Geological Survey of Canada
Commission géologique du Canada

PAPER 85-17

QUATERNARY GEOLOGY AND TILL GEOCHEMISTRY OF THE WESTERN PART OF CUMBERLAND COUNTY, NOVA SCOTIA (SHEET 9)

R.R. Stea
P.W. Finck
D.M. Wightman

1986

Canada

GEOLOGICAL SURVEY OF CANADA
PAPER 85-17

QUATERNARY GEOLOGY AND TILL GEOCHEMISTRY OF THE WESTERN PART OF CUMBERLAND COUNTY, NOVA SCOTIA (SHEET 9)

R.R. Stea
P.W. Finck
D.M. Wightman

1986

Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Ontario, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-85/17E Canada: $15.00
ISBN 0-660-11804-1 Other countries: $18.00

Price subject to change without notice

Authors' Addresses

R.R. Stea
Nova Scotia Department of Mines and Energy
1690 Hollis Street
Halifax, Nova Scotia
B3J 2X1

P.W. Finck
25 Vimy Avenue
Halifax, Nova Scotia
B3M 1G5

D.M. Wightman
Alberta Research Council
Geological Survey
4445 Calgary Trail South
Edmonton, Alberta
T6H 5R7

Critical Reader

L.A. Dredge

Original manuscript submitted – 1984 – 05
Final version approved for publication – 1985 – 08

CONTENTS

Appendixes

Tables

Illustrations

Figures

QUATERNARY GEOLOGY AND TILL GEOCHEMISTRY OF THE WESTERN PART OF CUMBERLAND COUNTY, NOVA SCOTIA (Sheet 9)[1]

Abstract

The area comprises two distinct physiographic regions, the Cumberland-Pictou Lowlands and the Cobequid Highlands. Bedrock, till, glaciofluvial, glaciomarine, alluvial, colluvial, marine, and organic sediments make up the surface materials.

Large areas of mechanically and chemically weathered bedrock, residuum, on the Cobequid Highlands are believed to derive from a pre-Wisconsinan nonglacial interval. The first glacier flow recorded in the area, thought to be Early Wisconsinan in age, was eastward across Chignecto Bay, then southeastward. It formed the compact, calcareous McCarron Brook Till. After this event there is some evidence for a brief nonglacial interval. Ice then flowed southward and southwestward from a centre over Prince Edward Island. The grey Joggins Till and the reddish-brown Eatonville Till were formed during this flow. The next glacial event was a pulse of southwestward flow which created the bouldery Shulie Lake Till and a moraine which blocks Parrsboro Gap. The Shulie Lake Till terminates along an east to west line north of the Cobequid Highlands marked by Shulie and Welton lakes. This till limit represents a glacier marginal stand. These successive till-forming ice flows are termed the McCarron Brook, Eatonville and Shulie Lake phases.

Deglaciation probably occurred at the end of the Eatonville Phase about 14 000 years B.P. as glaciomarine deltas were being constructed along the north shore of Minas Basin. Meltwater was cut off to the deltas during Shulie Lake Phase when the moraine across Parrsboro Gap was constructed. Radiocarbon dates and pollen evidence from buried peat and basal organic sediments north of Shulie Lake Till limit suggest that ice persisted there until 12 000 BP and perhaps as recently as 10 500 BP.

Marine limit decreases from 37 m above m.s.l. to 15 m northeastward along Chignecto Bay. Marine limit also decreases eastward in Minas Basin from 38 m at West Advocate to 22 m at Parrsboro. The decrease in marine limit along the flow path of the Shulie Lake Phase suggests that the formation of raised marine features on the south coast of Chignecto Bay was delayed by ice in the bay.

Pb and Zn geochemical anomalies in the locally-derived Shulie Lake Till suggest the presence of this type of mineralization in the Late Carboniferous Cumberland Group in the map area. Organic-rich channel-lag facies may have been the focus for Pb-Zn precipitation within the Cumberland Group sandstones. Cu and As anomalies in residuum developed from the Devono-Carboniferous Greville River Formation correlate with chalcopyrite-arsenopyrite mineral occurrences along Glooscap Fault.

Résumé

La région comporte deux zones physiographiques distinctes, les basses-terres de Cumberland-Pictou et les hautes-terres de Cobequid. De la roche en place, du till et des sédiments fluvioglaciaires, glaciomarins, alluviaux, colluviaux, marins et organiques forment les matériaux superficiels.

Dans les hautes-terres de Cobequid, de vastes zones de résidus de roche en place mécaniquement et chimiquement altérée ont vraisemblablement été formées pendant un intervalle non glaciaire pré-Wisconsin. La première avancée glaciaire enregistrée dans la région date vraisemblablement du Wisconsinien ancien; la glace s'est déplacée vers l'est en travers de la baie Chignecto puis vers le sud-est et a produit le till calcaire compact de McCarron Brook. Un bref intervalle non glaciaire semble avoir suivi cet événement. La glace s'est ensuite déplacée vers le sud et le sud-ouest à partir d'un centre dans l'Île-du-Prince-Édouard et a déposé le till gris de Joggins et le till brun rougeâtre d'Eatonville.

[1]Sheet 9 is the ninth of a series published by the Nova Scotia Department of Mines and Energy, e.g. Sheet 6 in Stea (1982a) and Sheets 7 and 8 in Stea and Grant (1982). Sheet 9 in this report is represented by Map 1630A and Figure 31.

L'événement glaciaire suivant a été une brusque avancée ves le sud-ouest qui a produit le till blocailleux de Shulie Lake ainsi que la moraine barrant le col de Parrsboro. Le till de Shulie Lake se termine au nord des hautes-terres de Cobequid en une ligne orientée est-ouest et marquée par les lacs Shulie et Welton. Ce till représente la limite extrême atteinte par l'avancée du front du glacier. Ces avancées glaciaires sucessives formatrices de till sont baptisées phases glaciaires de McCarron Brook, d'Eatonville et de Shulie Lake respectivement.

La déglaciation a probablement eu lieu à la fin de la phase d'Eatonville, il y a environ 14 000 B.P., à mesure que les deltas glaciomarins se sont formés le long de la rive nord du bassin des Mines. La moraine barrant le col de Parrsboro, qui s'est formée au cours de la phase de Shulie Lake, aurait empêché le passage des eaux de fonte jusqu'aux deltas. La datation au radiocarbone et l'analyse pollinique du pollens extrait de la tourbe enfouie et des sédiments organiques inférieurs au nord de l'extrémité du till de Shulie Lake laissent croire que la glace a persisté à cet endroit jusqu'à il y a 12 000 B.P. et peut-être même 10 500 B.P.

Le long de la baie Chignecto, en direction nord-est, la limite marine se ramène de 37 m au-dessus du niveau de la mer à 15 m. Elle baisse aussi vers l'est dans le bassin Minas, passant de 38 m à West Advocate à 22 m à Parrsboro. Cette descente de la limite marine le long du tracé de la phase glaciaire de Shulie Lake semble indiquer que la présence de la glace dans la baie a retardé la formation d'éléments marins soulevés sur la côte sud de la baie Chignecto.

La présence d'anomalies géochimiques (Pb et Zn) dans le till de Shulie Lake d'origine locale porte à croire que ce genre de minéralisation pourrait également exister dans le groupe de Cumberland du carbonifère supérieur dans la région cartographique. La précipitation du plomb et du zinc pourrait avoir été concentrée dans les résidus fluviatiles riches en matières organiques des grès du groupe de Cumberland. Il existe une corrélation entre les anomalies de Cu et d'As des résidus provenant de la formation dévonienne-carbonifère de Greville River et les venues minérales de chalcopyrite et d'arsénopyrite le long de la faille Glooscap.

INTRODUCTION

Scope of the report

This report summarizes the results of surficial mapping and trace element analyses of surficial deposits in Cumberland County. The research was funded through the Canada-Nova Scotia Co-operative Mineral Program 1981-1984. The aim of this project is to provide a data base in northern Nova Scotia on the nature and extent of surficial materials and the effects of glaciations, in order to aid in mineral exploration, environmental assessment and industrial construction. This study follows a program of till mapping and geochemistry initiated by the Nova Scotia Department of Mines and Energy and the federal Department of Regional Economic Expansion in 1977 covering southern Nova Scotia on the Meguma Terrane (Stea and Fowler, 1979; Stea, 1982a; Stea and O'Reilly, 1982; Stea and Grant, 1982). Mapping and research of the glaciofluvial and glaciomarine deposits along the north shore of Minas Basin was conducted by D. M. Wightman at Dalhousie University, Halifax (Wightman, 1980).

The mapping of erosional features of glacier movement and glacial deposits, along with detailed work on type stratigraphic sections allow correlation of ice flow patterns with deposits, especially till. This correlation will enable the nature and timing of glaciations in the region to be further elucidated, and allow for a better understanding of trace element dispersal patterns.

The area covered by this report lies between latitudes 45°15′N and 45°50′N and longitudes 64°20′W and 65°00′W; that is, west of the town of Parrsboro encompassing the Chignecto Peninsula (Fig. 1).

Previous work

Previous mapping done in the area has been of varying scale and purpose. Chalmers (1895) and Wickenden (1941) mapped parts of the northern portion of the area. Swift and Borns (1967) and Wightman (1980) produced maps of the glaciofluvial and glaciomarine sediments on the Minas Basin shore. MacNeill (1956) and soil survey scientists (Nowland and MacDougall, 1973) produced maps of the area dealing with aspects of surficial geology.

Concomitant with the previous mapping was the development of glaciation concepts for the region. Chalmers (1895) noted two main sets of striations, a set trending eastward and sets trending southward and southwestward. He attributed the first set to ice flowing eastward from the highlands of central New Brunswick which he called the Northumberland Glacier. The southward and southwestward trending striations were attributed to a later, separate ice mass centred on the isthmus of Chignecto, called the Chignecto

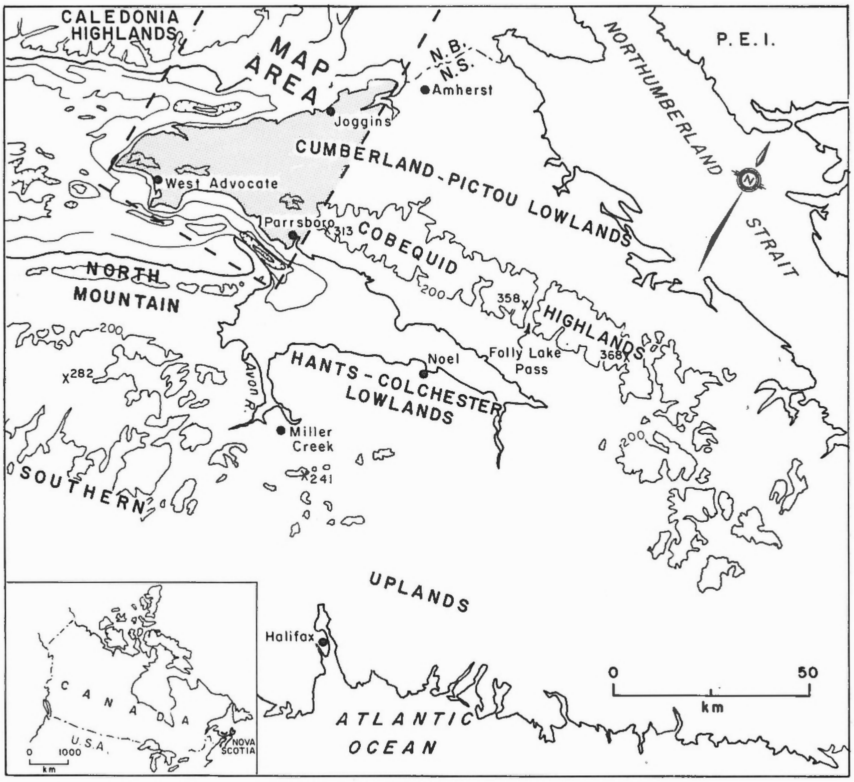


Figure 1. Physiographic divisions of mainland Nova Scotia and location of the map area.

Glacier. Goldthwait (1924, p. 83) explained the southward-trending striations in terms of a lobation of the Laurentide ice sheet called the Acadian Bay Lobe.

Chalmers (1895, p. 94) had previously considered a continental-based southward ice flow but dismissed the idea because he found that striations relating to this flow were not found on west-central Prince Edward Island. Prest's (1973) summary of ice flow events in Prince Edward Island would seem to concur with Chalmer's view. Prest and Grant (1969) and Grant (1977) further developed and refined a model of restricted Late Wisconsinan ice cover. In Grant's (1977, p. 252) reconstruction, the western part of the Cobequid Highlands remained ice free during this period with an ice cap centred on southern mainland Nova Scotia and New Brunswick and ice restricted to the north of the Cobequid Highlands.

Wightman (1980), however, argued for an ice cap which crossed the western Cobequid Highlands during the Late Wisconsinan on the basis of Cobequid erratics in outwash deltas along the northern shore of the Minas Basin. The deltas, although not directly dated, are thought to have formed about 14 000 years B.P.

Stea and Finck (1984) showed that ice flow centres affecting northern mainland Nova Scotia changed radically throughout Wisconsinan time from external centres to multiple centres on the province itself. Four till-forming ice flow phases were mapped, the last two believed to be of Late Wisconsinan age. They also argued for a more extensive Late Wisconinan ice cover. They found that the penultimate ice flow phase stemmed from a centre on the Southern Uplands of the Atlantic Coast of Nova Scotia that flowed north across most of the eastern Cobequid Highlands. This ice flow apparently did not affect the present study area (Stea and Finck, 1984, p. 482).

Method of study

After preliminary aerial photograph interpretation at a scale of 1:50 000 by D.R. Grant (Geological Survey of Canada) and the authors, field work commenced. Contacts were checked along roads, stream and coastal exposures. Samples were obtained primarily from fresh till exposure at selected sites, but also from residuum and stratified drift, at an average depth of 1 m below the surface. Two to four kg of sample were obtained. At randomly selected locations, a second sample was obtained at the same depth as the first to determine the effect of sampling error. A statistical comparison of the trace element values of these samples as well as duplicate splits made before the sample preparation and analytical stages is given in Appendix 1. The results show that none of the variation induced during the sampling,sample preparation and analytical stages can be cosidered significant.

A multiple till section near Joggins was profile-sampled at 1 m intervals to determine vertical variability within and between superposed till sheets. Podolak and Shilts (1978) and DiLabio and Shilts (1978) have shown that significant vertical variations in composition occur within Wisconsinan till sheets in Nova Scotia and modern glacier debris bands.

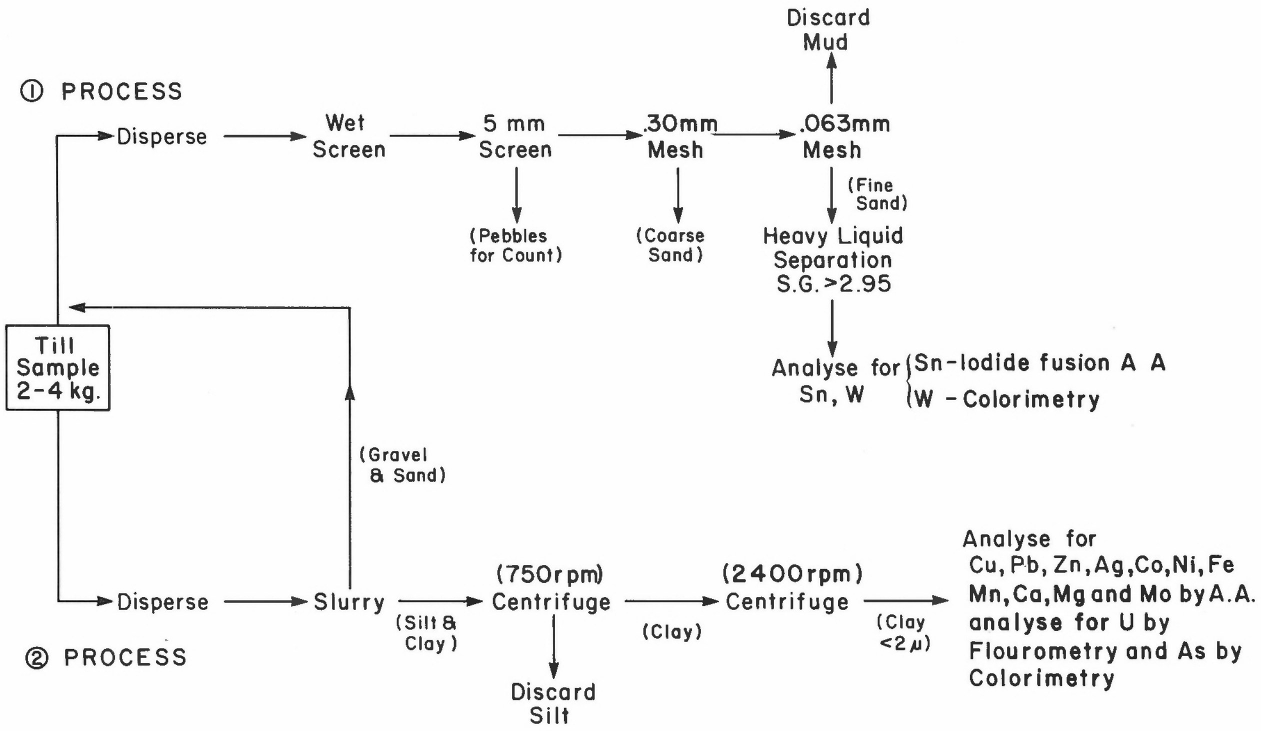


Figure 2. Sample preparation and analysis flow chart for the till samples.

Figure 2 briefly describes the sample preparation and analytical procedures used. The use of the clay fraction of the till for chemical analysis, instead of conventional sieved fractions was discussed in Stea and Fowler (1979, p. 4). The reasons are:

(1) Most samples (average sampling depth <2 m) have been depleted of labile components (sulphide and carbonate mineral grains) by weathering. The clay fraction fixes a proportion of the losts cations (Shilts, 1975).

(2) The clay fraction contains most of the metal leached from weathered samples. The sand and silt sized fractions are more variable in relative amounts from one till type to another and this variation can cause trace element concentrations to fluctuate to such an extent that they are not easily related to geological factors.

(3) The clay fraction is thought to contribute substantially to lake and stream sedments, making correlation of results with lake and stream sediment surveys possible (Rogers, et al., 1984).

(4) The anomaly-background contrast of the finest fractions of till is greater than in coarser fractions (Kauranne, et al., 1977).

Pebble counts were conducted on the +5mm −64mm fraction of all the till samples. Two hundred pebbles were counted and divided into seven categories: limestone and evaporite rocks, red sedimentary rocks, grey sedimentary rocks, intrusive rocks, volcanic rocks, metamorphic rocks, and others (Fig. 31). The pebble counts aid in the mapping of till units and in assessing the geochemical response of the till matrix. Wightman (1980) divided pebbles counted from the Five Islands Formation into 10 categories: sedimentary, cleaved sedimentary, breccia, metasedimentary and quartzite, granite, rhyolite, andesite, diabase and diorite.

The total till sample coarse gravel fraction (+5mm), medium to fine sand fraction (0.30 mm – 0.06 mm, used in the heavy mineral separation) and heavy mineral separates were weighed. This was done to assess the effects of varying sand and heavy mineral weights on Sn and W values (Toverud, 1982) and to develop a weighting factor (Appendix 2). The weights of these till fractions and pebble lithology percentages were statistically correlated with trace elements. The nonparametric Spearman Rank Correlation Coefficient (rho) was used in order to avoid assumptions concerning the normality and homogeneity of variance of the data as well as allowing for comparison of differing measurement criteria (Siegel, 1956).

Till fabrics were measured at the multiple-till section at Joggins. Seventeen sites were selected from top to bottom of the 25 m section. The trend of the long axis of 50 pebbles (long to short axis ratio 3:2 or greater) were measured from vertical and horizontal faces cut in the till at each site.

A preliminary study of soil profiles on the Eatonville and Shulie Lake tills is presented in Appendix 3. Chemical and physical data on the parent tills and their soils is given courtesy of Delmar Holmstrum of the Nova Scotia Department of Agriculture and Marketing and Chang Wang of Agriculture Canada. Standard soil-analytical techniques are used.

Figure 3. Photograph, looking northwards from Parrsboro Gap to Gilbert Lake. Note the broad, flat plain north of Gilbert Lake, former site of glacial "Potters Lake".

