Once the method was tested for effectiveness in identifying chemical trends in various grain sizes, the number of fractions were increased. For some samples all 1/2 phi fractions were analyzed. For others only selected fractions were analyzed to confirm geochemical grain size trends identified by the 1/2 phi fraction till analysis.

4.3 Results

A.) Bedrock Geochemistry

Samples of the three Paleozoic formations were collected from eleven bedrock outcrops and five Dummer Complex locations (Fig. 20). Dummer Complex sites were used where bedrock outcrops were not available. In total, 32 bedrock samples were analyzed for 11 elements and insoluble residue (I.R.). All chemical data are given on 100 percent carbonate basis in parts per million except for I.R. which is reported in weight percent Appendix II.

FIGURE 20. Site location map of bedrock geochemistry samples collected from bedrock and immature till sites.

Ten Gull River, ten Bobcaygeon and twelve Verulam Formation samples were analyzed. Access to bedrock outcrops of the Gull River Fm. was particularily difficult in the map area. Therefore, in 4 of the 5 locations pebbles were collected from Dummer Complex sediments overlying the Gull River Fm.

Average accuracy and precision as compared with standard rocks NBS- 631 and 634 is better than 5 relative percent for Ca, Mg, Sr, Mn and Fe, and better than 10 relative percent for Cu, Na, Zn, Ba, Al and Ni (ef. Brand and Veizer, 1980). Insoluble residue was determined gravimetrically and precision was better than 7 relative percent.

Statistical analysis of the bedrock geochemistry is given in Appendix II. A difference of means test (student's t test) was used to define significant differences between the formations at the 95 percent confidence level. The results of the student's t - test are summarized in Table 10.

Formations T - Tested	I.R.	Ca	Mg	Sr	Cu	Mn	Fe	Na	Zn	Ba	Al	Sr/CA ratio
Gull River to Bobcaygeon	X	X	X	X	-	X	X	X	X	-	-	X
Gull River to Verulam	X	X	X	X	X	X	X	X	-	-	-	X
Bobcaygeon to Verulam	-	X	-	-	-	-	-	-	-	-	-	X

Table 10. Results of t-test for the bedrock formations;
X significant difference - no significant difference

Calcium and the strontium - calcium ratios are significantly different between all three formations. The I.R., Mg. Sr, Mn, Fe and Na differentiates the Gull River Fm. from the Bobcaygeon and Verulam Formations. Cu is significantly different between the Gull River and Verulam Fms. Ba and Al show no significant difference between means for any of the formations.

Figure 21 illustrates the relationship of mean and standard deviation of the Gull River, Bobcaygeon and Verulam Formations for I.R., Ca, Sr, Mn, Fe, Na and the Sr/Ca ratio, all of which showed a significant difference of means between at least two of the formations.

Insoluble residues decrease from the Gull River to Bobcaygeon to the Verulam Formation, whereas the values of Ca and Na show the opposite trend. The mean values of Mn and Fe for the Gull River Fm. are substantially higher than for the other two formations which are similar in values. The Bobcaygeon Fm. has the highest values of Sr and Sr/Ca ratio. The Verulam Fm. and the Bobcaygeon Fm. both have lower mean values of 230 ppm and 500 ppm respectively (Fig. 20).

Geochemically the Gull River Fm. is chemically distinct from the Bobcaygeon and Verulam Fms. for I.R., Ca, Mg, Mn, Fe and Na. The Bobcaygeon and Verulam Fms. can only be differentiated using Ca and the Sr/Ca ratio.

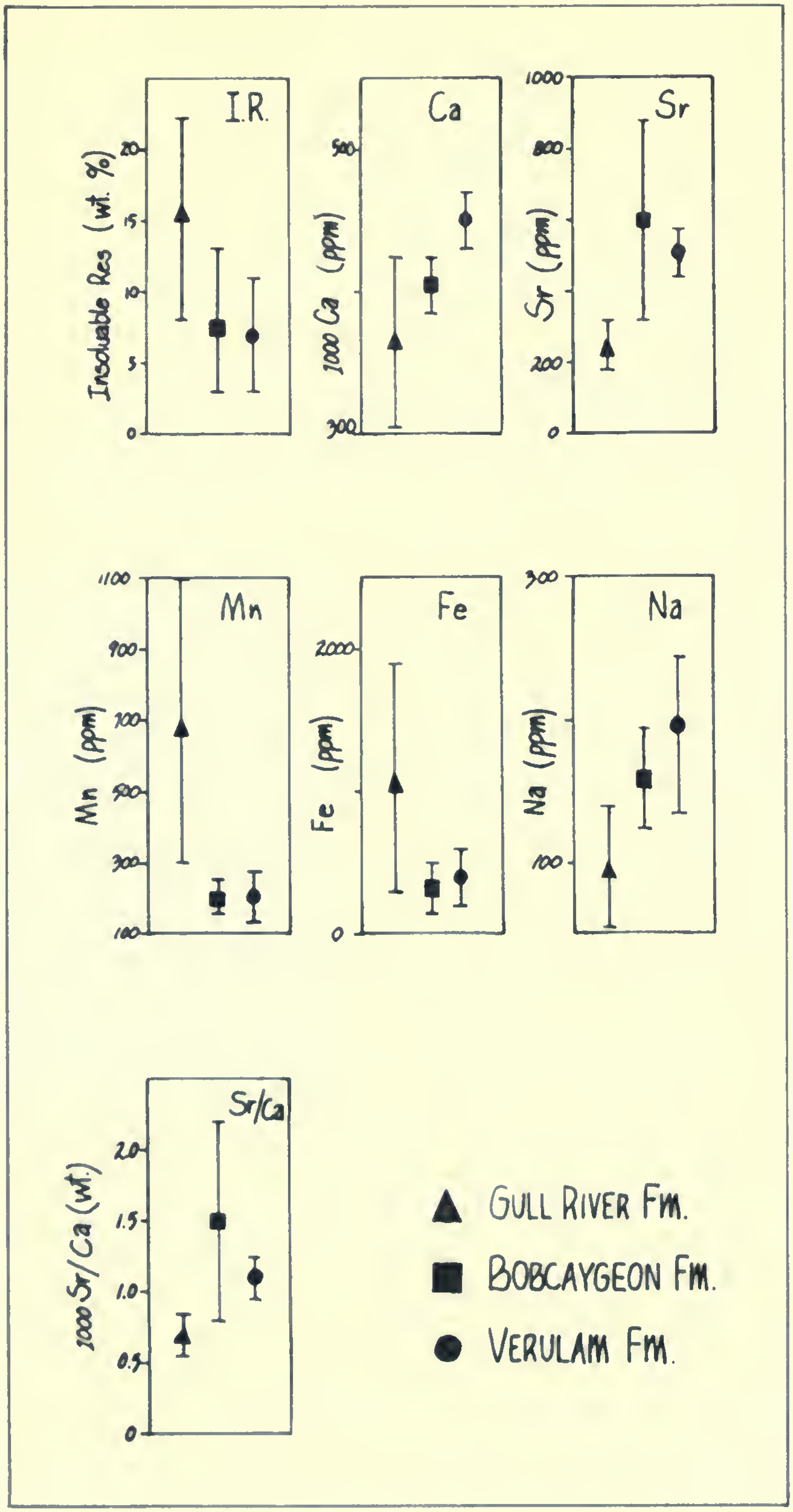

FIGURE 21. Means and standard deviations for the Gull River, Bobcaygeon and Verulam Formations.

B.) <u>Till Geochemistry</u> .

Nine till samples were selected for geochemical analysis; six are of the immature facies and three are of the submature facies. Figure 22 illustrates the location of the till sites on the underlying bedrock.

The samples were sieved as described previously and a total of 64 samples were analyzed (Appendix II).

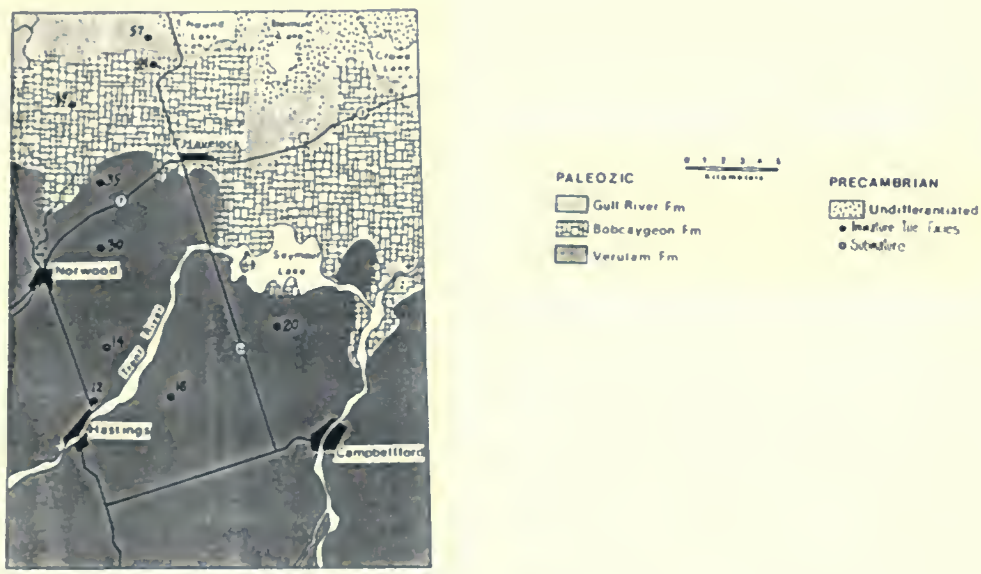

FIGURE 22. Location of till samples collected for geochemical analysis.

The non-carbonate component is represented by the insoluble residue. In the till samples, the I.R. increases rapidly form - 1.5 phi to 4.0 phi, decreasing slightly in the silt and clay fraction (Fig. 23).