Acknowledgments

This research was funded through the Canada-Nova Scotia Co-operative Mineral program 1981-1984. Dr. W. H. Poole of the Geological Survey of Canada managed the program and provided useful tips in the field. Dr. D. R. Grant of the Geological Survey of Canada, substantially helped the project with preliminary airphoto interpretation, useful discussions in the field, and critical reading. R. J. Mott analysed the pollen of the organic sites and the Geological Survey of Canada Radiocarbon Laboratory provided radiocarbon dates.

BEDROCK GEOLOGY AND PHYSIOGRAPHY

The study area consists of two distinct physiographic regions; the Cumberland-Pictou Lowlands (Goldthwait, 1924) and the Cobequid Highlands (Fig. 1). The lowland area is underlain predominantly by sedimentary rocks of the Cumberland Group (Late Carboniferous, Fig. 31) which consists largely of grey-green feldspathic sandstones and conglomerates with red polymictic conglomerates at its base (LCCa, Fig. 31). Coal seams intercalated with limestones occur in the Joggins area (LCCb, Fig. 31). North of Joggins younger strata are exposed, including rocks of the Windsor and Canso groups, dominantly redbeds.

The Cumberland-Pictou Lowlands in this region can be subdivided into an area of higher relief characterized by bedrock-controlled ridge and swale topography and more subdued areas with topography largely controlled by glacial deposits (Map 1630A). North of Shulie and Welton lakes (Fig.1; Map 1630A) there is a large, relatively flat area characterized by abundant bogs, hummocky and ribbed moraine, and internal drainage areas. It is bounded on the south by strongly rolling terrain, deeply incised by streams (Map 1630A). The boundary of these two areas also represents the boundary of two distinct till sheets. The significance of these terrains will be discussed further in the Quaternary Events section.

The Cobequid Highlands which rim the southern and southwestern coast of the peninsula are formed of metasedimentary, volcanic and plutonic rocks of Hadrynian to Late Carboniferous age that are segregated into numerous fault blocks and bounded on the south by the Minas Geofracture (Donohoe and Wallace, 1978; 1982; Keppie, 1982). The highland areas in Cumberland County gradually rise from west to east attaining elevations of 274 m. There is a scarp on the south side of the highlands which follows the Glooscap Fault zone (H.V. Donohoe, personal communication, 1984). Local prominences in the western Cobequid Highlands are generally underlain by granitic rocks. The region underlain by Carboniferous granites (Cg)on the western coast of the Chignecto peninsula is a good example (Fig. 31).

East of Parrsboro, the north side of the Cobequid Highlands is clearly defined by a scarp which may be attributed to differences in hardness between the basal Cumberland Group rocks and the basement Cobequid rocks in this area.

Another major feature of the western Cobequid Highlands is the pass from Parrsboro to Halfway River (Map 1630A; Fig. 3). Goldthwait (1924, p. 26) interpreted the pass as a wind-gap, created by stream diversion or piracy. He suggested that desertion of the pass by a through-flowing stream occured as a result of damming by glacial deposits since the floor of the pass is on a level with the adjacent lowlands. Halfway River flows southeastward towards the pass in a large valley and abruptly turns northeastward near Newville Lake. The size of the valley suggests that the reversal of drainage occurred in pre-Pleistocene times. The accordance of the pass and lowland levels does not necessarily imply drainage reversal caused by glaciation. South and southeast flowing glaciers may have selectively eroded the pass removing evidence of elevated former divides. The drainage divide in the Folly Lake pass of the eastern highlands (Fig. 1), lies well above the northern lowland surface again suggesting that the modern drainage pattern was established before the Pleistocene.

QUATERNARY UNITS

Note on stratigraphic nomenclature

The first heading under Quaternary Units is 'Bedrock' and this is subdivided on Map 1630A into 'Glacially Scoured Bedrock' and 'Residuum'. These subdivisions do not reflect surficial deposits per se, but they are important for mapping purposes as they represent surface conditions.

Glacial deposits are divided into lithostratigraphic units at the formational and member level. A formal approach to the description of the Quaternary sediments is preferred to genetic or sedimentological classification because it allows for the separation of observable features and data from inference. In addition, systematic classification allows for rigourous examination by subsequent workers.

A lithostratigraphic unit is defined in the North American Stratigraphic Code (1983) as a body of sedimentary strata which is distinguished on the basis of *lithic* characteristics and stratigraphic position. Widespread, mappable till units and till units that are traceable in the subsurface, related to discrete ice flows, are considered to be formations. Lithic attributes used to relate tills to ice flows include colour, texture, compactness, pebble lithology, geochemistry, fabric, and relationships to mapped erosional and depositional landforms. Glaciofluvial and glaciomarine deposits in the map area have already been mapped and defined as a formation by Swift and Borns (1967) and Wightman (1980). A discussion of the lithostratigraphy of these sediments is given in a following chapter.

Recent sediments are discussed informally and given genetic names because stratotypes were not discussed and lithic data was not collected from these sediments.

BEDROCK

Glacially scoured bedrock (R)

Areas along the Chignecto Bay coast are characterized by exposed bedrock with a discontinuous veneer of till and boulders. The topography is controlled by bedrock structure with strike ridges formed of relatively resistant sandstone units (Shaw, 1951, p. 15). The till is generally thin (<1 m), reddish brown and compact (Eatonville Till; Map 1630A). The surface of most of the bedrock exposures was scoured by glaciers that moved southwestward (Fig. 4). Many surfaces exhibit crossing striations with the younger striations curving to conform with local topographic trends. There is a pervasive reddish stain on many of the surfaces inscribed with the southwestward-trending striations. On the lee side of some outcrops and on the weathered upper surface of some others, are striations and grooves that trend eastward and southeastward.

Residuum (D)

The surface material of large areas in the western Cobequid Highlands is bedrock that has been fragmented, disintegrated and altered to varying degrees, in situ (Map 1630A). Mechanical and chemical weathering are implied, although fault-zone hydrothermal alteration and cataclasis may be locally important in the Glooscap Fault zone. Till is present in these areas, generally less than 1 meter thick. It can pinch out upslope against the friable rock and overly it as a thin veneer in some areas of the highlands (Map 1630A).

Bedrock lithology and cleavage development are two possible controlling factors in the depth and intensity of rock weathering. Metamorphosed, steeply-dipping slates of the Greville River Formation (DCG, Fig. 31), west of Parrsboro, have been disrupted and disaggregated to depths of 10 m below the surface (Fig. 5). Foliated Carboniferous granite at Cape Chignecto is broken for only 2-5 m. Homogeneous, apparently structureless granites in some areas of the highlands were also found to be deeply weathered with chemical alteration of feldspars noted. Glacial and Postglacial frost riving may have caused disaggregation of the slates, but a preglacial period of subaerial weathering is a more likely explanation to account for pervasively weathered granites. The age of the alteration is unknown, but it must predate the overlying till.

East of Parrsboro there are fewer areas underlain by residuum. Large and small scale erosional features of glacier movement become more apparent on the highland surface, including roche moutonnées, scoured basins occupied by lakes, and striations. This is in contrast to the highland areas west of Parrsboro, where there are no lakes and few striated outcrops.

Figure 4. Pressure shadow or miniature crag and tail features on the down-glacier or lee side of quartzite pebbles embedded in a sandstone matrix near Apple River, Nova Scotia. The inferred azimuth of ice flow is 210°.

TILL

McCarron Brook Till (MB)

Type locality, stratigraphy and extent

At the mouth of McCarron Brook, 1 km south of Joggins, shore cliffs reveal three till units with a total thickness of 20 m (Map 1630A). The section was first described by Wickenden (1941). Prest et al. (1972, p. 37) noted that, from bottom to top, the three till units are distinctly reddish, grey and yellowish. All the tills were attributed to fluctuations in southward and southwestward flowing ice. McCarron Brook Till is the lowest till in the sequence. Wickenden (1941, p. 144) described a continuous, thin layer of silt and clay on top of McCarron Brook Till north of Joggins. McCarron Brook Till occurs sporadically in other areas along the coast overlying bedrock and underlying other till units. It does not outcrop extensively in the county, but is locally present as small, unmappable "windows" through a younger till sheet of similar colour on the Cobequid Highlands.

Description

The McCarron Brook Till is generally greyish-red (10R4/2) in colour, very compact and massive with a silty matrix. The data obtained on this till unit are from samples taken at the type section at McCarron Brook. Variations in the McCarron Brook Till at this locality will be discussed in detail.

At the type section the McCarron Brook Till can be divided into 3 units based on colour. Unit a (Fig. 6), at the base, is greyish-brown; unit b is greyish-red; and unit c is reddish-brown. The McCarron Brook Till is very compact, forming slopes of 65° from the horizontal. It's matrix is silty and calcareous. The uppermost unit (c, Fig. 6) has numerous sand and silt stringers and black manganese oxide staining along joint planes. Unit a of the McCarron Brook Till overlies sandstone bedrock inscribed with striations trending 110°. Striations on a large boulder embedded in unit b trend 140°.

Clast lithology and provenance

The McCarron Brook Till at the type section is characterized by a high percentage of allocthonous metamorphic, volcanic and plutonic clasts and substantial vertical variations in lithology (Fig. 6). Allocthonous clasts (I of Fig. 6) including chloritized, foliated granitoid clasts, exhibit an overall upward decrease through the till but maintain a high average relative to the upper tills. Reddish-brown, calcareous

Figure 5. Residuum developed from steeply dipping shales of the Greville River Formation near West Advocate.

mudstone pebbles of Late Carboniferous or Triassic bedrock derivation (H of Fig. 6) show an increase upward in the till. In unit b locally-derived grey sandstones (A of Fig. 6) show great variability in percentages, with poorly-sorted local sandstones showing a marked increase. Gillberg (1967) also noted that local bedrock contributors in till exhibit a greater variability than far-travelled clasts.

The pebble assemblages of McCarron Brook Till suggest a western source area, changing to northwest towards the top of the unit (Calder, 1983). Chloritized granitoid clasts suggest a New Brunswick provenance (Stea, 1983), as chlorite alteration is common in the Caledonia Highlands (Ruitenberg, et al., 1979) and relatively rare in the Cobequid Highlands (H.V. Donohoe, personal communication, 1984). The upward increase in poorly-sorted sandstones and red calcareous mudstones in McCarron Brook Till suggest a southward swing in ice flow direction over large areas to the north underlain by redbeds (Calder, 1983).

Fabric

Till fabrics were measured at the type section and at a locality near Advocate Harbour where the McCarron Brook Till was found to outcrop in a small 'window' (till sample site 50; Fig. 31). At this site the McCarron Brook Till revealed a stong preferred orientation of clasts with 10 per cent striking from 090 to 100 degrees.

The results of till fabric analyses in the McCarron Brook Till at the type section show strong alignment of clasts in unit a paralleling the eastward trend of striations below unit a (Fig. 7). The lowest fabric in unit a is very strong with greater than 20 per cent of the clasts striking from 90 to 100 degrees. Units 1b and 1c however, display southwest-northeast striking fabrics which parallel the fabric of the upper units and the prominent southwestward ice flow trends in the region. The authors suggest that the pebble fabric in the upper 5 m of McCarron Brook Till has been realigned by the strong southwestward flow which formed the Joggins Till. The red matrix and increase in red mudstones towards the top of the McCarron Brook Till rule out a syn-formational southwestward ice flow, over largely grey sandstone terrane. Reoriented clast fabrics have been documented in the literature (Ramsden and Westgate, 1971; MaClintock and Dreimanis, 1964). Boulton et al. (1974) have experimentally shown that reorientation of clasts can be induced by shear. Boulton (1979, p. 29) has also noted that subglacial deformation can affect previously deposited till beneath a modern glacier.

Geochemistry

At the type section the McCarron Brook Till exhibits substantial vertical variations of Cu, Pb, Zn, Fe, Mn, Ca, and Mg in the clay fraction (Fig. 8). Unit b (Fig. 8) shows more variation than unit a with fluctuating values of all the analysed elements. The uppermost unit (c; Fig. 8),characterized by manganese oxide staining of joint surfaces, shows a distinct increase in Cu and decrease in Zn and Ca values. The vertical trace element patterns in McCarron Brook Till are analogous with the vertical distribution patterns of locally derived lithologies (Fig. 6).

The vertical distribution of zinc seems to mirror closely the distribution of metamorphic and granitoid erratics in the pebble fraction; Zn values decreasing as the percentages of far-travelled erratics decrease (Fig. 9). Conversely, calcium values increase with decreasing depth and correlate closely with the percentages of calcareous reddish-brown mudstones in the till (Fig. 9).

The presence of manganese stained joint surfaces on top of the McCarron Brook Till suggests post-depositional chemical modification in some form. The zone may represent a truncated soil. Stea and Finck (1984) noted similar modification near the surface of a correlative basal till unit at Cape John, Pictou County.

Compared to other till units on a regional scale, the McCarron Brook Till has high average Ca and Mg values (Table 1). Average values of metals in the clay fraction are

Table 1. Basic geochemical statistics for the major surficial units in western Cumberland County.

TILL TYPE ELEMENT	EATONVILLE TILL N = 72		SHULIE TILL N = 22		McCARRON BROOK TILL N = 15		JOGGINS TILL N = 16		RESIDUUM N = 6	
Ag	**.07** .06	.05-.50 .43	**.06** .18	.05-.10 .43	**.08** .05	.05-.2 .85	**.86** .05	.05-.2 .43	**.66** .26	.05-.1 .43
Cu	**41** 23	8-119 84	**61** 17	29-88 87	**28** 45	24-42 45	**39** 16	22-78 76	**147** 129	50-406 355
Ni	**40** 7	23-59 53	**42** 5	33-54 54	**37** 6	28-48 52	**35** 6	19-43 44	**62** 17	39-73 87
Pb	**24** 12	4-57 52	**53** 76	8-379 88	**22** 4	15-30 34	**21** 10	7-47 47	**25** 17	10-55 67
Zn	**101** 41	33-229 184	**148** 58	85-375 215	**109** 16	89-136 139	**121** 26	87-172 173	**71** 38	32-127 139
Co	**18** 4	9-25 26	**20** 5	14-31 34	**15** 3	11-21 23	**15** 4	8-21 25	**38** 18	20-61 64
Fe%	**4.8** .70	3.2-6.4 6.3	**4.9** .50	3.7-5.6 5.7	**3.9** .6	3.0-4.6 5.2	**3.8** .70	2.9-4.7 5.9	**4.9** .6	4.0-5.9 6.2
Mn	**1027** 611	300-4400 1933	**1390** 829	640-3550 1930	**694** 90	580-830 842	**812** 530	440-2650 1924	**1752** 914	810-3200 1986
Ca	**540** 1100	400-5600 3393	**650** 1312	100-4000 3797	**4380** 1056	3000-7100 6635	**3306** 1711	200-7000 6338	**317** 325	100-900 1141
Mg	**6810** 1981	1400-12000 9991	**6877** 802	5600-8200 8107	**8228** 1180	6000-10000 9887	**7313** 1916	4000-11600 11288	**7633** 2541	5400-12400 12773
Mo	**1.2** 1.0	.5-4.0 4.3	**1.1** .9	.5-3.0 4.3	**.5** *	* *	**.5** .2-.21	.5-1.0 4.3	**1.3** .6	.5-2.0 4.3
U	**1.00** .80	.5-4.00 2.90	**2.30** 4.80	.05-19.00 15.50	**.30** .18	.05-.60 4.30	**1.20** 3.20	.05-13.00 11.70	**1.67** 1.07	.80-3.50 4.16
As	**15** 6	4-33 33	**17** 10	.1-39 36	**10** 2	8-14 34	**15** 18	5-80 76	**51** 36	12-100 105
Sn	**23** 23	2-115 79	**20** 14	5-50 49	**52** 24	10-85 95	**26** 21	10-80 77	**13** 9	5-15 31
W	**9** 5	1-24 26	**18** 10	2-50 36	**12** 6	4-28 34	**16** 5	10-24 33	**6** 4	2-10 17
	MEAN STANDARD DEVIATION	RANGE 95TH PERCENTILE	All values in ppm except Fe%							*not calculable

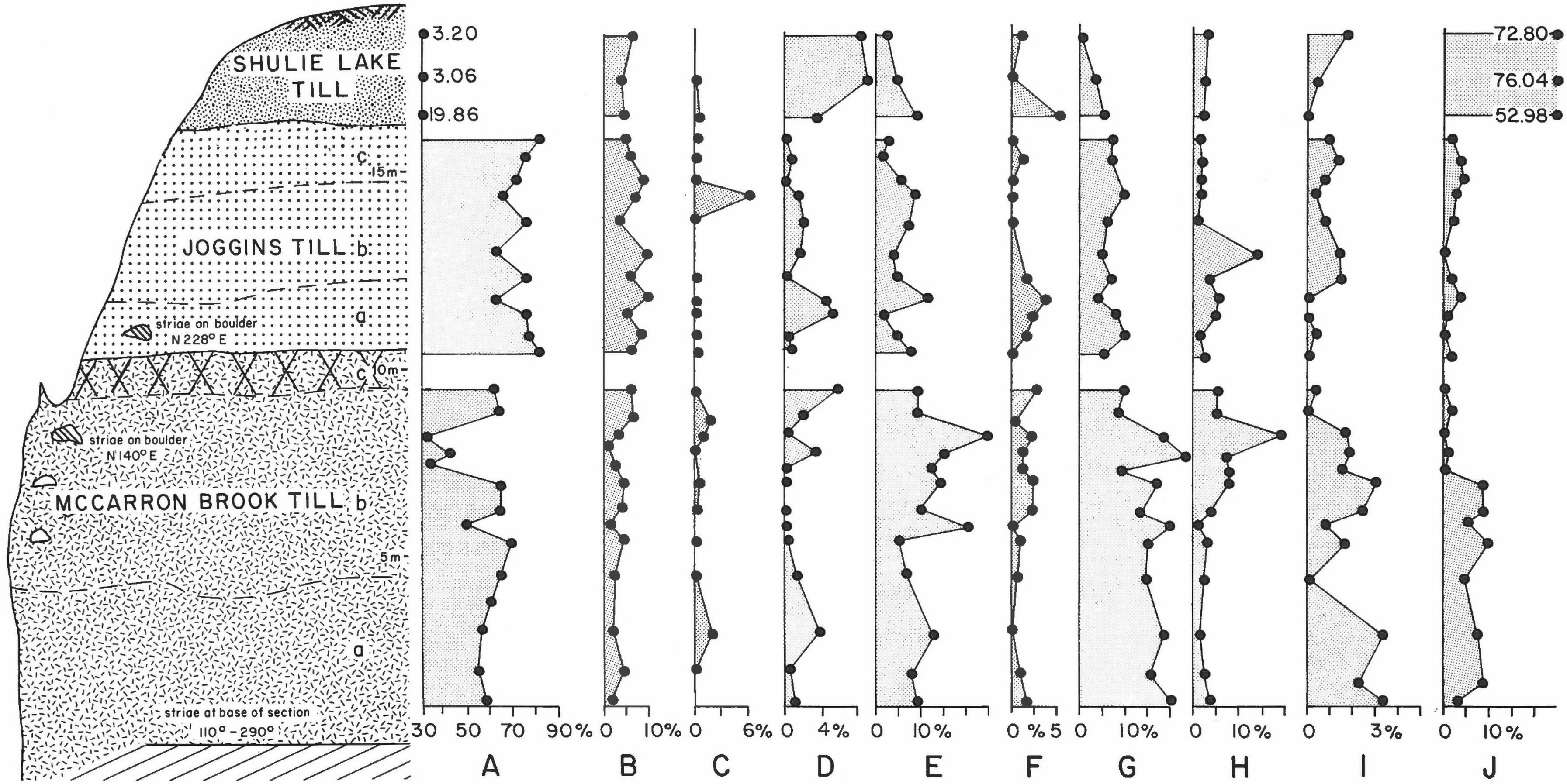
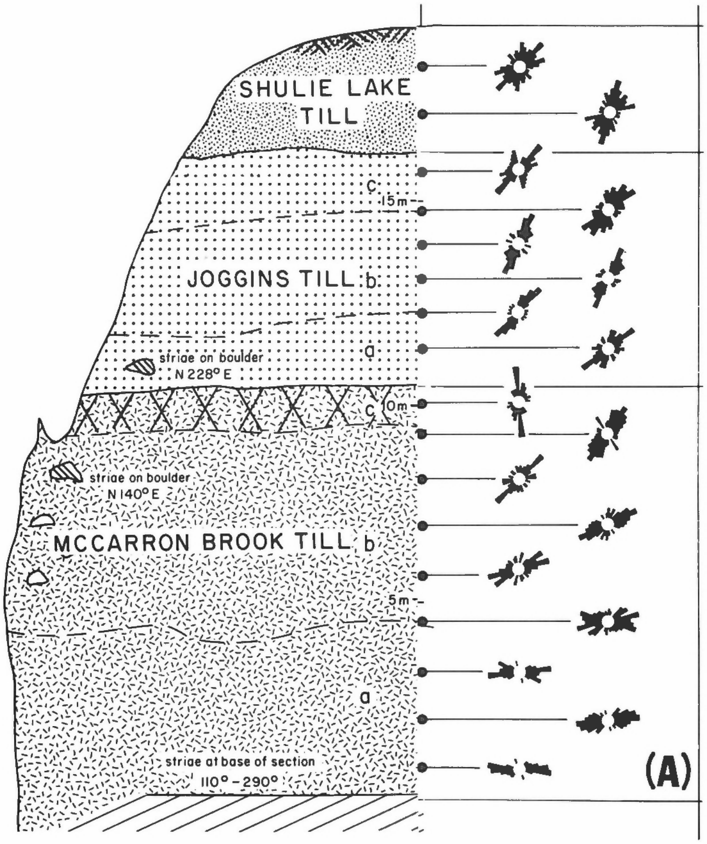


Figure 6. Vertical variations in pebble lithology; McCarron Brook multiple till section. Cross-hatching on the surface of a till unit represents signs of subaerial weathering (adapted from Calder, 1983).

A .... grey, well-sorted sandstone
B .... coal
C .... pelecypod limestone
D .... sideritic concretions and sediments
E .... poorly sorted sandstone
F .... non-fossiliferous limestone
G .... Brown-purple argillite
H .... calcareous, reddish-brown mudstone
I ..... metamorphic, volcanic, intrusive rocks
J .... weathered grey sandstone



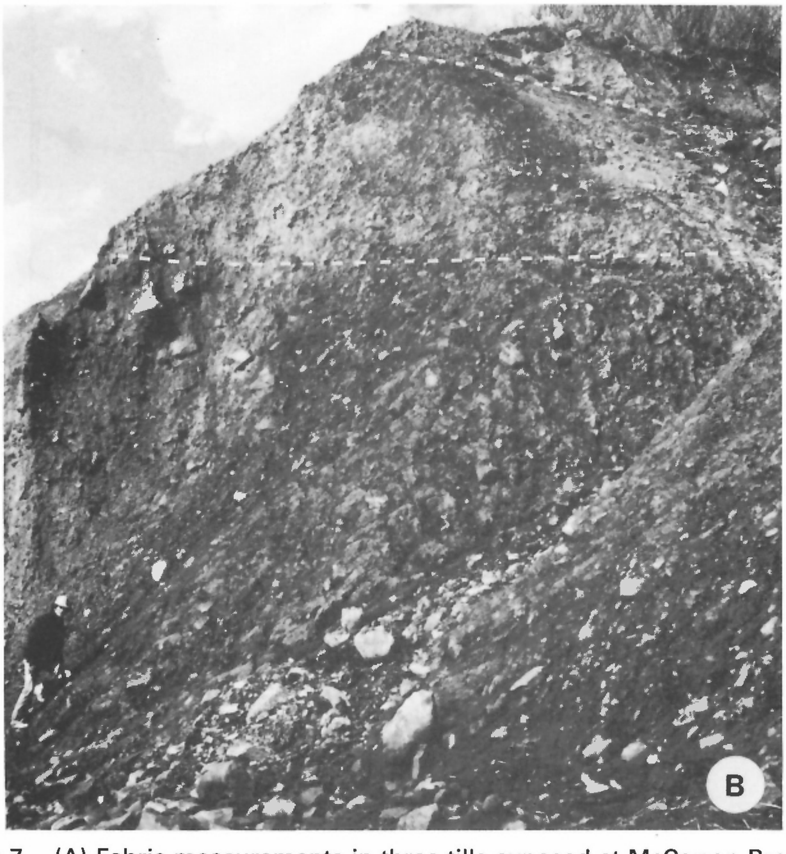


Figure 7. (A) Fabric measurements in three tills exposed at McCarron Brook, Cumberland County; (B) photograph of the section.

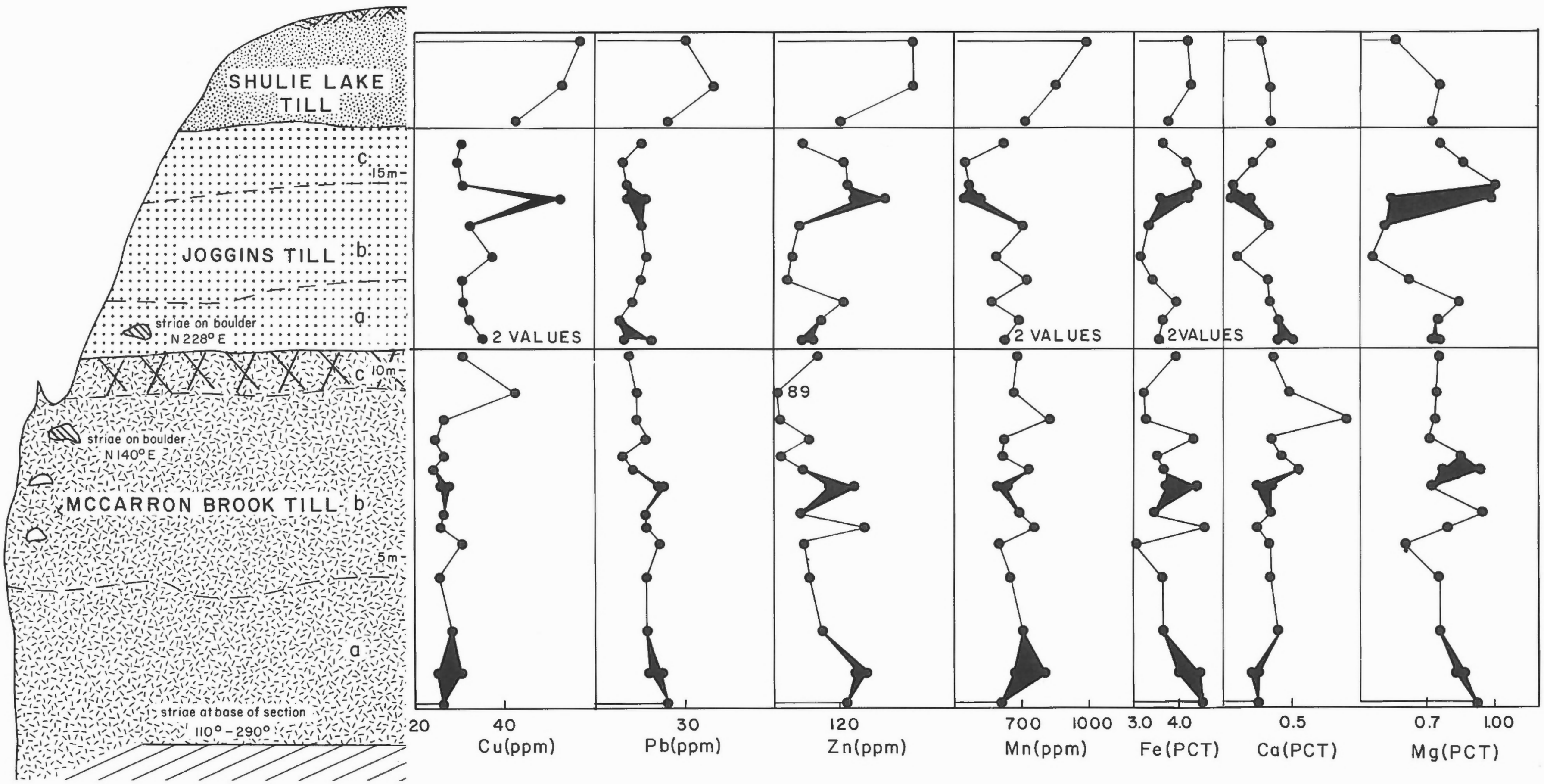


Figure 8. Vertical variations in geochemical parameters, McCarron Brook multiple till section. Analytical duplicates of selected samples are also plotted as darkened lines so the reader can visually assess the analytical uncertainty.

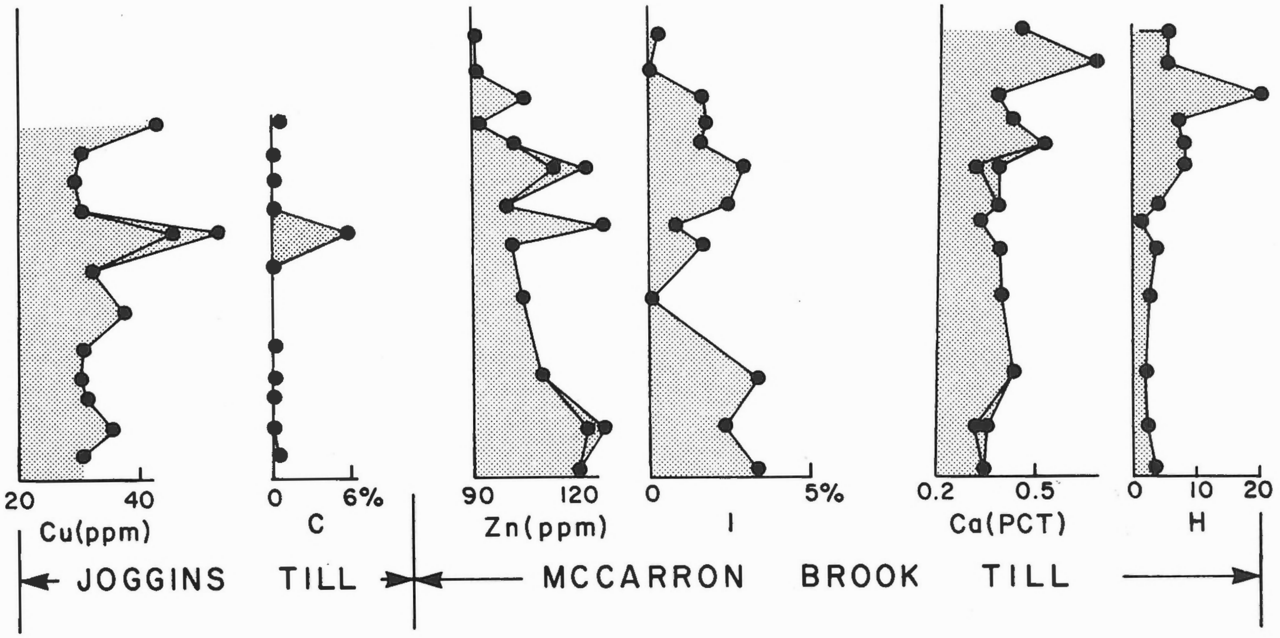


Figure 9. Sympathetic relationships of the vertical distribution of trace elements and pebble lithologies in the Joggins and McCarron Brook tills at the McCarron Brook type section. Lithology;
I = crystalline erratics
H = red mudstones
C = pelecypod limestone

generally low, with small standard deviations: Sn values from the heavy mineral separates are relatively high with a mean value of 52 ppm.

Figure 10 summarizes the statistical interrelationships between the trace elements and the lithological and grain size parameters. The Spearman Rank Correlation method was used to assess the relationships between these till parameters. Only statistically significant correlations are presented. A linear assemblage of positively correlated trace elements is: Ni-Co-Fe-As-Zn-Mn-Pb-Mg-U. Metamorphic and granitoid erratic percentages correlate positively with Fe, Co, Pb and Zn. It is apparent that this assemblage is allochthonous, relating closely to far-travelled erratics of probable New Brunswick provenance. A mafic source area is implied by the strong Ni-Co-Fe-Mg correlations. Mafic volcanic rocks are common in the eastern Caledonia Highlands (Ruitenberg et al., 1979). The sympathetic relationship between the percentages of erratic pebbles and the clay fraction geochemistry shown in Figures 9 and 10 suggests that the clay part of the matrix is largely allocthonous in the McCarron Brook Till. Rogers et al. (1984) found a strong Ni-Co-Fe-Mn association in the Lawrencetown Till which mantles drumlins on the Southern Uplands (Fig. 1). They termed this element association the 'drumlin effect.' This elemental signature is similar to the McCarron Brook Till elemental correlations. The cause of the 'drumlin effect' may be the southward dispersal of mafic material from the North Mountain basalt cuesta on to the Southern Uplands.

The fine sand (0.30 mm – 0.063 mm) weight and Cu association would tend to suggest a more local origin for this fraction. The autochthonous Joggins Till demonstrates higher values of Cu (Fig. 8). Heavy mineral separates of the fine sand fraction of the McCarron Brook till were analysed for Cu, Pb and Zn (Table 3). Samples in the upper part of the till have values of 500-968 ppm for all three metals. Unit a, however, has higher Cu, Pb and Zn values, similar to those of the overlying Joggins Till. The source of the elevated metal values in the heavies is believed to be sulphides associated with the coal beds and coal-bearing grey sandstones of the underlying Cumberland Group (J.H. Calder, personal communication, 1984). The McCarron Brook Till, especially the basal unit, (unit a) has a locally-derived fine sand fraction. The higher values of Cu, Pb nd Zn in heavy mineral concentrates of the fine sand fraction correspond to elevated percentages of local grey sandstone clasts (lithology A of Fig. 6).

Summary

McCarron Brook Till, the oldest recognized till unit, is a greyish-red, very compact, silty till. It is distinguished from overlying till units in areas underlain by sandstones by uniformly higher percentages of volcanic + intrusive erratics. Geochemically, can be differentiated from younger tills by higher Ca and Mg values (4000 to 8000 ppm). Till fabrics strike from 90 to 110 degrees and underlying striations trend eastward. In thicker sections the upper part of the McCarron Brook Till may have reset fabrics paralleling the orientation of upper till fabrics.

Joggins Till (J)

Type locality, stratigraphy and extent

The Joggins Till is the middle till in the three till sequence exposed at the mouth of McCarron Brook, Cum-

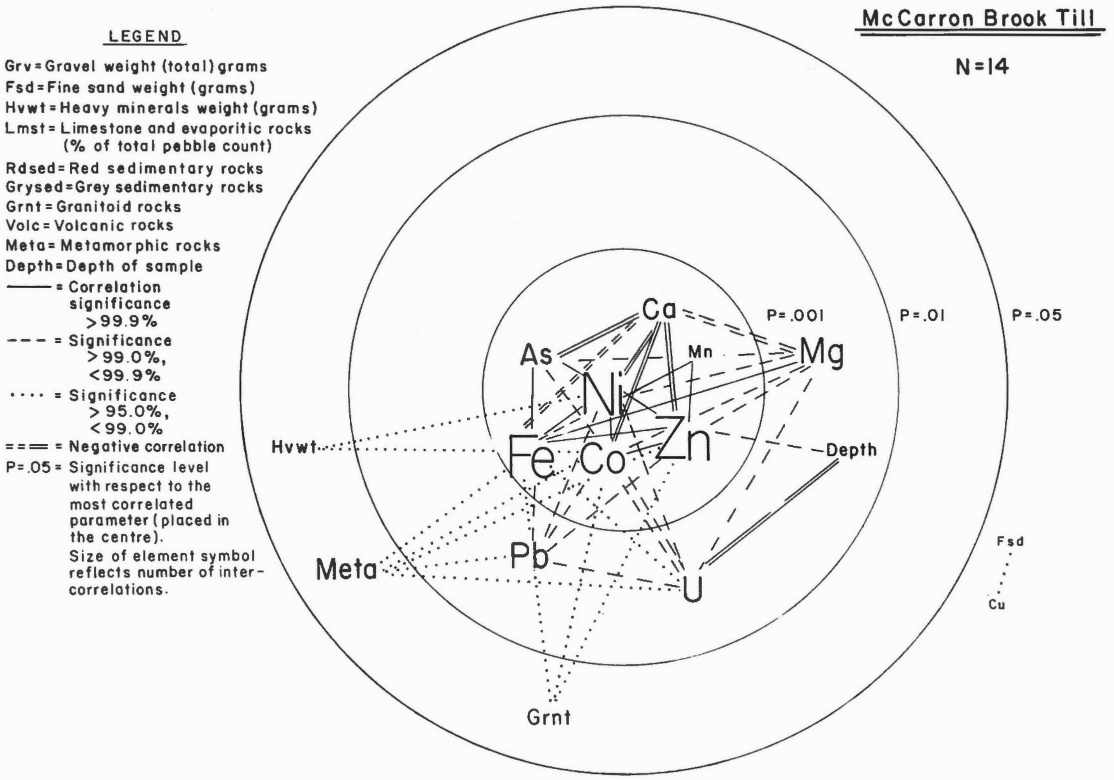


Figure 10. Net of significant Spearman Rank correlations between and within geochemical, lithological and grain size parameters analysed from the McCarron Brook Till. Intra-lithological and grain size correlations are ignored for simplicity. The parameter or parameters with the highest number of significant correlations are placed in the centre of the diagram. The rest of the parameters are linked with the "hub" parameters by tie lines that reflect the strength of the correlation and whether the correlation is positive or negative.

berland County (Fig. 7; Map 1630A). This till is exposed on the surface throughout the Joggins-River Hebert area, underlain by McCarron Brook Till and overlain in the south by Shulie Lake Till (Map 1630A). It grades laterally into the reddish-brown Eatonville Till which is derived in part from red sedimentary rocks. The Joggins Soil Series is developed on the Joggins Till (Nowland and MacDougall, 1973).

Description

Joggins Till is dark yellowish-brown (10 YR 4/2). It has a silty-clay matrix and relatively few clasts. The Joggins Till has a greyish cast throughout the mapped distribution area, although it is locally reddish-brown. The grey colour is largely due to the comminution of grey mudstones associated with the coal beds.

At the type section, it is moderately compact, forming shallower slopes than the McCarron Brook Till. Three units were defined from the base to the top: (a) Grey, massive, calcareous clay till; (b) Brownish-grey, calcareous till with 1-2 cm thick horizontal sandy partings; (c) Grey, massive, calcareous clay till (Fig. 6,7).

Clast lithology and provenance

The Joggins Till, at the McCarron Brook section, is distinguished by a high percentage of local grey sandstone clasts and coal clasts derived from the Joggins coal field outcropping several kilometres to the northeast (Calder, 1983). Associated with the coal beds are greyish,pelecypod-bearing limestones which also form a major peak in the lithology diagram of the type section (C in Fig. 6). Concomitant with the increase in coal clasts in the Joggins Till is a marked increase in grey sandstones (Fig. 6) to values greater than 70 per cent. The sandstones are derived from the underlying Cumberland Group.

Exotic lithologies such as volcanic and intrusive rock species are noticeably deficient in the Joggins Till, compared to the underlying McCarron Brook Till (Fig. 6; Table 2).

Fabric

Clast orientation in the Joggins Till is generally northeast-southwest, striking from 190° – 240° (Fig. 7). This is the trend of many of the ice flow features in the region (Stea, 1983; Map 1630A). The clasts in the lower units (a, b) appear to be more strongly oriented than in unit c which may reflect a lodgement origin for the lower units, and a melt-out origin for the upper units.

Geochemistry

The vertical distribution of trace elements in the Joggins Till at the type section (Fig. 8) suggest more variability in the

Table 2. Averages of major rock species for the till units in the study area.

Till Unit Lithological Parameter	Eatonville Till N = 70	Shulie Lake Till N = 22	Joggins Till N = 16	McCarron Brook Till N = 14
Limestone and Evaporites %	.1 .3 0 – 1.9	.2 1.0 0 – 5.0	1.4 1.8 0 – 6.0	1.6 .2 0 – 3.3
Red Sedimentary Rocks %	21.6 29.4 0 – 100	4.1 8.3 0 – 39.5	9.3 4.7 0 – 18.4	19.4 8.1 2.3 – 36.9
Grey Sedimentary Rocks %	28.9 33.9 0 – 98.9	89.5 10.3 58.8 – 100.0	83.1 7.2 69.4 – 100.0	67.4 19.0 5.2 – 80.9
Granitoid Rocks %	7.2 16.6 0 – 81.4	1.0 2.0 0 – 9.3	.2 .3 0 – .8	1.3 .3 – 1.1 0 – 4.6
Volcanic Rocks %	.6 1.5 0 – 7.2	.0 .1 0 – .6	.2 .2 0 – .7	.4 .4 0 – 1.2
Metamorphic Rocks %	35.8 37.1	3.7 5.8 0 – 24.30	.0 .1 0 – .7	6.3 23.1 0 – 86.7
	Mean Standard Dev. Range			

Table 3. Cu, Pb and Zn values in heavy mineral separates of the three till units exposed at the McCarron Brook type section.