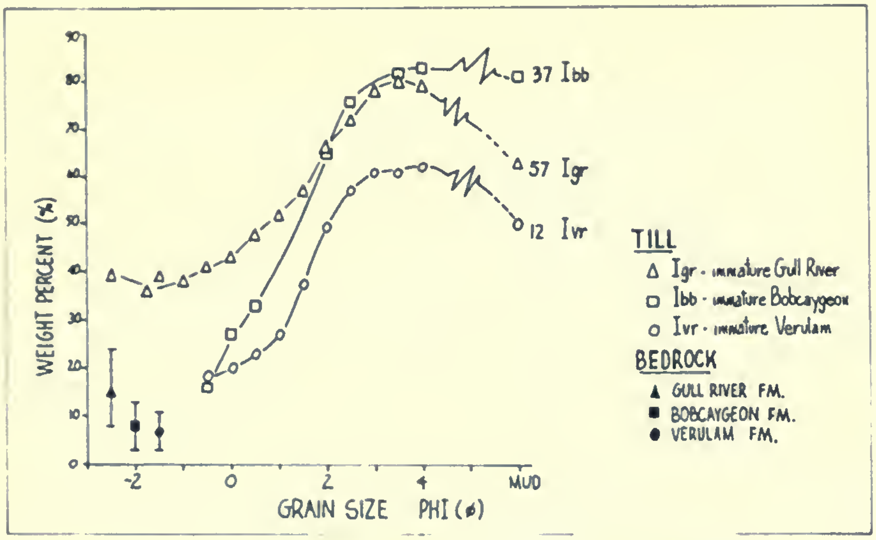

FIGURE 23. Insolu_ble residue in weight percent for the Gull River, Bobcaygeon and Verulam Formations, and the immature till subfacies.

Comparison of the insoluble residue of the immature and the submature till facies, at locations approximately the same distance downice. (Fig. 24), shows that the submature facies has a greater Precambrian Shield component. The difference increases from 13% at -0.05 phi to 24% at 1.0 phi, indicating the submature till facies is transporting a greater amount of long distance material than the immature till facies.

The Precambrian Shield component, representing long distance transport, can be calculated by subtracting the average I.R. value of the underlying Paleozoic formation from the I.R. of the associated till. For example sample 57 Igr (Immature Gull River till subfacies);

I.R. of 57 Igr at 0.0 ø =	43%
Average Gull River Fm. I.R.	15%
Precambrian Shield component	28%

The Gull River subfacies of the immature till has more I.R. than the other two subfacies. The Precambrian Shield component of sample 57 Igr increases from 25 percent at 0.0 phi to 65 percent at 4.0 phi, and decreases to 45 percent in the silt and clay fraction. The immature Bobcaygeon and Verulam subfacies both have less than 10 percent Precambrian Shield component in the - 0.5 phi fraction. This increases to 75 percent at 4.0 phi for the Bobcaygeon subfacies and 56 percent for the Verulam subfacies.

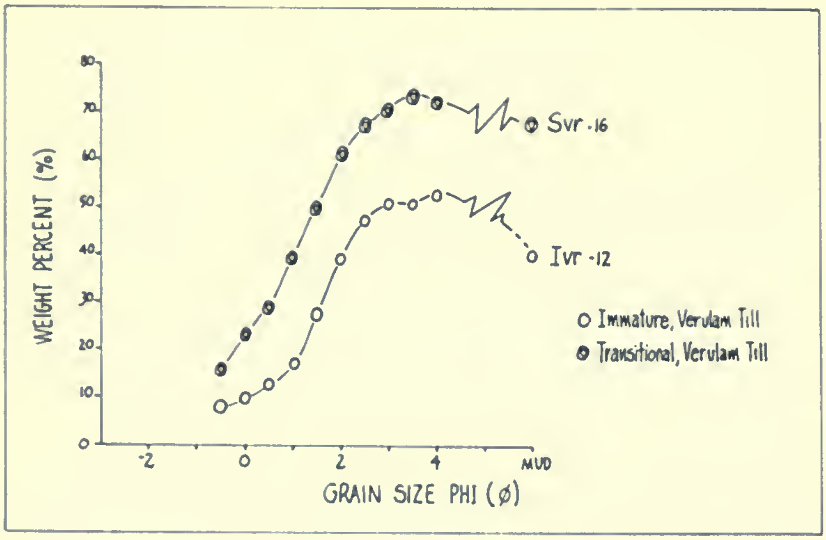

FIGURE 24. Insoluble residue and grain size for the immature and submature till facies.

Elements associated with the insoluble residue are Al, Zn, Cd and Cu (Brand and Terasmae, 1983). To test the amount of leaching of the insoluble residue by the dissolving acid, Al was plotted against I.R. (Fig. 25).

Aluminum is fairly constant at 500 ppm with increasing I.R. up to 30% I.R., where Al increases exponentially with increasing I.R. to over 5000 ppm at 80% I.R. This indicates that there is leaching of elements from the insoluble residue when values of I.R. are greater than 35 percent. For the Gull River subfacies of the immature till the I.R. concentrations are greater than 35% for

all grain sizes analyzed (Fig. 23). The I.R. is greater than 35% in the size fractions less than 1.0 phi. for the Bobcaygeon subfacies, and in the size fractions less than 1.5 phi for the Verulam subfacies. As a result, the geochemistry results of samples with greater than 35 percent I.R. are reflecting the process of leaching from the non-carbonate fraction rather than true values on the carbonate component.

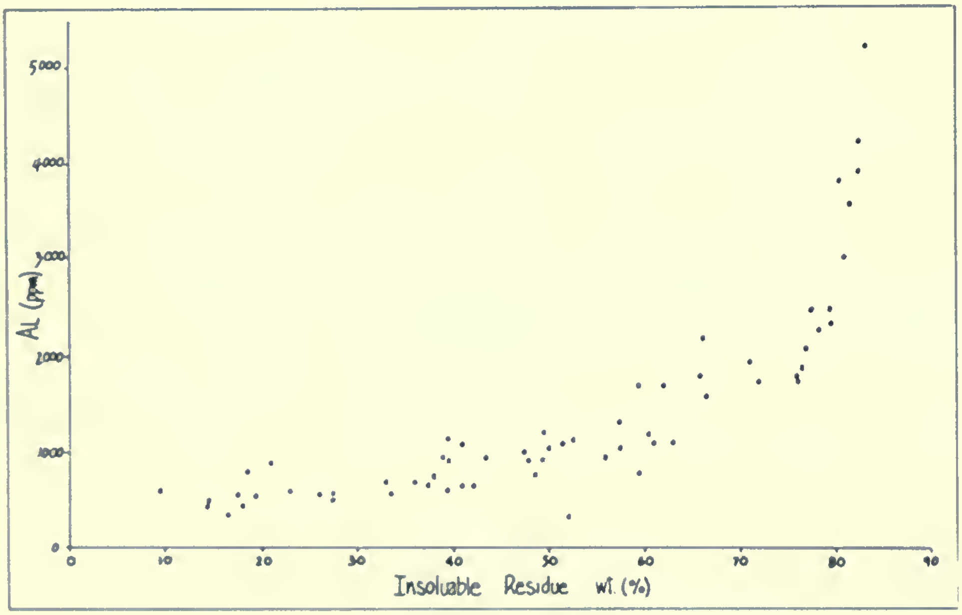

FIGURE 25. Aluminum concentration in ppm against insoluble residue for till geochemistry samples.

To overcome this problem of leaching, elements associated solely with the calcium carbonate lattice such a Sr and those elements partially associated with it such as Fe and Mn (Brand and Terasmae, 1983) were used to correlate till and bedrock geochemistry.

Figure 26 illustrates Sr values for the Gull River, Bobcaygeon and Verulam immature till facies. Sample 57 Igr correlates directly with the range of Sr determined for the Gull River Fm. in all grain sizes analyzed. The Bobcaygeon and Verulam subfacies show higher values and can be differentiated from the Gull River Formation and immature subfacies. However, they cannot be differentiated between themselves on the basis of geochemistry. A similar situation is seen in the Mn values (Fig. 27) where the Gull River subfacies can be correlated to bedrock geochemistry and differentiated from the other two subfacies. However, the Bobcaygeon and Verulam subfacies can not be distinguished. Both show a progressive increase of Mn in the finer grain sizes, where I.R. concentrations are greatest, suggesting some leaching effect.

4.4 Discussion

Bedrock geochemistry of the Gull River, Bobcaygeon and Verulam Paleozoic Formations indicates that only Ca and the Sr/Ca ratio can be used to differentiate these formations. The insoluble residue and Sr, Mn, Fe and Na values are significantly different between the Gull River and the other two Formations. Cu, Ba, Zn and Al are not useful as formational geochemical signatures. Although Mg shows a significant difference between the Gull River and the other two formations, the range is so

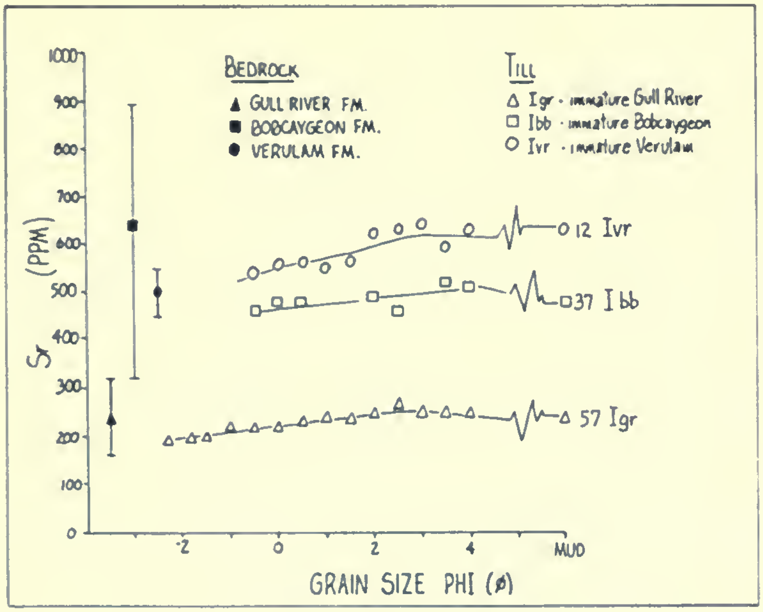

FIGURE 26. Sr content in ppm for the immature till subfacies.

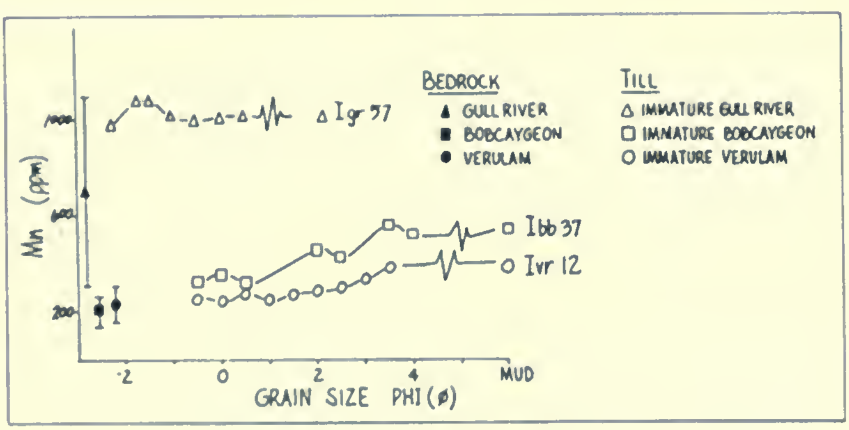

FIGURE 27. Mn content in ppm for the immature subfacies in varying grain sizes.

great in the results it cannot be considered as a useful indicator. The standard deviation of the other results is quite large as well (Fig. 10), making differentiation between the formations, especially between the Bobcaygeon and Verulam, tenuous. The Bobcaygeon and Verulam Fms. are not chemically distinctive from each other using the elements in this study.