Till	Sample	Depth (m)	Element value (ppm) of heavy minerals			Wts of till sample and fractions (grams)		
			Cu	Pb	Zn	Total Till	(-50) Sand (+230)	Heavy Minerals
Shulie Lake Till	t-82-2	1	IS	IS	IS	3783	537	0.9
	T-82-4	2.0	386	150	942	3700	307	1.41
	T-82-5	2.5	1190	1103	1745	3689	410	1.7
Joggins Till	T-82-9	3.0	1610	1420	3680	3732	370	4.4
	T-82-9	6.0	1345	919	1655	4142	154	2.1
	T-82-10	7.0	1425	1810	1910	4755	476	2.1
	T-82-13	9.0	698	325	598	4541	357	3.0
	T-82-15	10.0	1825	1185	1610	3374	202	3.1
	T-82-16	10.5	2360	1385	1570	2694	130	2.3
McCarron Brook Till	T-82-19	13.0	968	576	885	3742	562	2.9
	T-82-22	15.0	714	500	645	3883	523	2.6
	T-82-24	16.0	660	740	545	3482	362	2.8
	T-82-26	17.0	1716	518	2620	3333	325	3.0
	T-82-27	17.5	805	817	1160	3885	352	2.5
	T-82-28	18.0	1800	1628	2320	3740	396	2.5
	T-82-29	19.0	1940	1005	1215	3931	240	1.8
	T-82-30	20.0	2010	1305	2058	3374	334	2.4

* IS = insufficient sample

Table 4. Wilcoxon matched-pairs signed-ranks test for sample site, analytical and sample preparation duplicate.

TESTED LEVELS / ELEMENT	SAMPLE SITE DUPLICATES N = 14			SAMPLE PREPARATION DUPLICATES N = 18			ANALYTICAL (BLIND) DUPLICATES N = 16		
	Z	Prob.	Sig.	Z	Prob.	Sig.	Z	Prob.	Sig.
Ag	*	*	*	-1.095	.273	N.S.	-1.278	.201	N.S.
Cu	-.676	.499	N.S.	-.700	.484	N.S.	-.338	.735	N.S.
Ni	-.105	-.917	N.S.	-.761	.447	N.S.	-.980	.327	N.S.
Pb	-.507	.612	N.S.	-.889	.374	N.S.	-.980	.327	N.S.
Zn	0	1.000	N.S.	-.507	.612	N.S.	-1.521	.128	N.S.
Co	-.254	.800	N.S.	-.948	.343	N.S.	-.490	.624	N.S.
Fe	-.845	.398	N.S.	-.350	.726	N.S.	-.943	.345	N.S.
Mn	-.338	.735	N.S.	-.280	.779	N.S.	-1.677	.093	N.S.
Ca	-.314	.753	N.S.	-1.826	.068	N.S.	-.183	.855	N.S.
Mg	-.169	.866	N.S.	-.140	.889	N.S.	-.338	.735	N.S.
Mo	-.135	.893	N.S.	-.447	.655	N.S.	-.267	.789	N.S.
U	-.592	.554	N.S.	-.980	.327	N.S.	-.169	.860	N.S.
As	-.169	.866	N.S.	-1.050	.294	N.S.	-.254	.800	N.S.
Sn	-.524	.600	N.S.	-.254	.800	N.S.	*	*	*
W	-.085	.933	N.S.	-.560	.575	N.S.	*	*	*

Z STATISTIC	2-TAILED PROBABILITY y = .50 / SIGNIFICANCE N.S. = NOT SIGNIFICANT	* NOT CALCULABLE

geochemistry of the clay fraction than in the McCarron Brook Till. Cu values differentiate the Joggins Till from the lower McCarron Brook Till at the type section, as they are uniformly higher (Fig. 8). The peak in Cu values mimics the peak in the percentages of pelecypod limestone clasts associated with the coal beds (Fig. 9). As stated earlier, the reasons for this may be the sulphides associated with coal beds. The heavy mineral separates of the fine sand fraction were analysed for Cu, Pb and Zn (Table 3). The particular sample with the peak in Cu in the clay fraction had values of 1345 ppm Cu, 919 ppm Pb and 1655 ppm Zn in the heavy mineral separates. These data suggest that the clay fraction of the Joggins Till is autochthonous.

Figure 11 shows the relationships of trace elements and the lithological parameters. Cu and Zn are correlated with the largest number of elements. Elements positively correlated are Cu and Zn, As, Mn, Fe, Ni and U. Cu is positively correlated with the gravel weight. Since the gravel fraction is largely autocthonous this suggests that the clay fraction geochemistry of the Joggins Till has a strong local bedrock influence. Calcium exhibits a negative correlation with Cu and Zn and gravel weight while being positively correlated with depth (Fig. 11). Two possible reasons for this may be that a large portion of the calcium in the matrix is derived from reworked components of the underlying McCarron Brook Till, or weathering after the deposition of the Joggins Till depleted calcium in the upper parts of the till. The negative correlation of granitic erratic percentages with Zn in the clay fraction confirms a local origin for this fraction. In the underlying McCarron Brook Till Zn was positively correlated with erratic percentages.

Summary

Joggins Till is greyish, moderately compact, calcareous and clay-rich. It is differentiated from other mapped till units by colour, texture and the abundance of coal and limestone clasts derived from the coal seams in Cumberland Group rocks. The till matrix and gravel fractions are locally-derived. Till fabric and striations on embedded boulders trend northeast-southwest.

Eatonville Till (E)

Type locality, stratigraphy and extent

The stratotype for the Eatonville Till is located in a borrow pit 2 km east of Shulie Lake on the Shulie Lake Road (Fig. 12, 15; Map 1630A). Here, the Eatonville Till is overlain by the Shulie Lake Till and underlain by gravelly-sand and conglomerate bedrock (Fig. 12, 15). The contact of the two till units is gradational over 50 cm. Eatonville Till extends in a 10 km wide strip across most of the map area, covering much of the Cobequid Highlands, but locally pinching out against residuum and bedrock prominences (Fig. 13). D. R. Grant (personal communication, 1983) interprets this till-bedrock boundary zone as a glacier limit.

The Eatonville Till is found as a thin, discontinuous veneer on scoured, red-stained sandstone surfaces designated as bedrock on Map 1630A. Striations on the bedrock surface underlying the Eatonville Till generally trend southwestward (Fig. 13). The Westbrook Soil is developed on the Eatonville Till in the southern portion of the map area (Nowland and MacDougall, 1973).

The Eatonville Till grades laterally into the Joggins Till in the vicinity of Joggins (Map 1630A).

A principal reference section for the Eatonville Till is located on the Eatonville Road, near New Salem (till sample site 33; Fig. 31). At this site it is overlain by glaciofluvial sand and gravel (Apple River Member) and underlain by conglomerate of the Cumberland Group.

Description

The Eatonville Till is reddish-brown (10R4/6), compact, and composed of a silty-sand matrix (Fig. 14). The till can be fissile and is commonly jointed. Black manganese oxide staining is prevalent along fissility planes and joints. The sandy facies of the Eatonville Till (Es; Map 1630A) is stonier than the 'regular' phase of the Eatonville Till with lenticular sand inclusions (1-2cm wide) and clay 'skins' around clasts. It may have a melt-out origin. In general, the Eatonville Till becomes stonier in the southern portion of the map region underlain by conglomerate bedrock (Fig.13; Fig. 31).

The thickness varies from an average of 2 m in ground moraine areas to 10 metres in drumlins. It is associated with strongly rolling and deeply incised topography in the southern part of the map sheet (Fig. 5).

Clast lithology and provenance

Averages of the six major rock types for the Eatonville Till are given in Table 2. The average metamorphic and granitoid clast percentages are higher than in the other till units. In the southern portion of the area the Eatonville Till is composed of high percentages of well-rounded metamorphic and granitic rocks,largely derived from the Cumberland Group polymictic conglomerate which outcrops there (LCCc; Fig. 31 Shaw, 1951, p. 85). In the northern part of the map area, the Eatonville Till consists of greenish-grey feldspathic arenites of the Cumberland Group (LCCd, Fig. 31) with a small but significant percentage of red mudstones (Till Sample Site 105, Fig. 31). These clasts are believed to have been derived from regions north of Joggins underlain by rocks of the Windsor and Pictou groups (Fig. 31). This implies a south to southwestward ice movement, which agrees with striations found underlying the Eatonville Till. The red coloration of the matrix is also believed to be inherited from rocks originating in the vast area of Carboniferous redbeds north Joggins, since the Eatonville Till overlies a monotonous sequence of grey sandstones in the map area (LCCd, Fig. 31). The so called 'red' conglomerates of the southern part of the area (Fig. 31) are, in fact, purplish in colour, distinctly different from the reddish brown of the Eatonville Till matrix, so the red matrix colour in that area probably represents far-transported material rather than local sources.

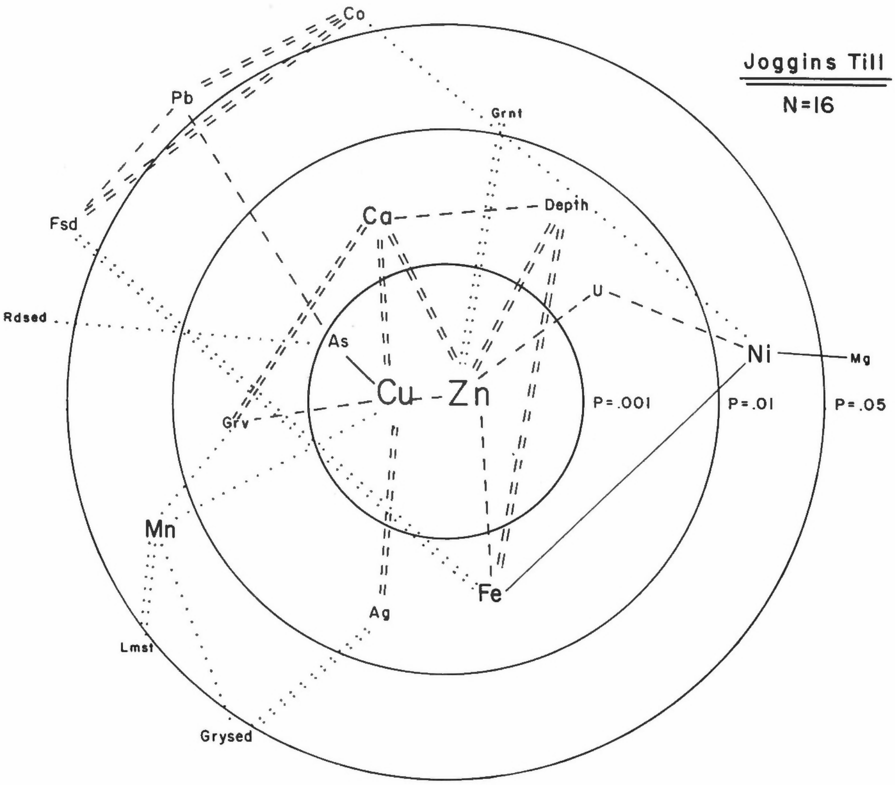


Figure 11. Net of significant correlations between geochemical, lithological and grain size parameters for the Joggins Till. See Figure 10 for explanation and legend.

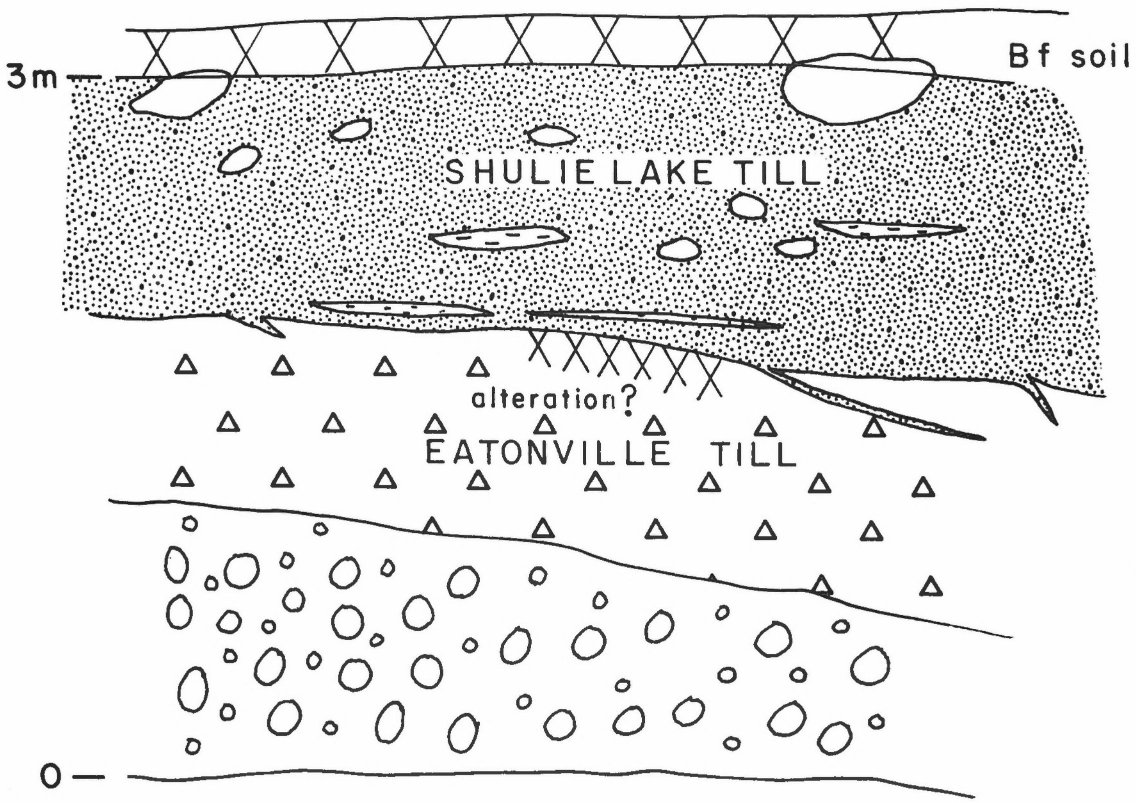


Figure 12. Diagrammatic representation of a section in a borrow pit on the Shulie Lake Road revealing the contact of the Shulie Lake Till and the Eatonville Till (See Map 1630A for location).

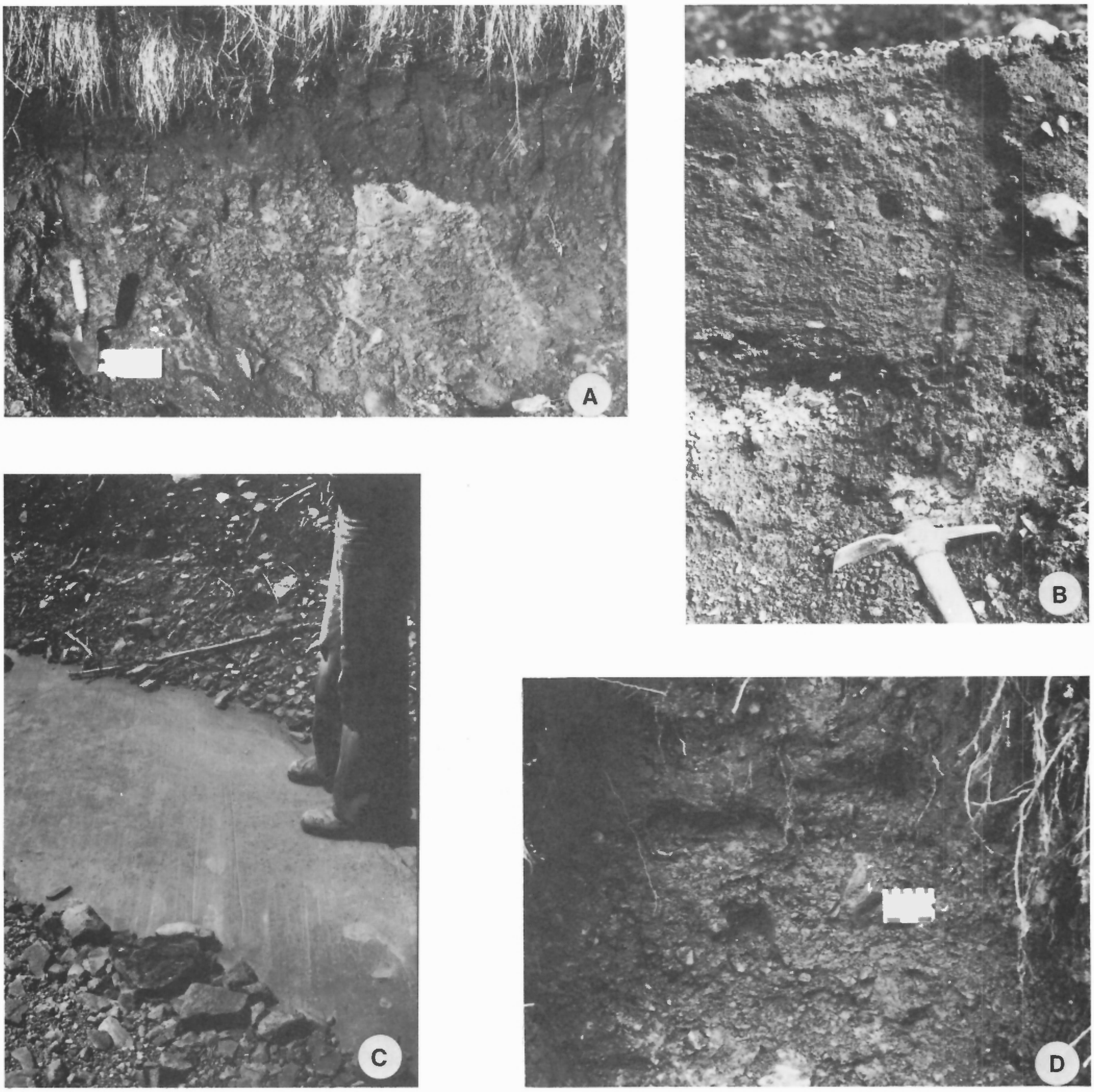


Figure 13. Photographs illustrating the variability of till units in the mapped area:
(A) Eatonville Till overlying sandstone bedrock; note the weathered joint planes.
(B) Eatonville Till overlying residuum of the Greville River Formation.
(C) Unidirectional striations and grooves trending 210° underlying the Eatonville Till on the Patriquin Road (Till sample site 96, Fig. 31)
(D) Shulie Lake Till

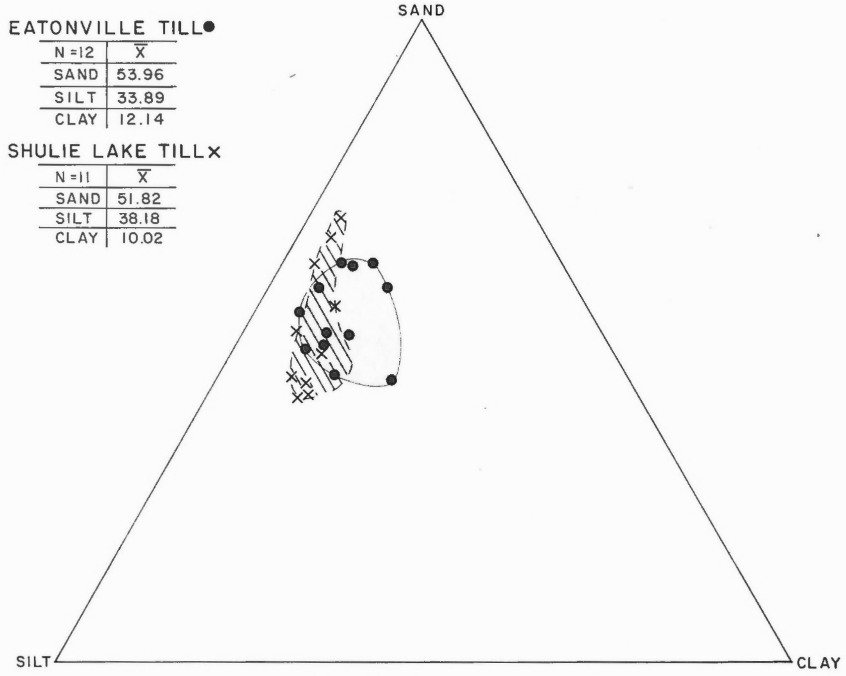


Figure 14. Sand, silt and clay ratios of the "C" horizons of the Eatonville and Shulie tills. Samples taken from the soil profile sites (Fig. 15).