The insoluble residue trend in the till samples may be related to terminal grades of the mineral constituents (Dreimanis and Vagners, 1971), or secondary enrichment of calcium carbonate in the silt and clay by ground water percolation. The submature till facies has a great amount of I.R. in all grain sizes, indicating more long distance transported Precambrian Shild material than in the immature till.

The method developed by Brand and Veizer (1980) for use on carbonate rocks is not effective when analyzing sediments with greater than 35 percent insoluble residue. The relationship between elements such as Al, which are associated with the non-carbonate component, illustrates the amount of leaching that has occured. By using elements which are primarily associated with the carbonate component, this leaching problem can be reduced.

4.5 Conclusions

Geochemistry of the Gull River, Bobcaygeon and Verulam Formations indicates the Gull River Fm. as signiicantly distinctive from the other two formations. The Bobcaygeon and Verulam Formations are not chemically distinctive.

By using Sr and Mn analysis associated with the calcium carbonate lattice, correlation of the immature Gull River subfacies to the Gull River Formation was possible. Correlation of the Bobcaygeon and Verulam subfacies were not possible to their bedrock sources.

The contribution of marbles from the Precambrian Shield is unknown (Fig. 28). The potential incorporation of marble must be considered as it constitutes approximately 30 percent of the immediate area in an up ice direction.

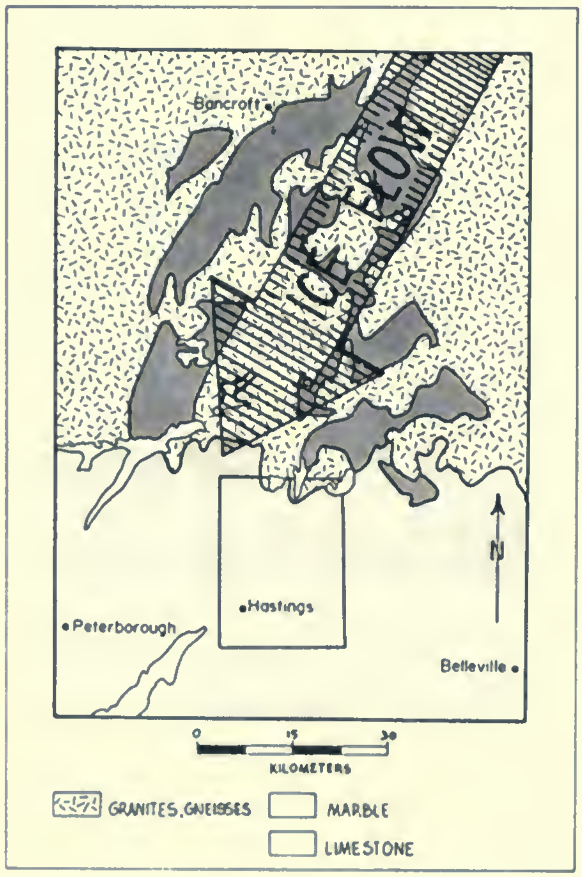

FIGURE 28. Generalized bedrock map indicating extent of marbles in an up ice direction from the map area.

The rapid increase of insoluble residue in the sand fraction indicates the immature till is composed of two components. A coarse fraction which is dominated by local carbonate bedrock constituents and a matrix composed of long distance Precambrian Shield material. The submature till facies which has more long distance transported clasts and more rounding, appears to have a greater amount of long distance transported material in its matrix.

The method used for till geochemistry is not effective due to the effects of leaching from the insoluble fraction. Modification of the method may reduce this effect.

The identification of a specific element which is chemically distinctive and localized would be of greater value than broad spectrum carbonate geochemistry, especially if attempting to correlate sediments to bedrock sources. The processes of erosion, transportation and deposition modify sediments. Identifying a specific geochemical signature which can be traced in distance and grain size would provide a valuable tool in understanding glacial processes.

5.0 MODEL OF DEPOSITION

5.1 Introduction

Controversy exists over the interpretation of the Dummer Complex. Traditionally the Dummer Complex has been interpreted as an end moraine (Mirynech, 1962, Chapman and Putnam, 1966). More recent work on the Dummer Complex by Schluchter (1979) and regional deglaciation studies of southern Ontario (Terasmae, 1979, Gadd, 1980) have proposed an alternative view as to origin of the Dummer Complex.

Studies on modern glaciers (eg. Boulton, 1968, 1970, Johnston 1971, Lawson 1979, Eyles, 1979) have provided insight into processes and sedimentation in the glacial environment. With this information and the data collected in this study, a model of deposition is proposed for the Dummer Complex using sedimentology, geological setting and glacial processes.

5.2 Traditional Interpretation of the Dummer Complex

Traditionally the Dummer Complex has been regarded as an end moraine (Mirynech, 1960; Chapman and Putnam, 1966; Prest, 1970; Dreimanis, 1977; Vivian, 1973). The orientation of the Dummer Complex is parallel to the Oak Ridges Interlobate Moraine was considered additional evidence for its interpretation as an end moraine (Gadd, 1980).

The traditional view (Mirynech, 1962), holds that during the late Wisconsin glacial ice flowed southwestward across the area as evidenced by striae and drumlin orientations. During deglaciation the Simcoe lobe retreated to a point north of the Paleozoic - Precambrian contact. A cooling of the climate resulted

in the re-activation of the ice and the glacier re-advanced, ripping up blocks of Paleozoic bedrock producing the sediments which characterize the Dummer Complex. The period of re-activation was short lived and the ice advanced only 4 to 20 Kilometers, not overriding the drumlins. The end of the re-activation period was caused by warming of the climate and the ice retreated rapidly northwards.

The re-advance of the Simcoe lobe was used to explain the closing of the Kirkfield - Fenelon Falls outlet, resulting in the Main Lake Algonquin phase.

5.3 Problems with the Traditional Interpretation

Papers by Terasmae (1980) and Gadd (1980) discuss the problems of the traditional interpretation of the Dummer Complex and overall deglaciation history of southeastern Ontario.

A.) Flow Indicators and Morainic Systems

Striae measurements by Henderson (1966), Terasmae (1965) and Gadd (1980) suggest changing ice-flow directions during the late Wisconsin. South of the Ottawa River the oldest set of striae indicate a southwesterly flow. Superimposed on this set are another set which trend in a westerly direction is the Kingston area. This change is not seen in the area north of the Oak Ridges Moraine covered by the Simcoe lobe - Striae and drumlin orientations are southwesterly suggesting there was no change of flow direction during retreat. The east-west orientation of the Dummer Complex is not normal to ice-flow as would be expected for an end moraine.

Although the Dummer Complex does parallel the Oak Ridges Moraine, it is important to mention that the Oak Ridges is an interlobate lateral moraine and the Dummer Complex interpreted as an end moraine. The Dummer Complex is parallel to the Precambrian - Paleozoic bedrock contact.

The Dummer Complex terminates at Tamworth and the Oak Ridges Moraine terminates at Trenton with no eastward extensions of these features (Henderson, 1973). This means there is no evidence that the margin of the ice sheet extended to the Adirondacks (Terasmae, 1980; Gadd, 1980). The termination of the Dummer Complex at Tamworth is coincidental with the eastern limit of the Paleozoic carbonates.

B.) Regional Deglaciation History

The regional deglaciation history of southeastern Ontario is poorly understood (Terasmae, 1980; Gadd, 1980; Sharpe, 1979; Karrow et. al., 1975). Specific problems relate to the opening and closing of the Fenelon Falls - Trent Valley outlet system between glacial Lake Algonquin, the Iroquois shoreline which disappears in the Trenton - Belleville area and the Champlain Sea C^{14} dates which are considerably older than the dates on Lake Iroquois. The overall relationship of Lake Algonquin - Lake Iroquois and the Champlain Sea (Sharpe, 1979) to the deglaciation of southeastern Ontario remains a problem.

C. Occam's Razor or a Matter of Simplicity

Recent work on modern glaciers and glacial sediments has provided insight into glacial processes. Although there is no modern equivalent of the continental glaciers of the past, ancient deposits can be related to modern glacial processes. Emphasis should be placed on the interpretations which are the simplest, relating where possible the deposit to a depositional environment without invoking a catastrophic event. If the Dummer Complex can be explained in terms of glacier ice dynamics without the necessity of a cooling climate and a change in ice mass, this interpretation should be given preference. As Occam's razor states, when there are more than one explanation, one must choose the one that involves the least number of assumptions.

5.4 Determination of Depositional Environment

The Dummer Complex is composed of scattered, pitted hummocks of blocky, angular debris. The northern margin is the Precambrian - Paleozoic bedrock contact. The southern margin is irregular and diffuse, with Dummer Complex deposits separated by drumlins. The drumlins do not show any indications of having been overridden. Dummer sediments are often associated with large expanses of bare or boulder strewn Paleozoic bedrock and have not been found overlying any other type of sediment. Deposits show rough alignment with southwest ice-flow indicated by the drumlins. One set of striae located in the Dummer Complex, 2 km. west of Round Lake, show parallel orientation with the drumlins. Subglacial or englacial eskers cut through deposits of the Dummer Complex.

Dummer sediments have a sandy-silty matrix supporting a large coarse component. The coarse component is made of large blocks of angular clasts of Paleozoic bedrock. The Paleozoic clasts are composed of the underlying bedrock lithology. There is no indication of sorting or stratification in the Dummer Complex.

The glacial depositional environment can be determined by examining sedimentological characteristics of the deposits and their relationship to other lateral sedimentary units (Boulton, 1970, 1976; Eyles et. al., 1983). Sediments associated with ice marginal processes are usually a complex association of resedimented flows. The flows often show layered or banded structures and an internal upward fining organization. These supraglacial flow tills are generally associated with meltwater and evidence of sorting, such as sand lenses in the till, is common. (Boulton, 1972).

Dummer sediments lack the characteristic sorting and bedding associated with secondary or supraglacial flow tills. Its massive, unstratified, unsorted structure suggests a subglacial environment of deposition. The rough alignment of the Dummer Complex hummocks with ice-flow as well as the cross-cutting by subglacial or englacial eskers supports the sedimentological evidence of a subglacial environment.

Sediments deposited subglacially are divided into lodgement till, melt-out till and deformation till (Boulton and Deynoux, 1981). As the Dummer sediments show no evidence of deformation, they must be either lodgement or subglacial melt-out till.

	Subglacial Melt-out till	Lodgement till	Dummer till
Sedimentary sequence	Above lodgement or glacier bed	Glacier bed	Glacier bed
Grain - size composition	Substantial fine sand/ mud fraction	Substantial fine sand/ mud fraction with boulder clusters	Substantial mud fraction, bouldery
Clast shape	Sub-rounded, facetted and striated	Sub-rounded, bullet - shaped, striated	Angular, equidimentional few striated clasts
Bedding	Massive	Massive	Massive
Clast orientation	Large scale areal consistancy with flow	Strong flow-parallel peaks	None decernable
Folding and faulting	Rarely apparent	May or may not be apparent	None apparent
Nature of contacts	Sharp	Sharp	Sharp
Geotechnical properties	Normally consolidated	Overconsolidated	Unknown
Jointing	Rarely	Common	None observed
Thickness	Thin, less than 2m	Any thickness	3 - 10 m
Uniquely diagnostic characteristic	None	Orientated bullet - shaped clasts	

Table 11 . Dummer Complex till compared to the criteria of differentiating primarily tills from Boulton and Deynoux (1981).

The immature till of the Dummer Complex has sedimentological properties of both lodgement and melt-out tills (Table 11). The immature till is found directly on the glacier bed, in this case the Paleozoic bedrock. Lodgement till always overlies the glacier bed or lodgement till. The thickness of Dummer deposits is up to 10 meters which exceeds the maximum thickness (2m) of subglacial melt-out till deposits. Lodgement tills can be of any thickness. The angular, equidimensional shape of the clasts of the immature till is not characteristic of either lodgement or melt-out till.

Over all, the sediments of the Dummer Complex appear to be a type of lodgement till in which the clasts have undergone little comminution or transport.

Three subglacial tills have been recognized in the area; the till which comprises the drumlinized areas, the immature till of the Dummer Complex and a transitional till with characteristics between the other tills. The immature till shows little or no transport while the mature till of the drumlins represents long distance transport, as illustrated by the pebble counts reported in chapter 3. The geochemistry appears to support this concept, as the matrix of the submature (transitional) till has more Precambrian Shield component than the immature till as represented in the insoluble residue values. The three tills appear to be lodgement facies subglacially produced, with distance of transport the controlling factor accounting for their differences.

5.5 Model of Deposition

Regional ice-flow south of the Ottawa Valley was southwestwards. As the ice flowed over the Algonquin Highlands the compressive flow changes to extensive (Fig. 29). This resulted in higher ice velocities and higher basal temperatures. The impermeable glacial bed of Precambrian bedrock along with the other factors mentioned formed a basal water film. This type of situation has also been reported in Sweden by Minell (1980).

As the ice progressed down the lee of the Algonquin Highlands, the extensive flow changed to compressional. In compressive zones, the lowering of ice velocities results in lower basal temperatures and this allows onfreezing of material at the base (Weertman, 1961).

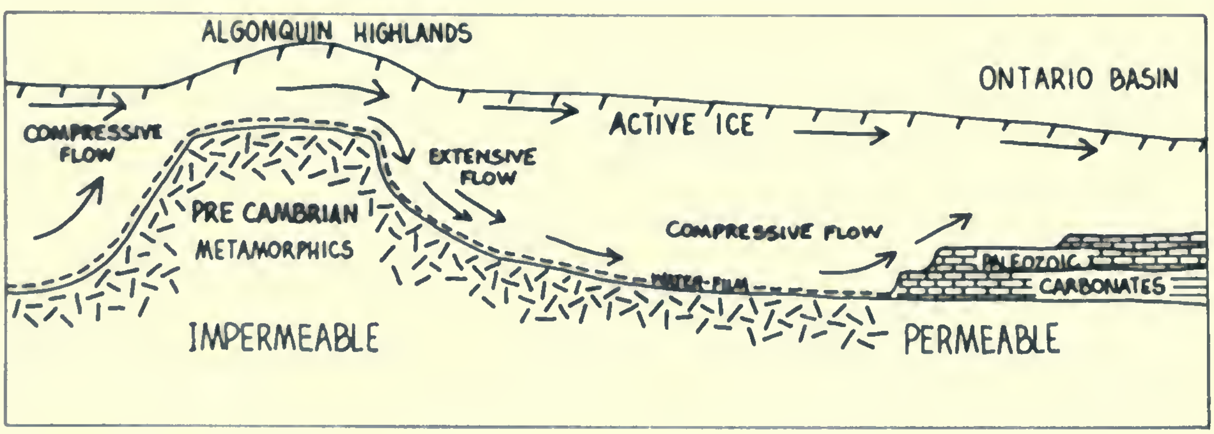

FIGURE 29. Schematic diagram of active ice conditions over the Algonquin Highlands.

Once the Paleozoic carbonates, in a series of north-facing escarpments, are encountered there is a change in ice dynamics. The basal water film dissipates into bedding phases, fractures, and solution features of the carbonate bedrock (Fig. 30).

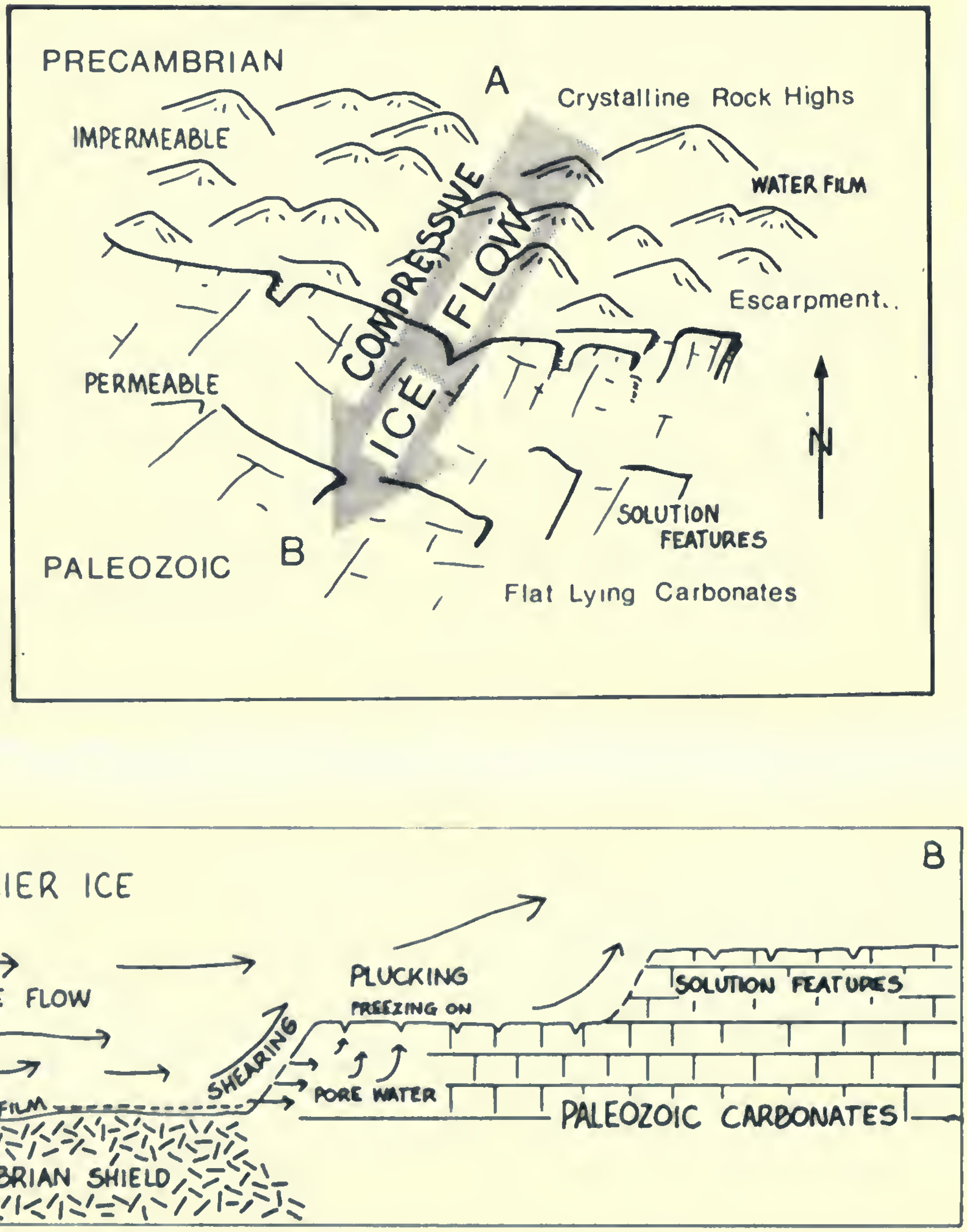

FIGURE 30. Ice conditions at the Precambrian - Paleozoic bedrock contact.

The result of the loss of the basal water film and the lower basal temperatures produces freezing-on at the glacier bed. The erosional capacity of the ice is aided by 1.) compressional flow, 2.) the saturation of the glacial bed producing excessive pore pressures thereby reducing the shear strength of the bed, and 3.) a frozen bed,thus lowering the effective glacier base below the ice-rock interface (Clayton and Moran, 1974; Kupsch, 1962). Since all these conditions are present in this situation, the ice has a great amount of erosive potential. The carbonate bedrock is sheared and plucked with the aid of freezing at the base, to the point where the ice becomes debris laden beyond its capacity to transport. The debris within the ice increases the shear strength of the basal ice to the point where cleaner ice overrides it and the debris laden ice acts as the glacier bed (Fig. 31).