Geochemistry

The basic geochemical statistics for the Eatonville Till are given in Table 1. Average values of metals closely match the older McCarron Brook Till average values except for Cu which is higher in the Eatonville Till. This is probably due to the redbed sources of both tills. A shale source for the matrix of the Eatonville Till is indicated by a close match between its Cu-Pb-Zn average values (41 ppm-Cu; 24 ppm-Pb; 101 ppm-Zn) and the average values of Cu-Pb-Zn in the earths shales (45 ppm-Cu, 20 ppm-Pb, 95 ppm-Zn; Turekian and Wedepohl, 1961). The Eatonville Till is deficient in Ca (540 ppm) compared to the McCarron Brook Till because of noncalcareous red shales and mudstones in Late Carboniferous redbeds of the Cumberland and Pictou groups. The redbed sources of the McCarron Brook Till are Triassic or Early Carboniferous in age and are largely calcareous .

The Eatonville Till differs from the laterally equivalent Joggins Till in average values of Zn and Ca (Table 1). Enrichment of Ca in the Joggins Till is due to the input of limestones from the coal beds. Zn enrichment is due to the incorporation of sulphide-rich coals and coaly-shales.

Figure 16 is a plot of the significant correlations between trace elements, grain size and the lithological parameters of the Eatonville Till. Pb and Zn are correlated with the largest number of parameters. Strong positive correlations occur between Pb and Zn and the percentages of local grey arenites of the Cumberland Group. Cu also appears to be associated with the local grey arenites. Granitic and metamorphic clast percentages, derived from local conglomerate and distant sources, show a negative correlation with Pb and Zn. Gravel weights also display a negative correlation with Zn. The gravel weights tend to be larger in areas underlain by conglomerate bedrock which suggests that the conglomerates are not sources for Pb and Zn. There is an assemblage of linearly correlated elements, namely Cu-Ni-Co-Mn-Mg-Ca-Sn. The Cu-Ni-Co-Mn assemblage is similar to the McCarron Brook Till elemental association, and may therefore represent reworked matrix components of this previously deposited till in the Eatonville Till or it may be due to the effects of weathering as most of the Eatonville Till samples are surface samples (1-2m). Cu, Ni, Co and Mn behave similarily in the secondary environment (Levinson, 1980, p.657).

Summary

Eatonville Till is reddish-brown and compact with a silty-sand matrix. It is polymictic and stony in the southern portion of the map area reflecting its derivation from adjacent conglomerates; in the northern part it consists mainly of arenites. A strong Pb-Zn geochemical association in the clay fraction of the till suggests that, in part, it is locally derived. Red mudstones in the pebble fraction and the red matrix coloration, however, imply some allocthonous input from redbed areas to the north. The Eatonville Till overlies rock surfaces with striations trending southwestward and forms drumlins that parallel thistrend.

Shulie Lake Till (SL)

Type locality, stratigraphy and extent

Shulie Lake Till is best exposed in a borrow pit 2 km east of Shulie Lake on the Shulie Lake Road (Fig. 12, 15; Map 1630A). Here, the Shulie Lake Till overlies the Eatonville Till and is overlain by soil of the Shulie Series (Nowland and MacDougall, 1973). The Shulie Lake Till extends over a large area west of Maccan River and north of Apple River. It

Figure 15. Stereoscopic view of the area near the type section (Marked by triangle) of the Eatonville and Shulie Lake tills. Location of the soil profile sites are also shown on this diagram (see Appendix 3). Note the differences in terrain north and south of the mapped Shulie Lake Till "limit" (dashed line).

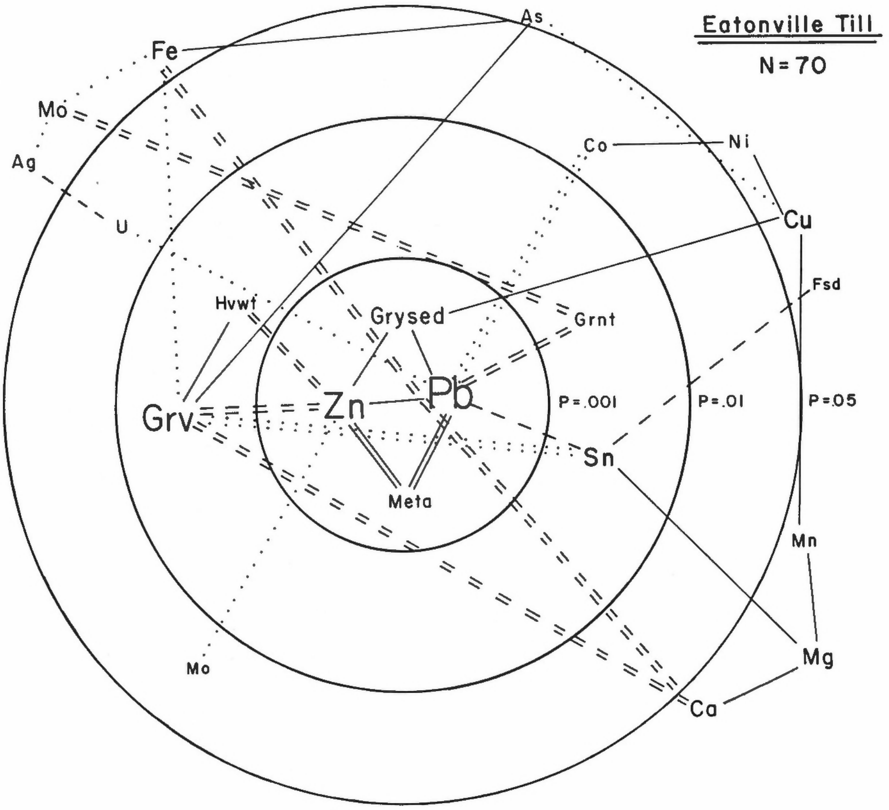


Figure 16. Net of significant correlations between geochemical, lithological and grain size parameters for the Eatonville Till. See Figure 10 for explanation and legend.

terminates abruptly in an east-west line marked by Welton and Shulie lakes (Fig. 15).

Description

Shulie Lake Till is light olive-brown (5Y 5/6), moderately compact to loose, very stony, with a silty-sand matrix (Figs. 13, 14). The matrix may locally have reddish hues which are due to the incorporation of Eatonville Till matrix components. Inclusions of Eatonville Till are occasionally found in Shulie Lake Till (Nowland and MacDougall, 1973, p. 49). The contact of the Shulie Lake Till and Eatonville Till at the type section is gradational and erosive, with evidence of shearing (Fig. 12). At this site the Shulie Lake Till has a distinct reddish hue due to the incorporation of the underlying Eatonville Till. The Shulie Lake Till varies in depth from less than 1 m as a thin, bouldery ground moraine to 10 m in ribbed moraine areas (Map 1630A). The upper metre of the Shulie Lake Till usually has a concentration of grey sandstone boulders. In areas mapped as SLs (Map 1630A) this boulder layer lies on a facies characterized by a sandy matrix with washed, coarse layers. The topography associated with this facies of the Shulie Lake Till features hummocks and kettles forming small scale, multi-basinal drainage systems. The basal facies of the Shulie Lake Till is generally associated with linear morainal forms or 'ribbed' moraine oriented perpendicular to the major southwestward ice flow.

Clast lithology and provenance

Shulie Lake Till consists almost entirely of grey arenite clasts (average: 89.6%, Table 2), with very little variation across the map area (Fig. 31). The source of many of the sandstone clasts in the till may be the long, parallel strike-ridges that outcrop in the northern part of the map area (Map 1630A). Shaw (1951, p. 15) stated that these ridges are formed of massive grey sandstone. The ridges are pervasively grooved and striated and bear little surface drift (Map 1630A). The intervening vale areas are underlain by grey siltstones, but these were not available for transport and comminution. Few fine-grained clasts are found in the overlying Shulie Lake Till.

In areas south of the ridges, underlain by the upper fine facies of the Cumberland Group (LCCd), the Shulie Lake Till is still largely composed of arenite clasts (till sample site 72; Fig. 31). Local sandstone bedrock sources may have provided many of the sandstone clasts in this area. Dispersal of sandstone clasts in the Shulie Lake Till on to the conglomerate terrane (LCCc, till sample sites 69,338; Fig. 31) further south is in the order of 5 km.

Geochemistry

Shulie Lake Till has significantly higher values of Cu, Pb, Zn, Mn, and U than the other till units (Table 1). Pb and

Zn appear to be the most variable elements with large standard deviations (Table 1). At the McCarron Brook Till Section (Fig. 8) the values of Cu, Zn, and Mn appear to increase with proximity to the modern soil. This suggests that soil formation processes and associated translocation of metals may be enhancing the values of labile elements in the clay fraction of the Shulie Lake Till. Shilts (1975) pointed out that the depth of oxidation in a surface outcropping till can be as much as 4 m.

Figure 17 is a plot of the statistical relationships of the trace elements and lithological and textural parameters of the Shulie Lake Till. Mn is the hub of most correlations. Two assemblages of related elements are apparent . They are: Mn-Pb-Zn, and Mn-As-Cu-Fe-U. Mn is positively correlated with the gravel and fine sand weights. Because Shulie Lake Till is largely composed of Cumberland Group grey sandstones the dominance of manganese may relate to manganese metal occurrences (manganite) found throughout the Cumberland Basin (Fig. 31). The correlations with manganese may also be caused or enhanced by surface oxidation and soil forming processes, possibly involving precipitation of metals like Cu and Zn with manganese oxides.

Sn is negatively correlated with manganese. Limestone, red sedimentary, metamorphic clast percentages and Ca values are negatively correlated with many elements that are positively correlated with manganese. These parameters represent the input of allocthonous sources, or the addition of older McCarron Brook and/or Eatonville till components by reworking.

Summary

Shulie Lake Till is olive-brown, loose, clast-rich and sandy. It is differentiated from older till units by colour and abundance of angular surface boulders. It is lithologically homogeneous, consisting of more than 90 per cent grey Carboniferous sandstones. The Shulie Lake Till is displaced up to 5 km southward onto terrain underlain by polymictic conglomerate without any noticeable change in lithology. Geochemically, it is distinguished from other till units by higher Mn values. The association of the Shulie Lake Till with ribbed morainal forms indicate that it was formed by a southwestward ice flow.

FIVE ISLANDS FORMATION

Introduction

The Five Islands Formation was originally defined by Swift and Borns (1967) to encompass both glaciofluvial and glaciomarine sediments that form terraced plains at the mouths of river valleys along the Minas Basin shore. Essentially, the Five Island Formation encompasses all the glaciofluvial and glaciomarine deposits created by glacier

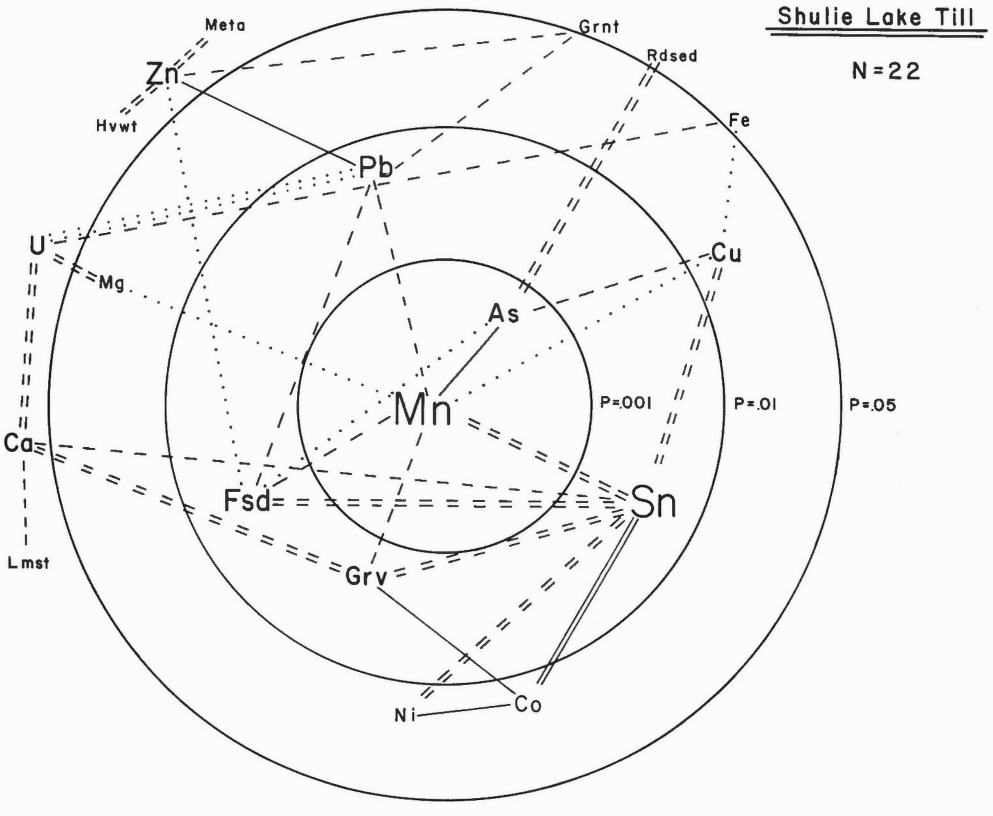


Figure 17. Net of significant correlations between geochemical, lithological and grain size parameters for the Shulie Lake Till.See Figure 10 for explanation and legend.

melting and sea level rise in the Late Wisconsinan. This formation is bounded by subglacial deposits at the base and Recent sediments and soil at the top.

Swift and Borns (1967) originally subdivided the Five Islands Formation into two members; the Advocate Harbour Member and the Saints Rest Member. The Advocate Harbour Member was interpreted to consist of two marine lithosomes; glacio-littoral and glacio-deltaic. The glacio-deltaic lithosome includes bottomset, foreset and topset beds. The glacio-littoral deposits were interpreted as beach and spit deposits. The Saints Rest Member was believed to be proximal glacial outwash.

Swift and Borns (1967) stated that the Saints Rest Member is characterized by metamorphic lithologies and disconformably overlies the topset beds of the Advocate Harbour Member, which are distinguishable on the basis of their content of sedimentary clasts. Wightman (1980), on the other hand, interpreted the topset beds of the glacio-deltaic sequence and the previously defined Saints Rest Member as a single depositional unit. He proposed that the lithological variations between the topsets and overlying outwash represented successive stages of northward retreat of an ice front to the Cobequid Highlands over succesive rock types.

The authors concur with Wightman's (1980) proposed redefinition of the Saints Rest Member, and would also agree that the Advocate Harbour Member can be considered as comprising the truly marine portions of the delta (bottomset and foreset beds) and raised littoral gravel.

The authors have added two more mapped units; the Apple River Member and the Newville Lake Member. The Apple River Member consists of glaciofluvial sediments deposited in proximity to melting ice. These sediments intertongue with outwash of the Saints Rest Member at the mouths of major valleys. The Newville Lake Member represents glaciolacustrine sedimentation in a lake ponded by melting ice during deglaciation.

Apple River Member (AR)

Type locality, stratigraphy and extent

The type section for the Apple River Member is in a gravel pit north of New Salem, 3 km south of Apple River (Fig. 18; Fig. 31). It is overlain by soil of the Hebert Series (Nowland and MacDougall, 1973) an orthic humo-ferric podzol. It is underlain at the type section by the Eatonville Till. The Apple River Member extends over a large area south of Apple River, but is confined to the flanks of major river valleys in other parts of the map area, such as the Parrsboro, Kelley and Hebert rivers.

Figure 18. Photograph of the gravel pit north of New Salem, type section for the Apple River Allomember. Note the abrupt changes in grain sizes between beds and cap of till on the surface.

Description

The Apple River Member includes stratified, water-deposited sediments that are associated with hummocky topography. It is characterized by abrupt changes in grain size between beds. Small and large scale crossbeds are common, composed of sandy-gravel and sand. They are usually in sharp contact with lenticular, parallel, medium to fine sand beds. Till inclusions and beds are common (Nielsen, 1976, p. 47). At the type section till 'blocks' are found on the surface of the deposit (Fig. 18). Faulting and disruption of beds is common. In the Apple River and Kelley River areas, the Apple River Member forms individual mounds or kames 10-15 m in height. Intervening areas may only have a thin (1-2 m) veneer of gravelly sand. Flanking Parrsboro valley the Apple River Member forms an undulating, pitted terrace with deposits up to 30 m thick. The 'Boars Back' ridge or esker (Chalmers, 1895, p. 84) stretches along Hebert River (Map 1630A). The Apple River Member in this area consists of two units, a lower (Unit I) bouldery, gravelly-sand, faulted, with fine sand beds; and an upper (Unit II) crossbedded, fine to medium sand with gravelly sand interbeds.

Clast lithology and provenance

The Apple River Member, associated with kames, kame terraces, and eskers along river valleys north of the Cobequid Highlands, is largely composed of well rounded, grey sandstones. Coal clasts were noted in an outcrop at the mouth of Haycock Brook (Map 1630A), suggesting a northerly provenance as coal seams of the Joggins coalfield outcrop to the north. Crossbed orientations in the upper unit of the Apple River Member in this region generally trend southward.

Intepretation

The sediments of the Apple River Member are interpreted to be ice contact stratified drift (Stea, 1983). Near Newville Lake a deltaic sequence consisting of large-scale foreset and topset beds is exposed (Map 1630A, Fig. 19). Faulting of beds seen at the proximal end of the exposure attests to the ice contact nature of this deltaic lobe.

The intimate association of till with these deposits, local faulting and folding of beds, and the variable, erratic bedforms suggest the proximity of ice and changing rates of meltwater flow.

Saints Rest Member (SR)

Type locality, stratigraphy, and extent

The type section for the Saints Rest Member is at Saints Rest, east of the map area (Swift and Borns, 1967, p. 703). A reference section in the map area is located east of Port Greville along the Minas Basin shore (Map 1630A). Here, the Saints Rest Member forms topset beds and overlies foreset and bottomset beds of the Advocate Harbour Member. It is overlain by soil of the Hebert Series (Nowland and MacDougall, 1973). The Saints Rest Member is exposed in a broad plain from Parrsboro to West Advocate along the coast and in a valley north of Newville Lake (Map 1630A). At Parrsboro and other areas along the north coast of Minas Basin the Saints Rest Member forms an outwash plain that grades distally into topset beds of a glaciomarine delta sequence.

Description

Saints Rest Member ranges in colour from greyish to yellowish-brown. It is massive to crudely bedded and consists of medium to coarse gravel with a sand matrix. Cut and fill structures are common (Wightman, 1980, p. 30; Swift and Borns, 1967, p. 697). The Saints Rest Member tends to be normally graded from proximal to distal parts of the delta sequences and inversely graded in vertical section. Grain size distribution curves generally show two modes — a coarse pebble-cobble mode and a coarse sand mode, with poorer sorting than the underlying marine deposits (Fig. 20).

The Saints Rest Member forms a discontinuous, terraced plain that stretches from Truro to Advocate Harbour (Swift and Borns, 1967, p. 693). The surface of the plain is flat, but locally pitted with kettle holes (Map 1630A). Infrared imagery reveals striking relict braided stream patterns on the surface, especially on Parrsboro delta. A series of terraces are developed in the outwash plain and deltas at Parrsboro, Diligent River and Port Greville (Map 1630A). Four terrace levels have been mapped at Parrsboro.

Clast lithology and provenance

Saints Rest Member along the Minas Basin shore west of Parrsboro is largely composed of sedimentary rocks — red and grey arenites, mudstones, cleaved sedimentary rocks, metamorphic (quartzite) and granitic clasts (Fig. 21). Triassic sandstone is locally present as a matrix component imparting a reddish tinge to some beds. The sedimentary rocks are believed to be derived from the Cumberland Group outcropping north of the highlands (Fig. 31). The metamorphic and cleaved sedimentary rocks are probably derived from the Greville River and Parrsboro formations (Fig. 31) of the Cobequid Highland massif.

Interpretation

The Saints Rest Member is interpreted as glacial outwash — an aggraded sequence of diffuse gravel sheets deposited by braided streams emanating from a glacier or ice cap (Wightman, 1980, p. 381). Wightman (1980, p.30) presented the evidence for this interpretation. The braided streams which deposited the outwash were graded to base level, i.e. sea level. Lateral migration of fluvial channels eroded the top of the marine foreset beds of the delta to base level, thus the topset/foreset contact represents an unconformity that approximates sea level at the time of deposition. The maximum height of this contact was taken to represent the maximum level of marine submergence.

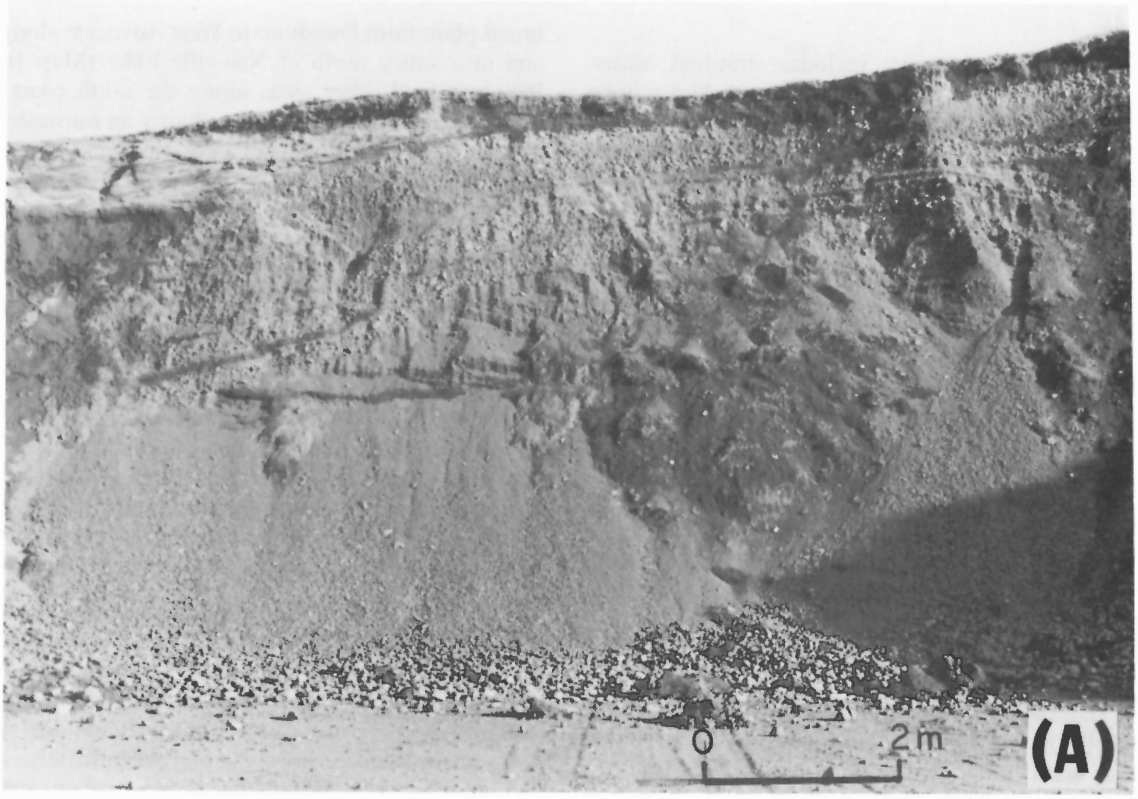


Figure 19. Photographs of the ice contact delta near Newville Lake.
(A) Proximal exposure: note faulting of beds.
(B) Distal exposure, showing large foreset beds and topsets.

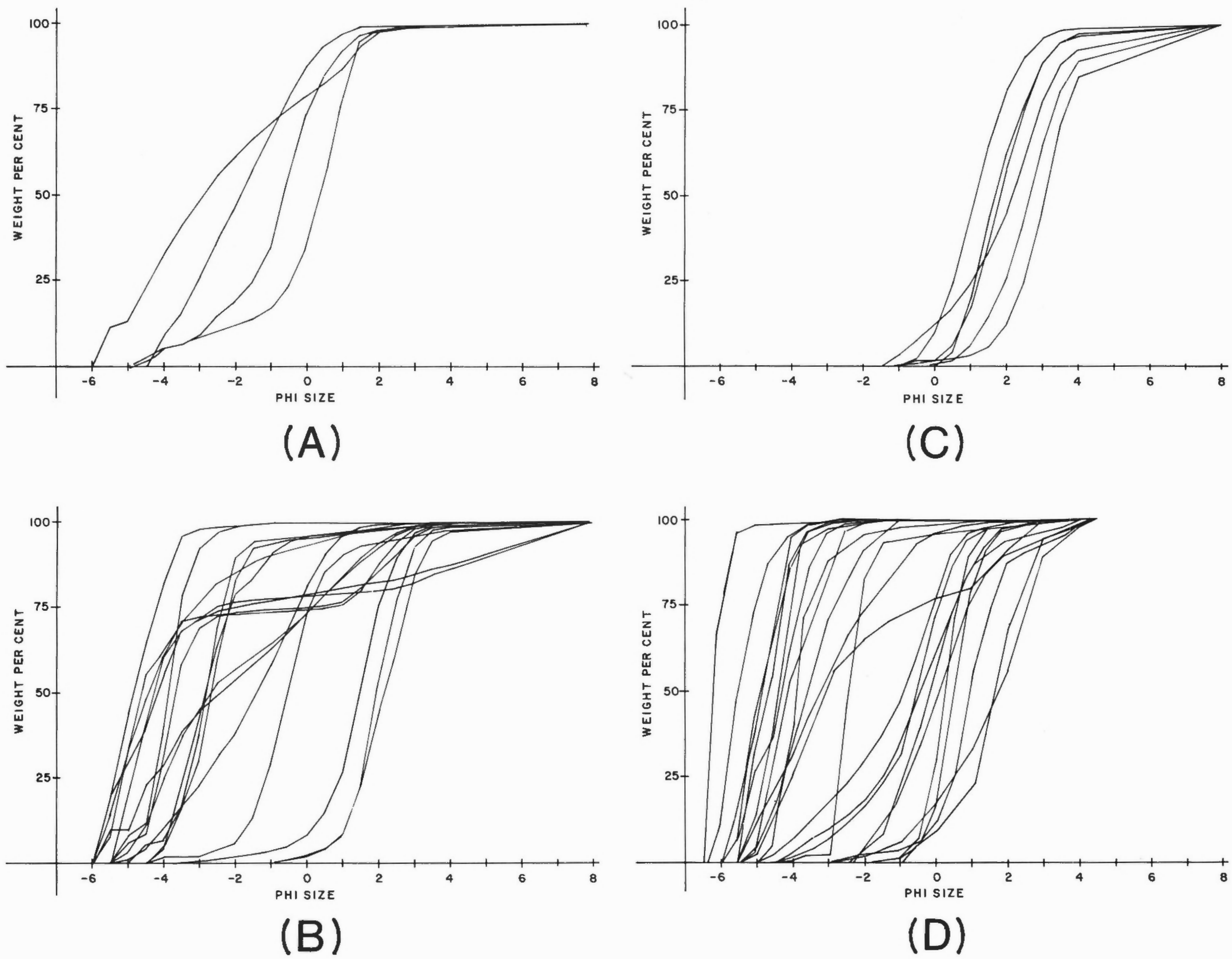


Figure 20. Grain size distributions for the Five Islands Formation (adapted from Wightman, 1980).
(A) Saints Rest Member; topset beds
(B) Advocate Harbour Member/glacio-deltaic facies; foreset beds
(C) Advocate Harbour Member/glacio-deltaic facies; bottomset beds
(D) Avocate Harbour Member/glacio-littoral facies.

Newville Lake Member (NL)

Type section, stratigraphy and extent

The Newville Lake Member is poorly exposed along Highway 2 south of Newville Lake (Map 1630A). The sediments form a broad, flat plain north of the moraine which forms the drainage divide in Parrsboro Gap, and south of Newville Lake.

Description

Newville Lake Member is composed of interbedded fine sand, silt and clay overlain by a veneer of recent peat and organics. The sediments range in thickness from 1 to 10 m.

Interpretation

Newville Lake Member is interpreted to be a lacustrine deposit of a former shallow Postglacial lake named Potters Lake by Wightman (1980, p. 294). The kame delta nearby (Fig. 19) is believed to have been deposited in an earlier, ice-dammed lake because no evidence of the high lake level has been found in the surrounding hills.

Advocate Harbour Member (AH)

Type section, stratigraphy and extent

Advocate Harbour Member consists of two facies — a marine glacio-deltaic lithosome and a glacio-littoral lithosome (Swift and Borns, 1967, p. 695). The type section for the glacio-deltaic lithosome (AHa) is at Lower Five Islands (Swift and Borns, 1967). A principal reference section for this facies in the map area is at Spencers Island (Fig. 22; Map 1630A). Here, foreset and bottomset beds of a delta are well exposed, overlying till and underlying the Saints Rest Member (topset beds). Figure 23 shows the tripartite structure of the classical 'Gilbert Type' delta and illustrates the rela-

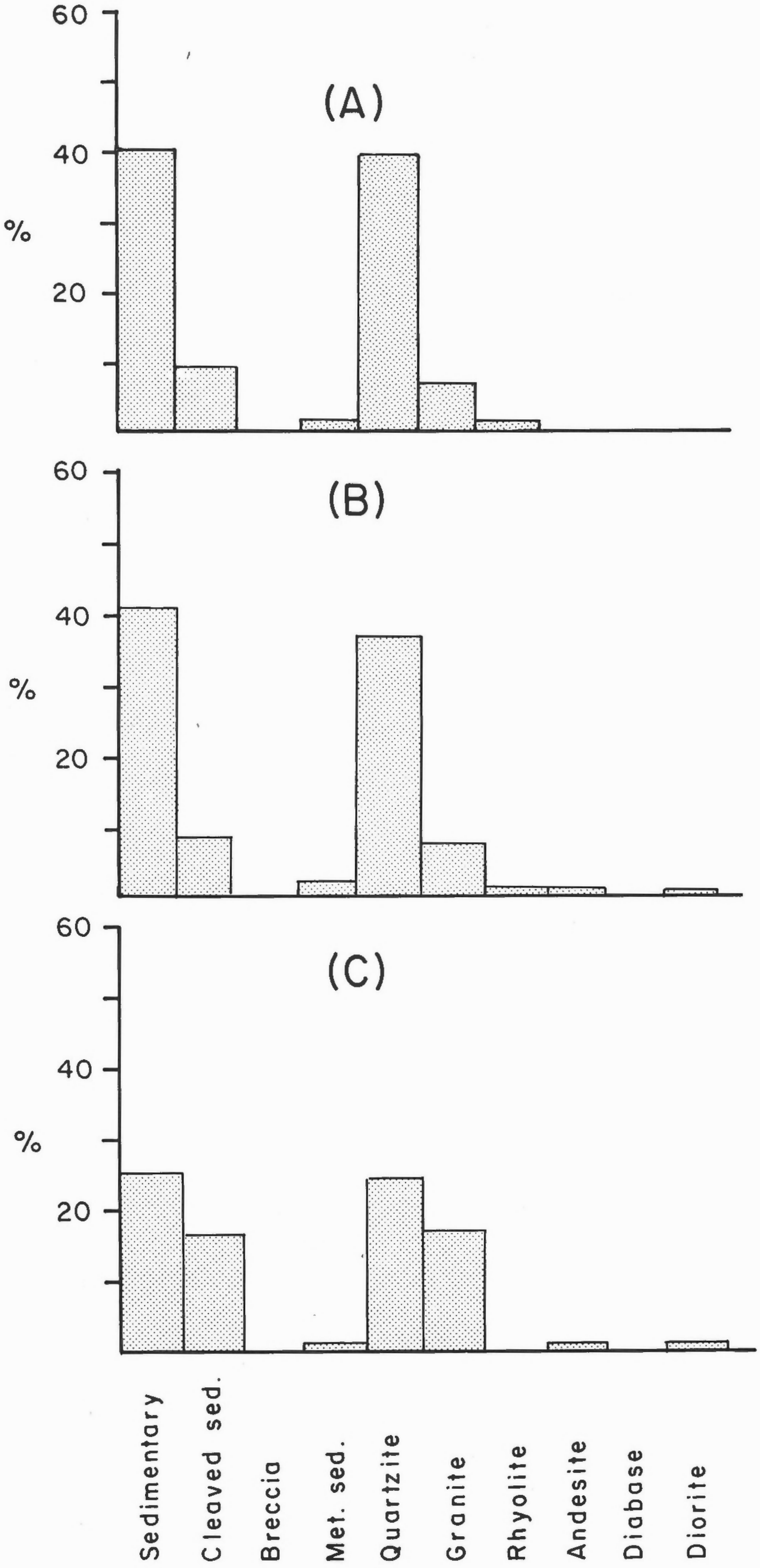


Figure 21. Pebble lithology of the Five Islands Formation in the map area (adapted from Wightman, 1980)
(A) Saints Rest Member
(B) Advocate Harbour Member; glacio-deltaic facies
(C) Advocate Harbour Member; glacio-littoral facies

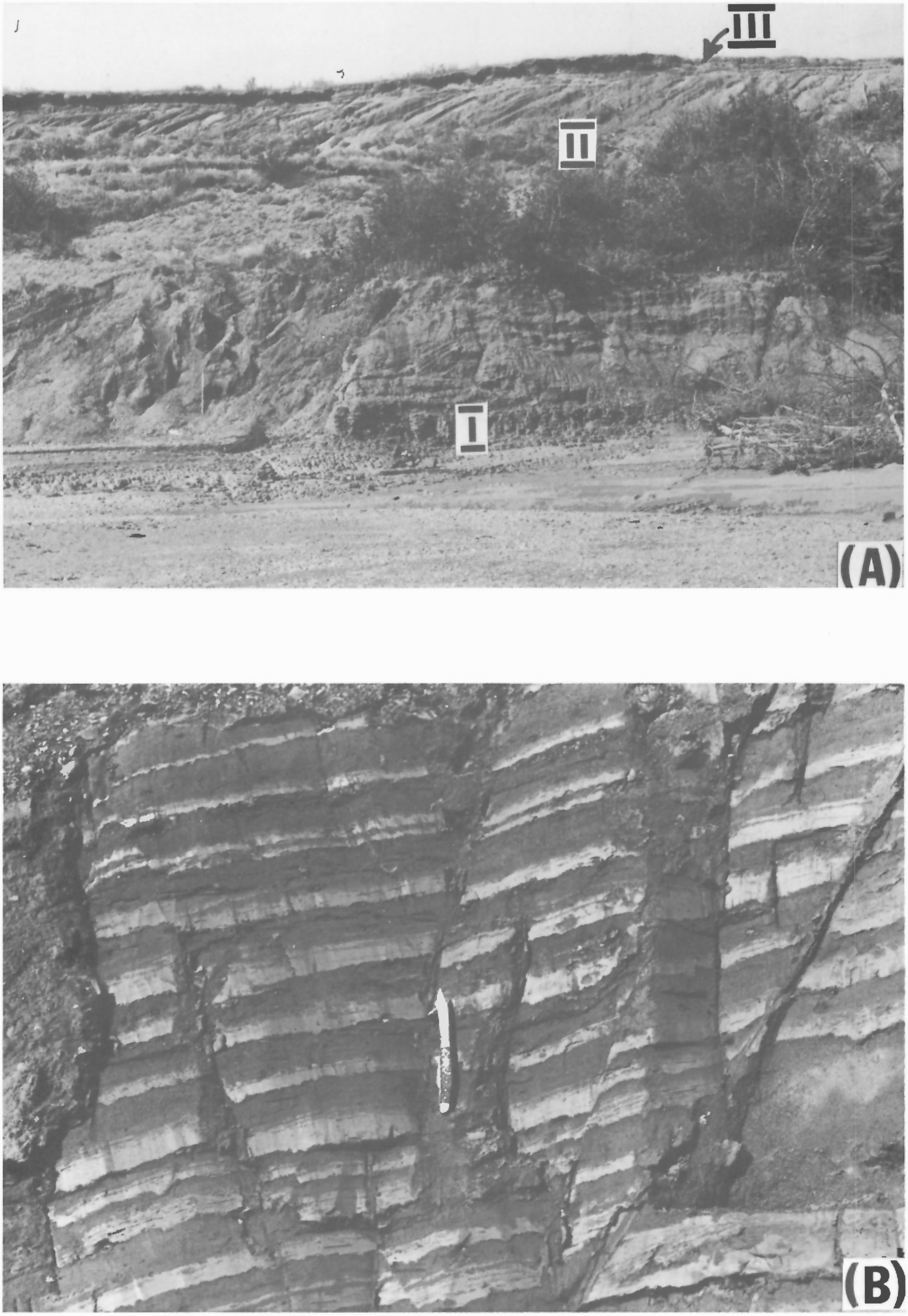


Figure 22. Photographs of the Spencers Island glaciomarine delta.
(A) Topset (III), Foreset (II), and Bottomset (I) structure revealed
(B) Close-up of the bottomset rhythmites

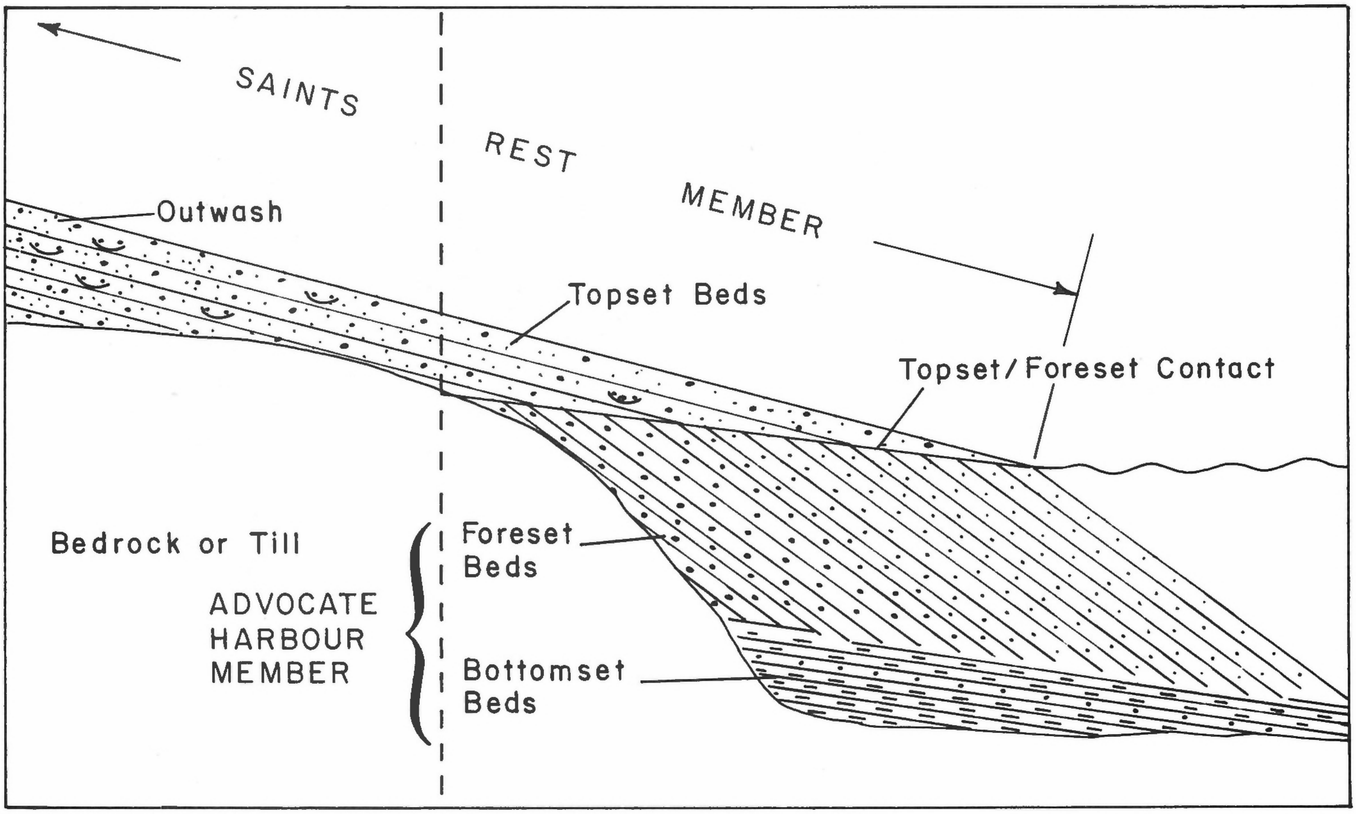


Figure 23. Diagrammatic cross-section of a 'Gilbert Type' delta showing the relationships between the topset, foreset and bottomset beds. The lithostratigraphic divisions of the Five Islands Formation are also illustrated on this diagram.

tionships between the individual glacio-deltaic units of the Advocate Harbour Member and proximal outwash at Spencers Island and elsewhere along the shore. These deltas form a discontinuous plain with the marine Advocate Harbour beds raised above modern high tide level.