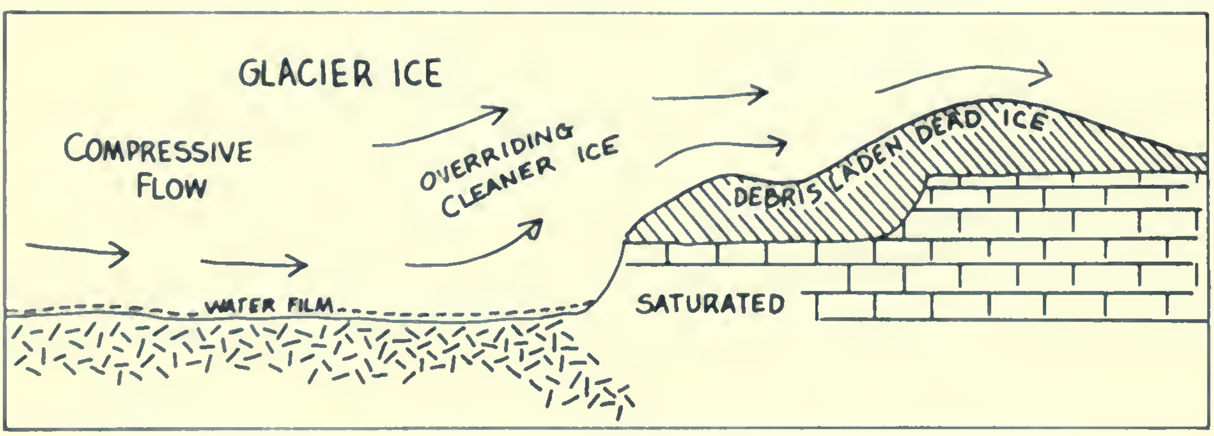

FIGURE 31. Schematic diagram of overriding of cleaner ice at the Precambrian - Paleozoic bedrock contact.

As the ice downwasted it thinned to such a point over the Algonquin Highlands that the ice to the south was cut off (Fig. 32). This resulted in the down-wasting of the ice over the area which contained the basal debris laden dead-ice, producing the pitted, hummocky topography of the Dummer Complex, Garnes and Bergersen (1980) have discussed similar situation in South Norway.

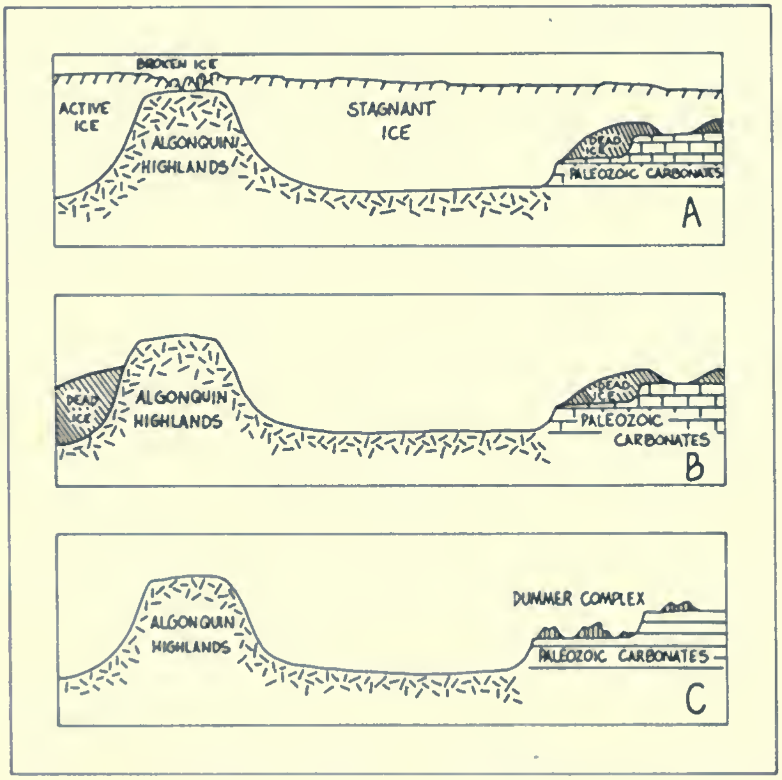

FIGURE 32. Ice stagnation and melt-out of the Dummer Complex.

5.6 Conclusion

The model presented explains the Dummer Complex in terms of the ice dynamics. It is felt that this interpretation answers many of the problems discussed earlier in terms of regional deglaciation of southeastern Ontario .

The position and orientation of the Dummer Complex is due to a particular set of geomorphological characteristics and the change from the Precambrian Shield to the Paleozoic carbonates. The parallel alignment of the Dummer Complex with the Oak Ridges Moraine has nothing to do with ice marginal positions.

The distribution of Dummer Complex deposits is defined by the Precambrian - Paleozoic contact at its northern margin and specific ice conditions along its southern margin. Ice conditions changed dramatically over short distances, as seen by the relationship of the drumlins and the Dummer Complex. The Dummer Complex representing an erosional zone and the drumlins a depositionary zone. The Dummer Complex may be similar to the subglacial transitional morainic forms described by Markgren and Lassila, 1980; Kurimo, 1980.

The sedimentological characteristics of the Dummer Complex represent a subglacial till which has not undergone any significant transport. The immature till of the Dummer Complex is composed of two components, the coarse angular fraction made of the underlying bedrock lithology and a long distance transported matrix, defined geochemically.

The pitted, hummocky morphology of the Dummer Complex, separated by expanses of bare or boulder strewn

bedrock plains is the result of large scale ice stagnation. Meltwaters washed areas between hummocks clean of debris.

In terms of the regional deglaciation history, this model of ice stagnation and subsequent rapid disintegration would result in rapid rebound as discussed by Terasmae (1980). The rapid rebound would provide the mechanism of the closing of the Kirkfield-Fenelon Falls outlet and the development of the Main Algonquin phase, without the necessity of a readvance. The massive stagnation of the Simcoe lobe caused the cessation of southwesterly discharge routes could account for the change in flow patterns of the Ontario basin lobe. This type of situation is reported by Aario and Forsstrom (1979).

Finally, the model presented here has the least number of assumptions compared to the alternative view of a cooling climate, short lived re-activation and advance of the ice front.

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APPENDIX I

FORMATION / Location	Dunham's Class				Folk's Class.				Fossil Content								Cement				Other Features				
	mudstone	wackestone	packstone	grainstone	dismicrite	micrite	biomicrite	biosparite	bryozoans	corals	crinoids	brachiopods	gastropods	pelecypods	trilobites	ostracods	syntax. overgr.	equant	2 - generations	solution-cavity	neomorphism	incip. dolo.	matrix	silicification	stylolites
Bobcaygeon																									
R-11 (a)	*							*			*	*			*	*		*	*		*		*		
R-11 (b)			*					*			*	*		*	*	*		*	*		*	*	*		*
R-11 (c)	*										*	*			*					*	*	*			
R-11 (d)			*					*	*		*	*		*	*		*	*			*	*	*	*	*
R-11 (e)		*						*			*	*		*	*	*	*		*	*	*	*	*		*
R-11 (f)			*						*		*	*			*	*		*	*			*	*		*
R-11 (g)			*						*	*	*	*			*			*		*	*	*		*	
R-11 (h)			*					.	*		*	*		*	*							*	*	*	*
R-23				*				*		*					*		*	*	*			*			
Gull River																									
R-38	*										*							*				*	*		*
R-12	*				*	*			*							*		*					*		*

Table 1. Summary of petrographic observations of the Gull River and Bobcaygeon Formations.

APPENDIX II

01Ivr	VA	A	SA	SR	R	
P€						0
GR						0
BB		15.5	2.6			18.1
VR	3.4	64.7	13.8			81.9
	3.4	80.2	16.4			116

02Ivr						
P€						0
GR						0
BB	0.9	3.5	1.7			6.1
VR	14.8	72.2	7.0			93.9
	15.7	75.7	8.7			115

03M						
P€	1.0	1.0	1.0	3.9	2.9	9.7
GR		1.0	2.9	1.9	1.9	7.8
BB		6.8	18.4	23.3	29.1	77.7
VR		2.9	1.9			4.9
	1.0	11.7	24.3	29.1	33.9	103

05Ivr						
P€						0
GR						0
BB						0
VR	9.6	76.3	12.3	1.8		
	9.6	76.3	12.3	1.8		114

06 S						
P€		0.8	2.4	2.4	1.6	7.2
GR			2.4	4.7	0.8	7.9
BB			2.4	10.[illegible]	8.7	21.3
VR	1.6	15.8	31.6	9.7	5.6	63.9
	1.6	17.3	35.5	27.0	18.6	127.

07Ivr						
P€	0.8	0.8				1.6
GR						
BB			0.8	1.6		2.5
VR	18.2	76.9	0.8			95.9
	19.0	77.7	1.6	1.6		121

08S						
P€			0.6	0.5		11.2
GR		1.9				1.9
BB		10.3	25.2	13.1		48.6
VR		14.0	20.5	3.7		38.3
		26.2	46.4	17.3		107

09M						
P€			3.2	2.4		5.6
GR			0.8	2.4		3.2
BB		12.0	28.8	5.6	0.8	47.2
VR		39.2	4.8			44.0
		51.2	37.6	10.4	0.8	125

10S	VA	A	SA	SR	R	
P€					0.9	0.9
GR			0.9	0.9		1.8
BB		2.7	41.1	28.6	2.7	75.0
VR	5.4	17.0				22.3
	5.4	19.7	42.0	29.5	3.6	112

11S						
P€	0.9					0.9
GR						
BB		5.4	10.7	3.6		19.7
VR	10.7	39.3	25.9	3.6		79.5
	11.6	44.7	36.6	7.2		112

12Ivr						
P€			0.9	0.9		1.8
GR				0.9		0.9
BB			0.9	0.9		1.8
VR	13.6	63.6	12.7	5.4		95.4
	13.6	63.6	14.5	8.2		110

14S						
P€		0.9				0.9
GR						
BB			1.8	2.7	2.7	7.3
VR	2.7	41.3	34.9	11.0	1.8	91.7
	2.7	42.2	36.7	13.7	4.5	109

15Ivr						
P€						0
GR						0
BB	1.8	4.5				6.4
VR	30.0	61.8	1.8			93.6
	31.8	66.4	1.8			110

16S						
P€		1.0		4.2		5.2
GR			1.0	3.1		4.2
BB		1.0	5.2	2.1		8.3
VR	4.2	57.3	20.8			82.3
	4.2	59.4	27.1	9.4		96

17Ivr						
P€						0
GR						0
BB						0
VR	19.4	79.8	0.8			100.
	19.4	79.8	0.8			129

20S						
P€		1.0				1.0
GR			1.0	1.0	1.0	2.9
BB		1.0	3.8	1.0		5.8
VR	1.9	82.7	5.8			89.4
	1.9	84.6	10.6	1.9	1.0	104

Pebble lithology and roundness results.