The type section for the glacio-littoral lithosome is at Clam Cove, along Chignecto Bay, where gullying along a logging road reveals a transition of surficial deposits from unaltered Shulie Lake Till, a beach berm with rounded stones, to upper shoreface marine sands (Fig. 24). The glacio-deltaic facies of the Advocate Harbour Member is exposed along the north shore of Minas Basin from Parrsboro to Spencers Island. The glacio-littoral facies of the Advocate Harbour Member is exposed along the coast of the Chignecto peninsula from Advocate Harbour to Joggins (Map 1630A).

Description

Glacio-deltaic facies (AHa)

The glacio-deltaic facies (AHa) is composed of bottomset and foreset beds in the classic 'Gilbert Type' delta style (Fig. 22, 23). The bottomset beds of the delta sequence are composed of reddish-brown, clay/silt, clay/sand, and clay/gravel couplets or rhythmites. The rhythmites are essentially flat lying or shallow (1-5°) southward dipping. Figure 20C illustrates the fine grain size and moderate sorting of the bottomset beds.

The foreset beds are generally a planar-bedded, openwork or closedwork, medium sand to coarse gravel (Fig. 20). Individual beds are normally graded. These beds are generally steeply inclined, dipping from 25°-34° in a seaward direction. At Spencers Island, the foreset beds either end abruptly at the bottomset beds or flatten to dips of 5-8° before pinching out over the bottomset beds in a tangential contact. At Port Greville (Map 1630A) sequences of foreset beds are stacked on top of another, separated by sharp planar, or erosional surfaces.

Glacio-littoral facies (AHb)

The deposits at Advocate Harbour (Map 1630A) are composed of shallow, horizontally extensive seaward dipping (2°-14°) strata composed largely of gravel with some sand (Fig. 20). At Squally Point (Map 1630A), the deposits are composed of 1-2° seaward dipping, massive, openwork gravel which fines upwards and is capped by a fine sand bed. The pebbles in the lower coarse unit are well rounded and largely spherical, indicative of a beach environment. The surface topography of the littoral deposits of the Advocate Harbour Member is generally flat, broken by ridges that parrallel the modern shore. These may represent supralittoral berms or storm ridges (Map 1630A). The ridges have steeply-dipping seaward sides and shallow-dipping landward sides. The Advocate Harbour Member ranges in thickness from 1 m on the landward limit where it pinches out against till to greater than 20 m in distal areas in the Advocate Harbour area.

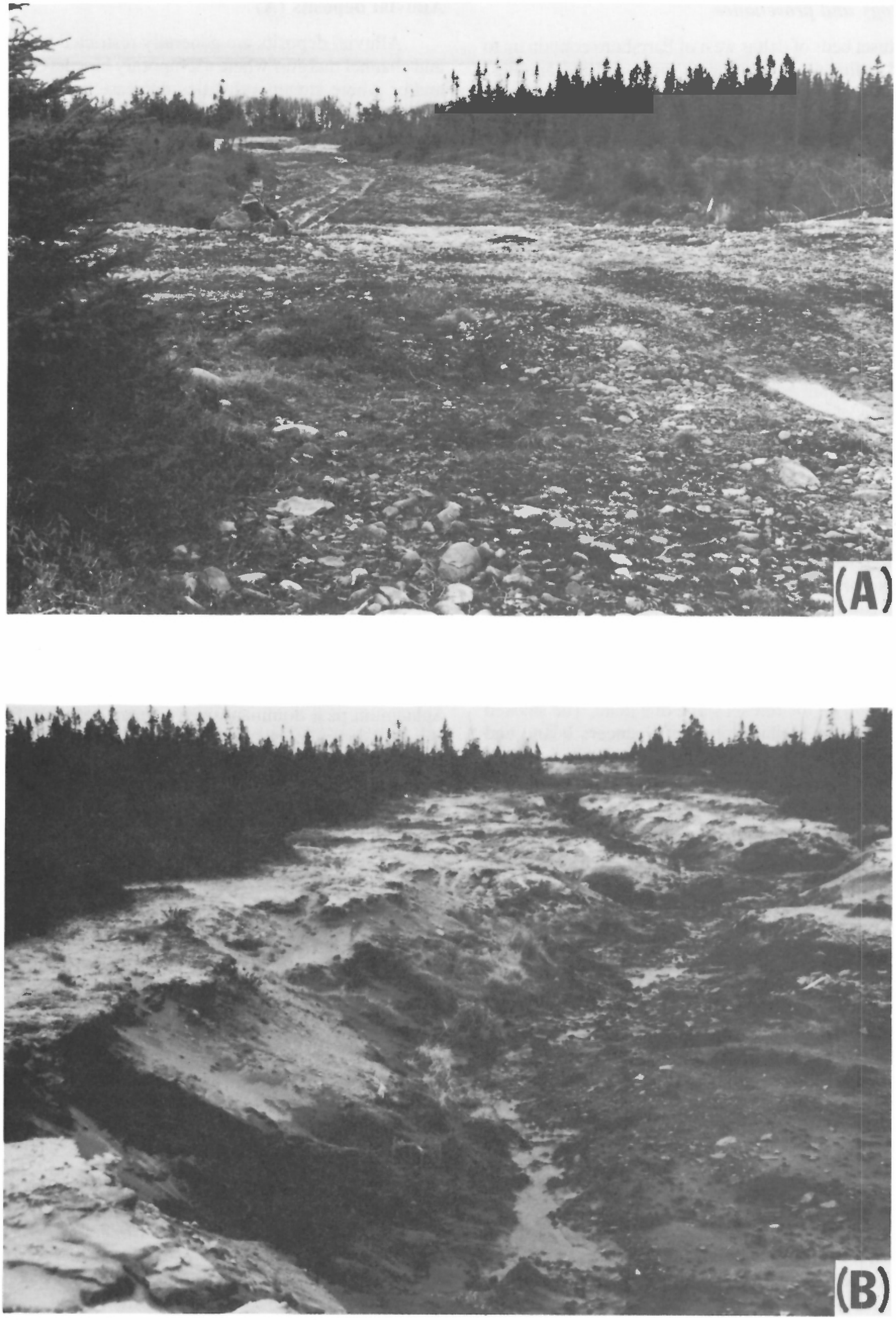


Figure 24. Raised beach at Clam Cove, south of Shulie (Map 1630a).
(A) View looking north with the raised beach in the foreground
(B) View looking south from the sand deposits; note the beach ridge in the background
The marine limit at this locality is 23 m above mean sea level.

Clast lithology and provenance

The foreset beds of deltas west of Parrsboro contain up to 40 per cent sedimentary lithologies (grey and red arenites, mudstones) and equal amounts of Cobequid Highland-derived metamorphic and granitic clasts (Fig. 21). The glacio-littoral deposits have similar pebble counts, but with half the amount of erodable sedimentary lithologies, reflecting the reworking processes of the nearshore marine environment (Fig. 21).

Interpretation

The glacio-deltaic facies of the Advocate Harbour Member is a marine deposit. Casts and molds of *Portlandia arctica*, a cold water marine bivalve, were found in the bottomset beds of the glacio-deltaic facies (Wightman, 1980, p. 254). The optimum habitat postulated for these fossils is "off the mouths of rivers carrying meltwater to the sea, or off glacier fronts, areas where large quantities of silt and clay are being deposited" (Wagner, 1977).

The bottomset beds are interpreted as seasonal deposits; the coarse layers were deposited during high discharge summer months; the fine layers were deposited during low meltwater discharge winter months. Wightman (1980, p.233-253) based this interpretation on the rhythmic nature of the beds and the coarsening upward sequence of clay beds grading to clay/sand couplets.

Wightman (1980, p.196) interpreted the foreset beds as marine deposits resulting from bed load deposition and sediment avalanching on the foreset slope of a delta. The stacked foreset sequences or 'deltaic lobes' at Spencers Island and Port Greville were probably caused by slumping or failure of the foreset beds (Swift and Borns, 1967, p. 696).

The glacio-littoral facies of the Advocate Harbour Member (AHb) is interpreted as regressive marine nearshore deposits including sublittoral, littoral, and storm ridge (supralittoral) deposits.

RECENT SEDIMENTS

Marine deposits (Ma,Mb)

Intertidal mudflats, salt marsh (Ma) and beaches (Mb) are included in this unit. Intertidal mudflat and salt marsh deposits are restricted to marginal areas of Minas Basin, Minas Channel and Cobequid Bay. The flats are predominately silt, fine sand and clay; overlain and interbedded with peat and organics (Fig. 25). Deposition of the mud is related to increased tidal activity commencing approximately 6300 years B.P. (Amos, 1978).

Beaches and spits characterize the high energy shoreline in Minas Basin, Minas Channel and Cobequid Bay. They are composed of fine to coarse gravel, either openwork or with a coarse sand matrix. Recurved spits are common, enclosing tidal inlets along Minas Basin. Strong longshore tidal currents in both directions may be the cause of these landforms.

Alluvial deposits (A)

Alluvial deposits are generally restricted to floodplains and channel margins where a temporary base level is achieved and/or where stream velocities decrease, such as the inner bank of meanders. The alluvial deposits are generally closed-work gravelly-sand grading upwards to fine silt, ranging in thickness from 1-5 m. Base level has risen rapidly in the Bay of Fundy over the last 4000-6000 years (Grant, 1977). This has resulted in the drowning of former shorelines and terrestrial environments by floodplain silt and marine silt.

Colluvial deposits (C)

Colluvial deposits are restricted to areas where the slope angle exceeds the angle of repose of the local sediments. It is common along the walls of deeply incised, north-south trending, V-shaped valleys in the Cobequid Highlands (Map 1630A). Along the Glooscap fault scarp it is an extensive surficial deposit (Fig. 26). Colluvium is generally composed of gravel, sand, and silt. It is a complex mixture of glacial deposits and weathered and frost shattered rock and formed by periods of downslope creep or mass movement. Colluvium ranges in thickness from 1 to 10 m.

Organic deposits (O)

Organic deposits in the form of raised or dome bogs occur frequently north of the Shulie Lake Till limit. They are generally irregular in shape, but some infill glacially scoured southwest-trending basins. They are composed primarily of a Sphagnum peat dominant over a Carex peat (W. Broughm, personal communication, 1984). At the base of many of these bogs is one metre or less of a greenish-grey ooze interpreted as gyttja (Appendix 3), underlain by sand or till. Average thickness of the bogs is 2.7 m (W. Broughm, personal communication, 1984).

INTERPRETATION OF QUATERNARY EVENTS

Introduction

Quaternary deposits and landforms in Cumberland County were created largely by the action of glaciers. Some features such as Parrsboro Gap, the scarps on both sides of the Cobequid Highlands, and deposits such as residuum or weathered rock, may have been inherited from pre-Quaternary time. A consequent north to south drainage pattern including the Petticodiac, Hebert and Parrsboro rivers is believed to have developed during the Cretaceous period (Goldthwait, 1924, p. 41).

The interpretation of the Quaternary history is mainly an exercise in the correlation of glacial deposits and landforms. Rampton and Paradis (1981a, p. 13) defined glacier flow 'phases' in southern New Brunswick based on the mapping of striations, drumlins, and ice marginal features and determined their relative ages by the maturity of landscapes within each glacier flow region. The authors approach is similar, with the added dimension of lithostratigraphy. Glacier flow

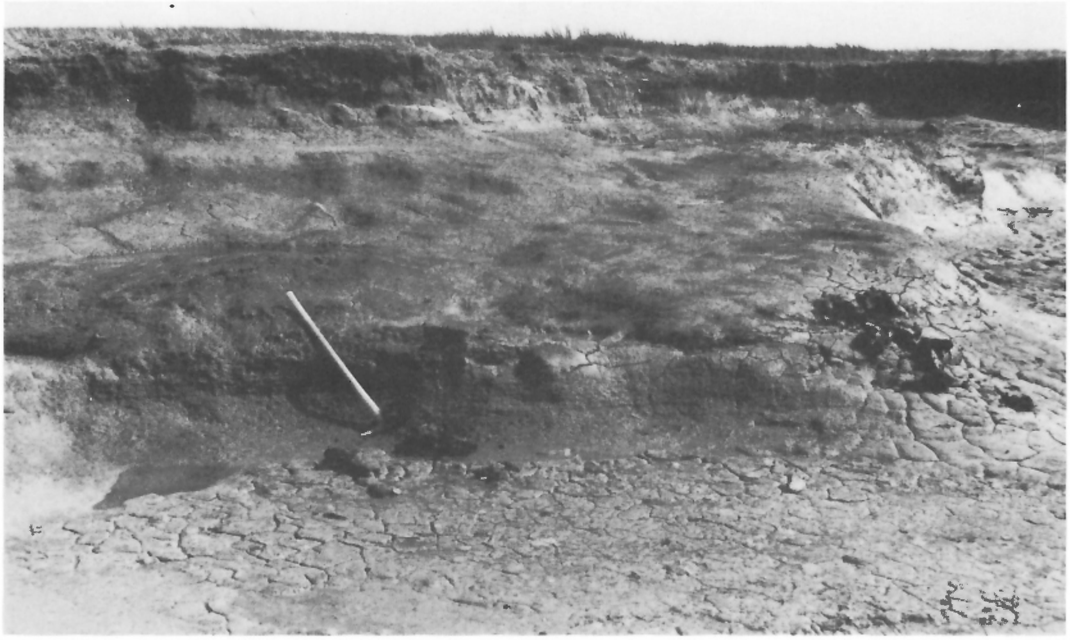


Figure 25. View of the salt marsh and estuarine mud near Minudie.

events may or may not produce tills. In depositional areas where tills are found in juxtaposition they can be used to interpret the sequence of events through the Law of Superposition. It is possible to link these superposed tills and regionally mapped till sheets with glacier flow phases by interpreting the lithological and geochemical provenance, fabric, and relationships to glacier erosional landforms of the tills.

Surface mapping alone can be inadequate in determining the sequence of ice flows if these flows were spatially separated or if in certain areas the erosional evidence or deposits left by earlier ice flows have been obliterated by subsequent ice movements. The Cobequid Highlands is a good example of this. If these early movements formed till sheets then it is possible to find them buried under subsequent tills in areas favourable for glacier deposition. The detailed study of till stratigraphy, weathering zones, and buried nonglacial organic beds allow the mapper to interpret the 'rank' of the till deposit; i.e. whether it represents a climatically-induced ice advance of regional extent or localized deposition related to changing ice divides or dynamics.

The authors base their interpretation of the sequence of glacial and nonglacial events on lithostratigraphic and geomorphic evidence and will name the events accordingly. Till-forming ice flow events are termed 'phases' conforming to Rampton and Paradis's (1981a) terminology. The nomenclature is informal in status. Attempts are made to link these phases with the regional climatostratigraphic scheme developed by Grant and King (1984).

Pre-Wisconsinan-weathering interval

As already mentioned, large areas of mechanically and chemically weathered bedrock on the Cobequid Highlands, especially in the highlands west of Parrsboro. This material, called Residuum (R, Map 1630A), was found under till. The genesis of this material is uncertain, but subaerial weathering is suggested. The reasons are :

1. Homogeneous, structureless granites in the eastern Cobequid Highlands were found to be mechanically and possibly chemically weathered.

2. Conical hills formed of residuum resembling inselbergs were found in protected areas south of the Glooscap Fault scarp.

McKeague, et al. (1983) described a gibbsite-bearing saprolite under till in the Cape Breton Highlands to have been formed by weathering under a temperate climate. Wang et al. (1981) interpreted similar residual soils in the highlands of central New Brunswick to be pre-Wisconsinan in age.

It is possible that these deposits and much of the Residuum in the Cobequid Highlands were formed during a pre-Wisconsinan temperate climatic interval, perhaps the Sangamon interglacial. Some or all may also be pre-Pleistocene as correlations are tenuous and the absolute age of the deposits is unknown.

McCarron Brook Phase

Striations trending 085° to 165° are found along the Chignecto Bay coast and in areas on the highlands (Map 1630A). These tend to be found on the northwest-facing parts of outcrop and are cut by fresher-looking, southwestward trending striations (Stea, 1983). The McCarron Brook Till was formed during this ice flow phase. Lithology and fabric at the type section of the till suggests that it was deposited by ice flowing eastward initially, changing to southeastward (Fig. 27). The McCarron Brook Phase is therefore designated

Figure 26. Photograph of colluvium consisting largely of phyllite clasts developed on steep sided valley walls near East Fraserville.

as a till forming ice flow that was eastward in its initial stage then southeastward.

Chalmers (1895) invoked the "Northumberland Glacier' to explain these eastward and southeastward ice flow trends. Prest (*in* Prest, et al. 1972, p. 43) stated that the initial ice movement to affect Prince Edward Island was toward 90° to 115°. Rampton and Paradis (1981a, p. 13, 1981b, p. 17) working in southeastern New Brunswick, termed this ice flow the 'Caledonia Phase' and initially suggested that it flowed eastward then southeastward. Later, they modified their interpretation to imply that eastward-trending striations in southern New Brunswick may be related to an earlier glaciation than the Caledonia Phase (Rampton et al.,1984, p. 41).

The East Milford Till in the Hants-Colchester Lowlands of Nova Scotia (Fig. 1) was also deposited by eastward to southeastward flowing ice and it overlies peat beds of interstadial and or interglacial rank (Stea, 1982b, c; Stea and Hemsworth, 1979).

The McCarron Brook Till can be correlated with the East Milford Till on the basis of fabric and relations to underlying striations, as well as some lithic properties such as compactness, colour and matrix (clay) geochemistry. Both tills are enriched in Ca and Mg relative to other till units reflecting, in part, their derivation from calcareous Triassic and Lower Carboniferous redbeds outcropping in Minas and Chignecto bays.

The McCarron Brook Phase is believed to have been of regional extent, representing a major ice movement that crossed the Bay of Fundy and covered mainland Nova Scotia. Chalmers (1895, p. 90) suggested that the source of the initial eastward-flowing 'Northumberland Glacier' was the highlands of central New Brunswick but believed that this glacier was of limited extent and did not cross the Bay of Fundy. Prest and Grant (1969, p. 12) and Stea (1982b) proposed that the early movement stemmed from the northern Appalachians. Early eastward-trending striations are widespread in mainland Nova Scotia. Eastward-trending striations (90°-110°) have been recorded across New Brunswick (Rampton and Paradis (1981a, p. 17), on Grand Manan Island (Legget, 1980, p. 442) and in Maine (Kite, et al., 1982, p. 8). The lithological, geochemical, and fabric variations of the McCarron Brook and East Milford tills and striations trending 120° to 165° provide evidence of shifting ice divides, from the west to the northwest of the map area. Ice centres on the Maritime Plain of New Brunswick (Rampton and Paradis, 1981a, p. 17), or Laurentide ice may have been the source of the later, southeastward movements. The limit of this ice movement may be the continental shelf edge where the Scotian Shelf Drift pinches out (G. Fader, personal communication, 1984).