- PC - Precambrian clasts, GR - Gull River Fm., BB - Bobcaygeon Fm., VR- Verulam Fm.
- I - Immature; S - submature, M- mature till facies.
- vr - Verulam, bb- Bobcaygeon, vr - Verulam immature subfacies.

21Ivr	VA	A	SA	SR	R	
PЄ			2.0	1.0		3.0
GR		3.0	2.0	4.0		10.0
BB			4.0	2.0		6.0
VR	10.0	60.0	8.0	3.0		81.0
	10	63	16	10		100

36Ibb	VA	A	SA	SR	R	
PЄ						
GR						
BB	12.0	85.0	3.0			100
VR						
	12.0	85.0	3.0			100

24Ivr	VA	A	SA	SR	R	
PЄ			0.6			0.6
GR			0.6	1.3		1.9
BB		14.0	2.5			16.6
VR	3.8	75.2	1.9			80.9
	3.8	89.2	5.7	1.3		157

37Ibb	VA	A	SA	SR	R	
PЄ			1.0	1.0		2.0
GR		2.9	2.0	5.9		10.8
BB	6.9	55.9	21.6	2.9		87.2
VR						
	6.9	58.8	24.5	9.8		102

27S	VA	A	SA	SR	R	
PЄ						
GR						
BB	13.2	86.8				100
VR						
	13.2	86.8				114

40Ibb	VA	A	SA	SR	R	
PЄ		2.3	4.6			6.9
GR		3.4	3.4	1.1		11.5
BB	27.6	46.0	4.6	3.4		81.6
VR						
	27.6	51.7	12.6	4.6		87

29IVR	VA	A	SA	SR	R	
PЄ				0.7		0.7
GR		2.2	4.4	5.2		11.9
BB		9.6	3.0			12.6
VR	2.2	51.1	21.5	21.5		74.8
	2.2	63.0	28.9	5.9		135

42I	VA	A	SA	SR	R	
PЄ		0.8	0.8	2.4	0.8	4.7
GR		4.7	15.0	8.7	2.4	30.7
BB	7.1	54.3	3.1			64.6
VR						
	7.1	59.8	18.9	11.0	3.1	127

30Ivr	VA	A	SA	SR	R	
PЄ		1.1				1.1
GR				1.1		1.1
BB		3.2	12.8	4.3	2.1	22.3
VR	1.1	46.6	27.7			75.5
	1.1	51.1	40.4	5.3	2.1	94

43Ibb	VA	A	SA	SR	R	
PЄ						0
GR						0
BB	6.0	73.5	20.5			100
VR						0
	6.0	73.5	20.5			166

32S	VA	A	SA	SR	R	
PЄ			0.8			0.8
GR						
BB		31.7	45.8	11.7		89.2
VR		10.0				10.0
		41.7	46.7	11.7		120

44Ibb	VA	A	SA	SR	R	
PЄ						
GR						
BB	8.9	64.9	24.6	1.6		100
VR						
	8.9	64.9	24.6	1.6		191

33Ivr	VA	A	SA	SR	R	
PЄ		0.8	0.8			1.7
GR						
BB		2.5	1.7			4.2
VR	5.1	81.4	7.6			94.1
	5.1	84.7	10.2			118

46M	VA	A	SA	SR	R	
PЄ						1.0
GR						0
BB	3.9	50.5	2.9			57.3
VR	12.6	29.1				4[illegible].7
	16.5	79.6	2.9			103

34Ivr	VA	A	SA	SR	R	
PЄ		2.7	2.7	2.7		8.0
GR		0.9	3.6	2.7	3.6	10.7
BB		0.9	4.5	3.6	0.9	9.8
VR	2.7	59.8	4.5	4.5		71.4
	2.7	64.3	15.2	13.4	4.5	112

481bb	VA	A	SA	SR	R	
PЄ		1.2		1.2		2.4
GR		1.2	1.2	1.2		3.6
BB		36.9	10.7	1.2		48.8
VR		45.2				45.2
	.	84.5	11.9	3.6		84

51Igr	VA	A	SA	SR	R	
PЄ						
GR			1.0			1.0
BB	9.6	30.8	53.8	3.8	1.0	99.0
VR						
	9.6	30.8	54.8	3.8	1.0	104

62Igr	VA	A	SA	SR	R	
PЄ						0
GR	45.5	54.5				100
BB						0
VR						0
	45.5	54.5				121

55Ibb						
PЄ			1.8			1.8
GR		3.5	7.1	0.9		11.5
BB		21.2	64.6	0.9		86.7
VR						
		24.8	73.5	1.8		113

63Igr						
PЄ						0
GR	7.6	49.6	35.3	5.9	1.7	100
BB						0
VR						0
	7.6	49.6	35.3	5.9	1.7	119

57Igr						
PЄ		1.8	7.3	11.0	1.8	22.0
GR		5.5	35.8	36.7		78.0
BB						0
VR						0
		7.3	43.1	47.7	1.8	109

64gr						
PЄ		0.8	3.2	0.8		4.8
GR	8.1	37.1	31.5	12.1	6.5	95.2
BB						
VR						
	8.1	37.9	34.7	12.9	6.5	124

58Ibb						
PЄ		0.9				0.9
GR		2.8	1.8			4.6
BB	13.9	65.7	14.8			94.4
VR						0
	13.9	69.4	16.7			108

65M						
PЄ		1.7	4.2			5.9
GR		0.8	1.7	0.8	2.5	5.9
BB		7.6	22.0	13.6	2.5	45.8
VR	0.8	19.5	10.2	4.2	3.4	38.1
	0.8	29.7	38.1	18.6	8.5	118

59Ibb						
PЄ		0.6	0.6			1.2
GR		1.2	1.8	1.2		4.2
BB	6.1	41.2	29.1	15.2	3.0	94.5
VR						0
	6.1	43.0	31.5	16.4	3.0	165

66Ivr						
PЄ		0.8	0.8			1.6
GR						0
BB		0.8	2.4	3.2		6.4
VR		63.2	18.4	8.8	1.6	92.0
		64.8	21.6	12.0	1.6	125

60Igr						
PЄ						
GR	24.5	75.5				100
BB						0
VR						0
	24.5	75.5				110

67M						
PЄ		2.7	3.6	0.9		7.2
GR			1.8	1.8	1.8	5.4
BB		8.1	31.5	40.5	6.3	86.5
VR			0.9			0.9
		10.8	37.8	43.2	8.1	111

61M						
PЄ		2.2	5.1	2.2		9.5
GR			2.2	2.2	0.7	5.1
BB		2.9	35.0	24.1	6.6	68.6
VR		3.6	5.1	5.1	2.9	16.8
		8.8	47.4	33.6	10.2	137

68Ivr						
PЄ		1.0				1.0
GR						0
BB		1.0				1.0
VR	1.0	55.9	31.4	8.8	1.0	98.0
	1.0	57.8	31.4	8.8	1.0	102

69Ivr	VA	A	SA	SR	R	
PЄ			1.9			1.9
GR						0
BB				0.9		0.9
VR	10.3	79.4	7.5			97.2
	10.3	79.4	9.3	0.9		107

70Ibb						
PЄ		1.8	0.9			2.7
GR			0.9			0.9
BB	2.7	26.4	49.1	16.4	1.8	96.4
VR						0
	2.7	28.2	50.9	16.4	1.8	110

72Ibb						
PЄ			1.0			1.0
GR						0
BB	6.9	88.1	3.0	1.0		99.0
VR						0
	6.9	88.1	4.0	1.0		101

73Ibb						
PЄ		0.8				0.8
GR		3.3	4.1	2.5		9.9
BB	0.8	33.9	40.5	13.2	0.8	89.3
VR						
	0.8	38.0	44.6	15.4	0.8	121

74S						
PЄ		10.5	4.4	1.8		16.7
GR		3.5	2.6			6.1
BB		27.2	33.3	16.7		77.2
VR						
		41.2	40.3	18.4		114

75Ibb						
PЄ						0
GR						0
BB	13.2	80.2	6.6			100
VR						
	13.2	80.2	6.6			106

76Ibb						
PЄ		1.0				1.0
GR				1.0		1.0
BB	5.8	77.7	14.6			98.0
VP						0
	5.8	78.6	14.6	1.0		103

77Igr	VA	A	SA	SR	R	
PЄ			1.8		0.9	2.7
GR	6.4	42.7	2.7	0.9		52.7
BB	11.8	27.3	3.6		1.8	44.5
VR						0
	18.2	70.0	8.2	0.9	2.7	110

78Igr						
PЄ		2.6	3.5			6.2
GR	8.8	40.7	8.8	2.6		61.1
BB	2.6	28.3	1.8			32.7
VR						0
	11.5	71.7	14.2	2.6		113

79Igr						
PЄ			1.0			1.0
GR	8.6	61.9	18.1	3.8		92.4
BB		5.7	1.0			6.6
VR						0
	8.6	67.6	20.0	3.8		105

80Ibb						
PЄ		3.5	1.8			5.3
GR						0
BB	7.9	71.1	15.8			94.7
VR						
	7.9	74.6	17.5			114

81Igr						
PЄ		4.0	1.6			5.6
GR	10.5	49.2	2.4			62.1
BB	12.9	19.4				32.3
VR						
	23.4	72.6	4.0			124

82Ibb						
PЄ		0.9	7.5	0.9	0.9	10.4
GR			0.9		2.8	3.8
BB	5.7	33.0	14.2	8.5	4.7	65.1
VR	2.8	17.0	0.9			20.7
	8.5	50.9	23.6	9.4	8.5	106

83Ivr						
PЄ						
GR			1.0	1.0		2.1
BB	5.2	22.9	15.6			43.7
VR	22.9	31.2				54.2
	28.1	54.2	16.7	1.0		96

84Ibb	VA	A	SA	SR	R	
PЄ		3.7	0.9			4.6
GR	10.2	73.7	12.0			95.4
BB						
VR						
	10.2	76.8	13.0			108

85Ibb						
PЄ			3.7	1.9		5.6
GR			0.9	0.9		1.9
BB		5.6	12.1	15.0	15.9	48.6
VR	3.7	15.9	14.0	7.5	2.8	43.9
	3.7	21.5	30.8	25.2	18.7	107

86Ibb						
PЄ					0.9	0.9
GR			0.9	2.6		3.5
BB	6.2	78.8	3.5	3.5		92.0
VR		3.5				3.5
	6.2	82.3	4.4	6.2	0.9	113

87Ibb						
PЄ			3.0	1.0		4.0
GR		1.0				1.0
BB	8.9	60.4	22.8	3.0		95.0
VR						
	8.9	61.4	25.7	4.0		101

88Ivr						
PЄ						0
GR						0
BB		1.7				1.7
VR	9.4	86.3	2.6			98.3
	9.4	88.0	2.6			117

APPENDIX III

BEDROCK FORMATION	SAMPLE NUMBER	INSOLUBLE FRACTION	SOLUBLE FRACTION	CA	MG	SR	CU	MN	FE	NA	ZN	BA	AL	NI	SRCA
G	20	4.73	91.22	419930	3613	290	2.63	177	231	57	0.35	510	67	-	0.71
U	30	19.64	83.36	419490	4656	267	4.11	336	1225	31	2.16	377	267	-	0.64
L	53A	25.12	74.85	259582	75535	230	5.61	1150	1271	159	12.25	268	559	-	0.91
L	53B	17.94	82.06	412800	3619	342	1.95	271	521	68	1.46	630	341	-	0.83
	53C	9.52	90.48	365770	3317	349	1.65	292	335	61	0.30	360	133	-	0.95
R	53D	7.94	92.06	336410	7995	279	5.43	917	1277	41	0.98	490	109	-	0.72
I	55A	13.62	86.38	385453	4638	292	4.86	719	924	104	2.32	522	281	-	0.76
V	55D	14.60	85.40	338140	50917	163	5.85	1037	1334	128	5.27	233	251	-	0.48
E	57A	8.12	91.88	403120	28842	169	5.44	1232	2951	62	3.27	323	102	-	0.42
R	57B	24.72	75.28	273880	81311	171	5.55	990	1271	165	11.03	243	376	-	0.61
B	20	8.15	91.82	434910	3746	551	3.59	158	275	130	0.87	307	248	-	1.27
O	35	8.68	91.32	432800	3233	626	3.61	153	221	120	2.41	373	264	-	1.51
B	45A	8.56	91.44	426640	3578	859	3.61	188	327	143	0.44	502	137	-	2.01
C	45B	6.82	93.18	396090	2934	1038	4.41	203	169	186	0.04	362	39	-	2.62
A	45C	19.24	80.76	414550	5077	615	3.10	213	653	225	0.37	382	315	-	1.48
Y	45D	5.68	94.32	391510	3977	886	3.50	146	153	164	4.77	396	54	-	2.26
G	45E	11.38	88.02	390333	5913	960	4.77	245	544	102	1.62	595	269	-	2.41
E	62	6.37	93.63	380350	3526	317	4.39	212	336	145	0.89	264	51	2.98	0.58
O	55	6.30	94.00	423520	3136	273	3.51	266	331	122	4.64	541	29	-	0.64
N	56	3.69	95.31	395430	2938	273	3.27	232	275	114	0.83	246	45	5.45	0.69
	04	8.20	91.80	467490	3539	522	4.19	255	562	190	1.19	354	242	4.63	1.28
	04A	6.40	93.63	433270	3821	435	3.54	227	431	169	0.36	437	192	4.08	0.97
	13	3.38	95.12	463180	3485	473	4.01	358	180	134	0.96	483	89	5.93	1.02
V	19	7.32	92.95	398643	4639	553	3.13	188	471	203	1.13	473	191	3.71	1.40
E	22	3.92	95.08	457340	3352	440	2.28	206	162	118	1.14	367	99	2.03	0.96
R	25A	4.73	95.27	462840	3989	514	3.31	177	334	208	0.73	354	71	1.06	1.15
U	25B	12.37	82.63	436150	5262	516	4.42	189	545	282	7.08	399	451	1.57	1.13
L	25C	5.31	94.19	459370	5043	507	3.36	155	312	183	2.18	215	136	2.60	1.11
A	25D	11.80	88.23	448050	8113	550	3.57	186	555	259	2.32	202	308	1.64	1.23
M	26	3.04	96.96	459010	3610	452	3.25	154	163	232	0.93	333	64	0.93	0.93
	30	9.32	93.93	437550	3144	449	3.63	178	366	182	1.54	377	295	-	1.03
	31	4.92	93.05	458320	4219	578	2.73	134	107	204	3.47	346	95	1.53	1.24

Bedrock geochemical results in ppm, Insoluable fraction in weight percent
- not analyzed.

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Statistical results of bedrock geochemical data.

TILL GEOCHEMISTRY

SAMPLE	PHI	IR	CA	MG	SR	NA	FE	AL	CU	MN	ZN	BA	NI
C1201	-0.50	17.90	392110	3210	540	170	540	410	9.00	252	3.30	240	N/A
C1202	0.00	19.50	421110	3490	560	100	3300	530	9.20	240	1.20	400	N/A
C1203	0.50	22.00	412200	3400	560	170	1700	500	8.60	270	1.20	390	N/A
C1204	1.60	27.30	420410	3600	550	170	1170	500	7.00	240	3.00	250	N/A
C1205	1.50	37.50	400710	3620	560	100	1200	830	4.60	260	2.60	250	N/A
C1206	2.00	41.30	370060	3700	620	240	1570	920	11.00	205	2.70	220	N/A
C1207	2.50	52.10	352640	4050	630	280	1490	1640	8.10	290	2.20	290	N/A
C1208	3.00	60.90	345140	4120	640	210	1070	1100	8.70	330	5.10	430	N/A
C1209	3.50	66.30	313170	2930	590	340	1310	1700	10.00	300	8.30	350	N/A
C1210	4.00	82.60	320703	4750	630	310	2270	1090	10.60	570	8.00	530	N/A
C1211	4.50	61.90	342960	3590	630	220	2040	1070	15.60	300	16.80	200	N/A
C1412	-3.75	14.30	404250	4210	840	150	820	410	11.70	220	7.90	940	3.3?
C1413	-6.25	14.50	403190	4500	860	170	740	490	13.50	730	6.90	370	3.9
C1414	-1.00	17.70	403250	4160	830	145	950	550	15.30	250	7.00	470	7.60
C1415	-0.50	10.10	405410	4140	870	220	770	810	11.50	200	9.70	470	4.20
C1416	-3.25	25.10	405190	4210	863	195	1110	C8C	16.10	240	14.90	480	4.10
C1417	0.25	5.20	342040	3720	910	200	760	990	15.00	210	11.00	330	5.40
C1418	2.60	47.73	406640	4570	500	310	1290	1000	25.50	320	11.40	630	4.70
C1419	2.25	52.54	390743	4590	930	370	1730	1120	12.00	300	14.10	291	9.20
C1420	2.50	55.90	402220	4781	970	330	1840	960	26.90	140	22.30	380	11.10
C1621	-0.50	25.60	390140	3700	810	190	750	560	12.00	173	4.30	660	N/A
C1622	0.00	32.90	356190	3710	820	200	1670	710	11.60	250	7.00	450	N/A
C1623	0.50	30.70	360500	4050	635	220	1420	970	12.70	220	4.10	510	N/A
C1624	1.00	40.30	371726	4200	930	270	2710	1220	16.30	300	0.50	290	N/A
C1625	1.50	55.50	330136	4660	632	250	3010	17?0	17.60	15?	6.70	470	N/A
C1626	2.00	71.00	320050	5100	840	400	3750	1970	17.00	190	2.60	250	N/A
C1627	2.50	73.90	330630	5350	630	800	4620	1090	26.60	480	12.00	330	N/A
C1628	3.00	86.40	331080	5330	860	303	4230	1010	17.40	640	16.20	340	N/A
C1629	3.50	82.60	305670	6450	590	900	4500	1990	42.00	810	11.50	360	N/A
C1630	4.00	81.60	339940	6150	570	740	4100	1370	30.90	730	11.90	260	N/A
C1631	4.50	77.60	332176	6190	629	390	5219	2500	49.90	560	16.50	171	N/A
C2032	2.00	51.70	296900	3770	142	160	870	220	7.60	160	3.00	100	C.0?
C2013	4.50	55.00	249360	2402	320	110	1910	770	10.10	740	14.60	100	0.00
C3634	2.00	42.20	363000	3510	570	250	1090	840	9.00	290	4.20	310	N/A
C3635	4.50	35.60	136177	2426	385	210	2435	1156	49.?0	950	17.60	240	N/A
C3536	2.00	41.00	419310	3010	528	200	1045	850	12.70	363	5.40	340	N/A
C3537	4.50	43.50	393120	3460	510	300	2710	1750	22.60	640	22.40	390	N/A
C3738	-3.50	10.56	422540	4730	460	150	700	140	7.50	120	3.00	390	N/A
C3739	0.00	22.40	410600	5000	400	160	900	200	4.50	150	6.40	510	N/A
C3740	0.50	32.62	422260	5020	482	102	810	350	2.92	110	2.00	460	N/A
C3741	2.00	66.30	369520	6070	490	200	2150	1530	N/A	450	9.00	660	N/A
C3742	7.50	76.10	320190	6070	460	520	2405	1790	N/A	410	10.00	530	N/A
C3743	3.50	67.50	379900	6240	520	850	9670	4770	N/A	960	10.90	470	N/A
C3744	4.00	93.10	360600	3640	510	1150	4770	9240	19.60	510	20.30	410	N/A
C3745	4.50	91.20	157130	13060	400	410	5030	3030	69.40	540	37.10	380	N/A
C9546	2.00	73.10	359140	15320	380	420	2200	1090	11.50	890	15.90	100	12.60
C9547	3.00	73.62	205300	9002	393	810	2140	2290	48.70	790	16.20	190	6.95
C9548	4.00	83.00	370026	17000	300	3100	5020	4520	177.00	1410	56.20	380	10.60
C9549	4.50	86.10	317040	20020	302	229	3160	2180	67.00	1096	21.00	420	4.00
C9750	-0.25	15.45	307930	2920	2?3	300	1400	900	10.10	972	13.40	190	6.1
C9751	-1.75	35.90	314400	2910	240	210	2110	860	17.10	1990	11.90	450	4.0?
C9752	21.50	35.49	363970	2020	208	468	2018	930	10.40	1130	6.00	18?	7.1?
C9753	-1.00	37.00	411270	2910	220	230	1970	750	22.00	1010	12.10	100	3.1?
C9754	-4.50	41.10	401900	2940	200	240	2220	1070	23.20	990	14.40	100	3.1?
C9755	0.60	43.40	397050	2920	220	270	2440	950	24.10	1000	10.90	250	3.1?
C9756	3.50	43.70	032100	2920	210	290	2230	920	20.10	1010	12.40	290	3.30
C9757	3.60	51.40	413700	2910	240	N/A	N/A	1010	24.10	N/A	10.00	290	3.60
C9758	1.50	52.60	415960	2950	263	N/A	N/A	1310	23.10	N/A	12.00	330	3.10
C9759	2.00	56.00	302900	2910	257	N/A	N/A	1410	22.30	N/A	22.00	700	3.00
C9760	2.50	75.00	192?20	14250	270	N/A	N/A	1750	11.70	N/A	21.50	100	3.40
C9761	3.00	78.60	335400	12930	250	N/A	N/A	1800	43.00	N/A	22.00	140	1.??
C9762	1.50	75.62	297000	11960	255	N/A	N/A	2500	56.00	N/A	20.40	190	5.00
C9763	0.00	70.70	277170	10150	250	N/A	N/A	2370	70.30	N/A	21.30	200	4.50
C9764	4.50	8?.20	283940	19060	24?	N/A	N/A	2110	32.20	N/A	25.70	142	[illegible]

Till geochemical results, IR (insoluable residue) in weight percent, chemical results in ppm. N/A - not analyzed.

	INSOLUBLE	CA	MG	SR	NA	FE
C12 SAMPLE						
N	11	11	11	11	11	11
MEAN	62.300	376612.727	3710.400	591.818	277.273	1609.000
MODE	17.930	311110.000	3710.000	560.000	176.000	1200.000
MAX	82.606	471310.000	4250.000	840.000	340.000	2140.000
RANGE	64.700	190120.000	1040.300	160.000	170.000	1900.000
STAND DEV	11.761	70811.679	312.156	38.823	60.678	582.726
MIN	17.900	311110.060	3210.000	540.000	170.000	940.000
C14 SAMPLE						
N	9	9	9	9	9	9
MEAN	77.000	419716.444	4787.889	597.778	731.111	902.222
MODE	1.700	367848.000	4210.000	510.000	160.000	685.000
MAX	55.900	416256.000	6791.000	660.000	320.000	1269.500
RANGE	48.702	142218.000	1081.000	155.000	210.000	580.000
STAND DEV	18.551	41740.637	518.102	49.544	84.179	213.012
MIN	9.206	342646.000	3720.000	510.000	140.000	680.000
C16 SAMPLE						
N	11	11	11	11	11	11
MEAN	61.464	353313.455	5100.909	819.182	409.091	3170.000
MODE	72.400	328010.000	2710.000	830.000	190.000	590.000
MAX	82.606	397142.000	6450.000	640.000	980.000	5210.000
RANGE	57.000	71610.000	2740.000	70.000	770.000	4170.000
STAND DEV	21.303	20870.373	1122.813	21.100	205.621	1504.830
MIN	25.606	320050.000	3710.000	570.000	190.000	890.000
D20 SAMPLE						
N	2	2	2	2	2	2
MEAN	55.756	278012.000	2625.000	130.000	745.036	1295.001
MODE	51.706	269666.000	2490.000	120.000	180.000	670.000
MAX	55.000	290918.090	7770.000	140.000	310.000	1920.000
RANGE	8.100	41916.000	790.000	20.000	170.000	1250.000
STAND DEV	5.728	29641.936	203.001	14.142	120.700	883.883
MIN	51.706	249010.000	2486.000	320.000	106.000	670.000
C30 SAMPLE						
N	2	2	2	2	2	2
MEAN	40.800	471013.009	3015.000	475.000	240.000	1765.000
MODE	19.600	104170.000	2420.000	100.000	230.000	1080.000
MAX	62.206	361086.000	3610.090	575.909	257.995	2589.999
RANGE	2.000	177710.000	1196.900	195.000	24.000	1190.000
STAND DEV	1.906	125859.946	841.457	134.350	16.142	902.078
MIN	15.600	184176.000	2420.000	300.000	230.000	1010.000
C33 SAMPLE						
N	2	2	2	2	2	2
MEAN	44.756	401463.000	1535.000	525.000	290.000	1575.000
MODE	41.000	263010.000	1460.400	520.000	800.409	1049.000
MAX	48.500	419016.000	1610.000	510.000	300.000	2710.000
RANGE	7.500	15016.000	150.000	10.000	20.000	1670.000
STAND DEV	5.303	24812.377	106.066	7.071	14.142	1180.860
MIN	41.000	383510.000	1460.000	520.000	280.000	1940.000
C37 SAMPLE						
N	8	8	8	8	8	8
MEAN	50.363	352148.000	7030.250	483.000	676.250	2742.500
MODE	16.590	326110.000	6070.000	400.000	160.000	700.000
MAX	53.186	423215.000	10000.000	520.000	1150.000	5570.000
RANGE	61.670	97076.000	6150.000	60.000	1000.000	4370.000
STAND DEV	27.029	35712.471	2174.335	21.321	182.134	1921.429
MIN	16.500	326156.000	4710.000	460.000	150.000	700.000
D35 SAMPLE						
N	6	6	6	6	6	6
MEAN	73.432	319445.000	13725.500	127.500	715.000	1700.500
MODE	64.140	265382.000	5007.000	300.000	210.000	2769.000
MAX	83.806	359146.000	21020.000	210.000	1390.000	3020.500
RANGE	17.700	93560.000	17011.000	90.000	1120.000	2760.000
STAND DEV	7.543	14100.759	7401.712	65.000	311.444	1227.366
MIN	66.106	265502.000	8002.000	300.000	226.000	2263.000
D37 SAMPLE						
N	15	15	6	15	7	7
MEAN	55.187	300176.000	11167.500	232.000	300.857	2036.204
MODE	10.406	277316.000	12910.000	250.000	290.000	1400.000
MAX	71.700	321716.965	42116.000	770.000	406.000	2460.000
RANGE	47.006	748056.001	7690.000	70.000	170.000	1060.000
STAND DEV	16.223	56713.110	1136.470	21.000	50.021	360.881
MIN	15.906	277110.005	12716.000	200.000	210.000	1400.000

Statistical results of till geochemistry.

	AL	CU	MN	ZN	BA	NI
C12 SAMPLE						
N	11	11	11	11	11	0
MEAN	823.273	10.145	317.273	4.745	310.000	N/A
MODE	434.000	6.103	246.000	1.700	250.000	N/A
MAX	1200.000	18.609	570.000	10.000	410.000	N/A
RANGE	776.000	12.303	336.000	8.800	210.000	N/A
STAND DEV	292.154	3.469	97.507	2.557	67.231	N/A
MIN	434.000	6.109	240.000	1.200	220.036	N/A
C14 SAMPLE						
N	9	9	9	9	9	7
MEAN	756.667	18.760	265.556	11.711	430.000	6.167
MODE	410.000	11.500	210.000	6.900	290.030	5.360
MAX	1120.000	22.900	346.000	22.309	610.090	11.109
RANGE	710.000	10.560	136.000	15.460	320.100	7.860
STAND DEV	255.069	7.450	45.394	4.910	104.163	2.635
MIN	410.000	11.500	210.000	6.900	290.090	3.309
C16 SAMPLE						
N	11	11	11	11	11	0
MEAN	2171.010	15.092	450.000	8.591	366.455	N/A
MODE	560.000	12.009	440.000	2.800	371.000	N/A
MAX	3770.000	40.900	810.000	16.500	660.000	N/A
RANGE	3430.000	30.660	640.000	13.700	489.090	N/A
STAND DEV	1233.960	21.031	221.314	4.273	161.273	N/A
MIN	560.000	10.309	170.009	2.709	171.090	N/A
C20 SAMPLE						
N	2	2	2	2	2	2
MEAN	545.000	12.950	200.000	9.250	130.000	0.000
MODE	320.000	7.600	160.000	4.890	100.000	0.000
MAX	770.000	18.300	240.000	14.160	160.000	0.000
RANGE	450.000	10.700	80.000	10.190	60.000	0.000
STAND DEV	318.198	7.566	56.567	7.137	42.426	0.000
MIN	320.000	7.603	160.000	3.000	100.000	0.000
C30 SAMPLE						
N	2	2	2	2	2	0
MEAN	895.000	249.923	315.000	50.600	275.000	N/A
MODE	660.000	9.000	200.000	4.700	240.000	N/A
MAX	1130.000	490.160	396.000	97.150	310.000	N/A
RANGE	510.000	481.100	70.000	93.400	70.000	N/A
STAND DEV	360.624	340.181	49.497	66.044	49.497	N/A
MIN	660.000	9.000	206.000	4.200	240.000	N/A
C35 SAMPLE						
N	2	2	2	2	2	0
MEAN	1205.000	20.190	426.000	14.460	345.000	N/A
MODE	650.000	13.720	360.000	5.450	340.000	N/A
MAX	1750.000	27.660	490.000	27.460	390.000	N/A
RANGE	1100.000	14.960	130.000	22.000	50.000	N/A
STAND DEV	777.817	10.576	84.853	15.556	35.355	N/A
MIN	650.000	13.760	360.000	5.450	340.000	N/A
C37 SAMPLE						
N	8	9	9	8	8	0
MEAN	2151.500	20.640	433.750	13.175	463.750	N/A
MODE	340.000	3.469	310.000	3.000	300.000	N/A
MAX	5240.000	49.469	560.000	27.100	640.000	N/A
RANGE	4900.000	47.000	250.000	25.300	340.000	N/A
STAND DEV	1667.313	13.967	96.906	10.227	101.977	N/A
MIN	340.000	2.400	310.000	1.800	300.000	N/A
D99 SAMPLE						
N	6	6	6	6	6	6
MEAN	2697.500	40.550	992.550	33.725	267.500	9.025
MODE	1000.000	23.500	690.000	15.900	100.000	9.000
MAX	4920.000	147.060	1510.000	56.260	420.000	20.480
RANGE	3720.000	95.560	720.000	40.760	320.000	20.400
STAND DEV	1333.901	43.375	335.767	17.175	140.181	8.600
MIN	1000.000	23.500	690.000	15.900	100.000	0.000
C97 SAMPLE						
N	15	15	7	15	15	15
MEAN	1140.030	17.127	1070.003	20.173	293.400	4.937
MODE	500.000	16.600	1010.000	8.860	390.000	1.109
MAX	2590.000	75.160	1006.000	35.760	450.060	13.722
RANGE	1020.000	57.900	116.000	26.900	290.000	9.000
STAND DEV	615.370	17.481	43.302	8.833	80.717	2.008
MIN	500.000	16.600	970.000	8.009	160.000	1.109

Statistical results of till geochemistry.