The age and duration of the McCarron Brook Phase is unknown as it has not, as yet, been dated directly. Wood from peat beds found underlying the East Milford Till at Miller

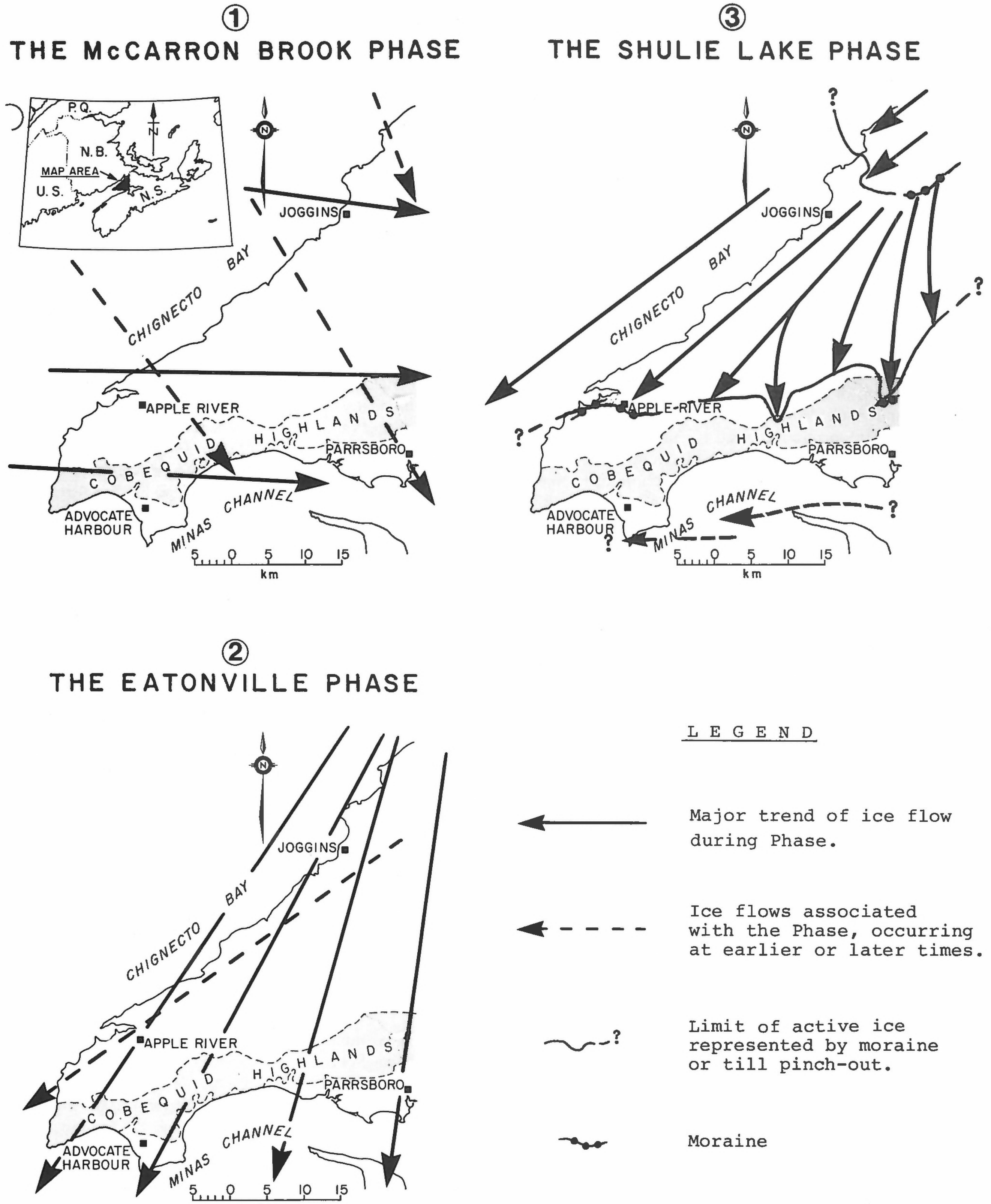


Figure 27. A summary of the ice flow events that affected western Cumberland County during the Wisconsinan Stage.

Creek in central Nova Scotia (Fig. 1) produced a non-finite radiocarbon date (>52,000, GSC-2694). Striations relating to the 'Caledonia Phase' were found to overlie a wave-planed rock bench at Rockport, New Brunswick 4 m above the modern marine bench (Rampton and Paradis, 1981). Grant (1980b) assigned this bench to the Sangamon or Stage 5E of the oxygen isotope record. The age of the McCarron Brook Till is speculated to be Early Wisconsinan, because the non-glacial beds at Miller Creek were interpreted to be interstadial in rank (Stea, 1982b). Grant (1980a) and Grant and King (1984) named this early glaciation the Fundy Stade.

Post-McCarron Brook Phase nonglacial interval?

Wickenden (1941, p. 144) noted a continuous layer of silt and sand separating the McCarron Brook and Joggins tills north of the type section. The authors observed manganese staining at the top of the McCarron Brook Till at the type section. Stea and Finck (1984, p. 479) noted similar alteration of the surface of a correlative basal till unit at Cape John, Pictou County. Cornish (1980) described oxidation effects on the surface of the East Milford Till in a borehole near Noel, Nova Scotia (Fig. 1). MacNeill (*in* Prest, et al., 1972, p. 33) and Morner (1973) described a widespread sand and gravel layer separating the East Milford Till from the overlying till(s).

This evidence suggests a minor nonglacial interval of short duration. Some soil development may have taken place. The growing number of finite Mid-Wisconsinan dates on wood in Nova Scotia and New Brunswick such as the Hillsborough Mastodon site (37,200 ± 1,310, GSC-2469; Grant *in* Blake, 1983, p. 9) may provide a minimum age for this phase.

Eatonville Phase

Striations trending 190° to 220° across the map area (Map 1630A) relate to a phase of ice movement termed the Eatonville Phase (Fig. 27). Inland these striations swing from southwestward to southward-trending inland. They cut relatively degraded, southeastward-trending striations produced during the McCarron Brook Phase at several localities. The sense of ice movement is indicated by miniature crag and tail features on conglomerate bedrock (Fig. 4). Drumlins and fluting parallel these southward and southwestward striations.

The Eatonville Till was formed during this ice flow phase. It overlies bedrock surfaces bearing southwestward-trending striations (Fig. 13). Clast lithology of the Eatonville Till suggests a northeasterly provenance. The Eatonville Till covers most of the Cobequid Highlands, especially in areas east of Parrsboro (Map 1630A).

The Eatonville Till can be correlated across Minas Basin with the Hants Till (Stea, 1982b, c; Stea and Finck, 1984) on the basis of colour, texture, and stratigraphic position.

Both tills were formed, at least initially, by a strong southwest to south ice movement that crossed the Cobequid Highlands. This ice flow was more vigorous in highland areas east of Parrsboro as southward-trending (170°-190°) erosional features such as striations and 'mini' crag and tails attributable to the Eatonville phase are found in abundance there. In the highland areas west of Parrsboro Eatonville Till frequently pinches out against rock prominences formed of residuum, but is thicker and more more widespread in the eastern highlands. Grant (1977) originally favoured a nunatak hypothesis for these rock prominences. Since the ice of the Eatonville Phase extensively scoured the highlands east of Parrsboro which attain greater elevations (Fig. 1), it is unlikely that the western highlands would have survived as nunataks. The Eatonville Till limit against rock may be explained instead by a cold-based zone in the covering ice cap. The rocks of the western highlands are largely cleaved siltstones and wackes of the Greville River Formation (DCG, Fig. 31) which are generally more permeable than the volcanic and igneous rocks that make up the highlands east of Parrsboro. Sugden (1973, p. 191) maintained that rock type is an important factor in the prevention of basal slip, which is the dynamic process that controls glacier erosion. He provided examples of terranes in Greenland underlain by porous rocks, that show few signs of erosion. The occurrence of large scale erosional forms noted in the highlands east of Parrsboro (D.R. Grant, personal communication, 1982; Map 1630A), are restricted to areas underlain by Jeffers Formation volcanic rocks (HJ, Fig. 31).

The southward-flowing ice sheet of the Eatonville Phase may have been partially blocked by the North Mountain cuesta (Grant, 1977, p. 253) in the southern parts of the Bay of Fundy.

The location of the centre of this ice mass is uncertain. It is clear that it was north of the Northumberland Strait coastline because of the distribution of ice flow features in northern mainland Nova Scotia (Stea and Finck, 1984, p. 478). Goldthwait (1924) presumed that the Acadian Bay Lobe overrode Prince Edward Island, but Prest (1970, p. 710) noted few southward trending striations. Prest's (1973) flow pattern 2a appears to be contiguous with the initial part of the Eatonville Phase suggesting that this ice divide was located over Prince Edward Island. Rampton and Paradis (1981b, p. 18) located the centre of ice flow responsible for the Chignecto Phase on the western end of Prince Edward Island and called it the 'Escuminac ice center'. This ice cap is essentially a compromise between the Chalmer's Chignecto Glacier and Goldthwait's Acadian Bay Lobe

The maximum extent of the Eatonville Phase may be offshore Nova Scotia. Grant (1963, p.163) linked the evidence of southward-flowing ice on the southern upland of mainland Nova Scotia (Fig.1) to the formation of drumlins. These are mantled by the reddish-brown allocthonous Lawrencetown Till (Grant, 1975; Stea and Fowler, 1979). The long axis orientation and Antigonish Highland erratic content of many drumlins in eastern Nova Scotia suggest a strong southward movement that terminated offshore.

The age of the Eatonville Phase is uncertain as the Eatonville Till and its bounding deposits have not been dated directly. A Middle to Late Wisconsinan age is implied by the superposition of Eatonville Till over McCarron Brook Till.

Ice relating to this phase was probably present through to Late Wisconsinan time as no intervening major nonglacial interval is recognized in the map area.

Grant and King (1984) assigned the Hants Till, a correlative of the Eatonville Till to the Digby Stade of Middle Wisconsinan age.

Shulie Lake Phase

Striations trending 215° – 240° in the map area were formed by an ice flow termed the Shulie Lake Phase (Fig. 27). At several localities these striations were found to cut earlier, southwestward-trending striations (210° – 220°, Map 1630A). The authors also observed striations and grooves relating to the Shulie Lake Phase on a sandstone ridge, changing in orientation from 220° to 250°. Chalmers (1895, p. 74) also noted curving striations of the same orientation at many localities and attributed them to an ice cap in its waning stages. The Shulie Lake Till was formed during this ice flow phase. It is a yellowish-brown, sandy till composed primarily of grey sandstone clasts dispersed southwestward on to conglomerate bedrock terrain.

The Shulie Lake Till pinches out abruptly along an east to west line which passes through Shulie and Welton lakes. Eatonville Till is the surface till sheet in the areas south of the limit. The terrain is strikingly different on both sides of the line; rolling and deeply incised on the south side but hummocky, forming a small scale, multibasinal drainage system on the north side (Fig. 15). Ribbed moraine parallels the drift limit. Streams with relatively low gradients north of the Shulie Lake Till limit suddenly cut deeply into the terrain south of the limit. An example is Greville River (Fig. 15). Meltwater channels run perpendicular to the limit and appear to emanate from it in some areas (Map 1630A). The eskerine system in the Fox River Valley and the unbreached moraine across Parrsboro Gap may have been formed by lobes of this ice mass. Crowl and Sevon (1980) noted similar relationships at the Late Wisconsinan Olean drift boundary in eastern Pennslyvania. They termed this type of border 'indistinct end moraine.'

The Shulie Lake Till limit may represent the limit of an extensive ice readvance or the boundary between active ice and stagnant ice remaining from the Eatonville Phase. There is no compelling evidence in the map area for a major interstadial interval between the two phases although a period of stagnation may have occurred. The absence of distinct terminal moraines at the limit and the lack of major discontinuities of marine limits (Map 1630A) on Shulie Lake Till tends to favour the latter hypothesis. A preliminary soil investigation, however, found that there is deeper soil development on Eatonville Till south of the limit than on Shulie Lake Till (Appendix 3). The mean value of solum depth in the soils on Eatonville Till south of the limit is 54.4 cm. The mean value of the soil developed on Shulie Lake Till is 41.1 cm. Chemical data on the two soils, however, are very similar (C. Wang, personal communication, 1984). The apparent maturity of the terrain and deeper soil development south of the limit could be explained by initial dissipation of stagnant ice formed during the Eatonville Phase in the southern region, while ice north of Shulie Lake remained either stagnant or active. Westward-trending ice contact drainage indicated by meltwater channels in the southern part of Map 1630A may be a result of the stagnant, older Eatonville Phase ice. Meltwater drainage invariably trends southward from the Shulie Lake Till limit (Map 1630A).

Wickenden (1941, p. 145) described morainal deposits south of Amherst which he termed the Joggins – Amherst Moraine. This area is mapped as the sandy facies of the Shulie Lake Till on Map 1630A; and trends in a southwest to northeast direction east of Joggins. Prest (*in* Prest et al., 1972, p. 37) suggested that this moraine was formed by a minor forward pulse of ice. The authors believe that it may represent the position of a former active ice zone, left after the main Shulie Lake Phase ice stagnated. The 'Boars Back' esker zone which runs along Hebert River terminates just south of the Joggins 'moraine', and may delineate the width of the stagnating Shulie Lake Phase ice. Koteff and Pessl (1981) promoted the hypothesis of 'stagnation-zone retreat' to explain the lack of true end moraines and abundance of ice contact stratified drift at ice marginal positions in New England. The ice contact stratified drift and moraines in the Apple River area and the Shulie Lake Till limit may mark the initial position of the active-stagnant zone in the ice during the main Shulie Lake Phase, while the Joggins-Amherst 'moraine' and 'Boars Back' Esker represents the final position of this zone.

The location of the ice centre during the Shulie Lake Phase may have been the isthmus of Chignecto, or slightly to the north in the Northumberland Strait area (Fig. 2). Prest (1973; flow pattern 2C) noted late northward and westward movements of ice in the Northumberland Strait area. Chalmers (1895, p. 94) proposed the name 'Chignecto Glacier' to denote this ice mass. The Port Elgin Flow Pattern of Rampton and Paradis (1981a, p. 29) is probably correlative with the flow patterns in the northern part of the map area associated with the last phase of active ice that formed the Joggins-Amherst Moraine.

The age of the Shulie Lake Phase is believed to be Late Wisconsinan. Shulie Lake Till represents the surface drift in the region and has minimal soil development. The Shulie Lake Till is overlain by marine deposits believed to be Late Wisconsinan in age. A more detailed discussion of the age of the Shulie Lake Phase is given in the section on Deglaciation which follows.

Grant and King (1984, p. 183) state that during the Scotian Stade of Late Wisconsinan age, ice flowed outwards from ice caps on the Atlantic Uplands (Southern Uplands; Fig. 1). It is not certain whether this expansion of ice caps was coeval with the Shulie Lake Phase.

Evidence of other ice movements in the area

Prest (1970, p. 710), Downey (1979) and Stea and Finck (1984, p. 483) provide evidence for northward-moving ice on the Cumberland-Pictou lowlands and the eastern Cobequid Highlands. Stea and Finck (1984) postulated that the source of this ice was the Southern Uplands (Fig. 1). Evidence of northward outflow, however, is lacking in the western highlands (See also Borns, *in* Prest, et al., 1972, p. 36). Stea and Finck (1984, p.483) suggested that North Mountain and/or calving in the deep Minas Channel prevented the Southern Uplands ice from crossing the map area. Rampton and Paradis (1981a, p. 18) speculated on an early northward flow, affecting the Amherst area, before the onset of the Caledonia Phase.

Westward-trending striations mapped by the authors and Chalmers (1895, p. 66) in the Spencers Island area (Map 1630A) attest to an ice mass, moving westward, out of Minas Basin. The relative age of movement cannot be adduced from evidence in this map area but studies in the Hants-Colchester Lowlands south of Minas Basin have demonstrated that it was the last to affect the region (Stea, 1982b, c; Stea and Finck, 1984). This movement formed the Rawdon Till and apparently stemmed from a centre east of Truro. The formation of the Isle Haute Moraine (Fader et al., 1977) may have been a result of the confluence of a Shulie Lake or Eatonville Phase ice lobe in Chignecto Bay and/or a lobe flowing out of the Minas Channel. Linear troughs in the Minas Basin and Chignecto Bay lend support to this hypothesis (see Fig. 1).

Deglaciation and marine events

Deglaciation

The spectacular delta deposits of the Five Islands Formation are the products of glacier melting and relatively high sea levels. Swift and Borns (1967, p. 703) and Wightman (1980, p. 329) interpreted the deposits as prograding outwash deltas derived from stagnating ice.

Borns (*in* Prest et al., 1972, p. 34) and Wightman (1980, p. 383) state that the ice that formed the delta had originally crossed the Cobequid Highlands whereas Grant (1977) implied that the deltas were associated with the limit of Late Wisconsinan ice which he placed on the north flank of the Cobequids and in the major valleys.

The evidence of a complex sequence of Late Wisconsinan ice flows in the map area and east of the map area (Stea and Finck, 1984) demands a modification of the earlier hypotheses of deglaciation. The waning of the southward-flowing Eatonville Phase ice mass probably represented the start of the deglaciation of the region. Wightman (1980, p. 327) reasoned that the high percentage of Cobequid Highland lithologies in the Saints Rest Member throughout the map area suggests an ice mass which had initially crossed the Cobequid Highlands from north to south and wan not confined to the valleys. The implication of this evidence is a greater ice volume in the Late Wisconsinan than was postulated by Grant (1977).

The Shulie Lake Phase represents reactivation of the Eatonville Phase ice after the initial melting. During the Shulie Lake phase the unbreached moraine at Gilbert Lake in Parrsboro Gap was created, as was the 'indistinct end moraine' defined by the Shulie Lake Till limit. Meltwater was then cut off to the delta at the mouth of Parrsboro Gap and other major valleys. A subsequent ice marginal stand in the map area was in the area of the sandy facies of the Shulie Lake till also known as the Joggins-Amherst moraine (Wickenden, 1941) where the 'Boars Back' esker terminates.

Marine onlap

Borns (*in* Prest et al., 1972) maintained that ice first disappeared in the western Cobequid Highlands. Littoral deposits of the Advocate Harbour Member overlie glacio-deltaic deposits at West Advocate to a maximum of 32 m above MSL (Map 1630A). This implies that sediment supply by melting ice had ceased, and regression had occurred, before much emergence had taken place. Raised marine features on the north shore of Minas Basin decline in elevation to the east. All these deposits are glacio-deltaic except for the littoral deposits at Advocate Harbour. The eastward decline of this paleoshore has been explained by an eastward deglaciation and differential ice loading. Wightman and Cooke (1978) and Grant (1980) attributed this the tapering of the effective regional ice load, but Prest (1970, p. 710) invoked an eastward-retreating ice lobe in Minas Basin. The evidence of eastward deglaciation in the areas south of Minas Basin is strong (Stea, 1982b, c; Stea and Finck, 1984), although evidence for an eastward deglaciation on the north shore of Minas Basin is lacking. The westward-trending striations near Spencers Island imply a westward flow of ice which may have reached the deeper parts of the Bay of Fundy. An eastward deglaciation in Minas Basin is therefore a strong possibility.

The regional ice load model is incongruous with the pattern of marine limit decrease along Chignecto Bay (Fig. 28). Since the axis of the bay is subparallel to the general trend of isobases inferred by the ice load model there should be little differential uplift along its length. Our data show a deflection of isopleths (lines of equal emergence) to the northwest so that they are perpendicular to the axis of the bay and to the direction of ice flow during the Shulie Lake Phase. This implies that marine incursion was delayed as this ice lobe retreated up the bay and inland. Rampton and Paradis (1981a, p. 32) also explain discordancies in marine limits in New Brunswick by the existence of residual ice caps.

A plot of emergence data on the Minas Basin coast (Wightman, 1980, p. 345) shows a strong linear trend suggesting that if there was an eastward deglaciation in Minas Basin, it was at a constant rate.

Ages

The deltas along the north shore of Minas Basin, although not dated directly, are assigned a Late Wisconsinan age because they belong to the same general phase of submergence in the Bay of Fundy which farther west has been dated between 13 000 and 14 000 years B.P. The relative and absolute ages of the deltas on the north side of Minas Basin and marine deposits on the Chignecto Bay coast are unknown. The timing of deglaciation and the significance of the Shulie Lake Phase limit can be assessed by the palynology and radiocarbon dates on lake and bog cores north and south of the limit (Fig. 26). Mott (unpublished report, Appendix 4) studied the pollen stratigraphy of a core from Leak Lake, south of the moraine at Gilbert Lake believed to

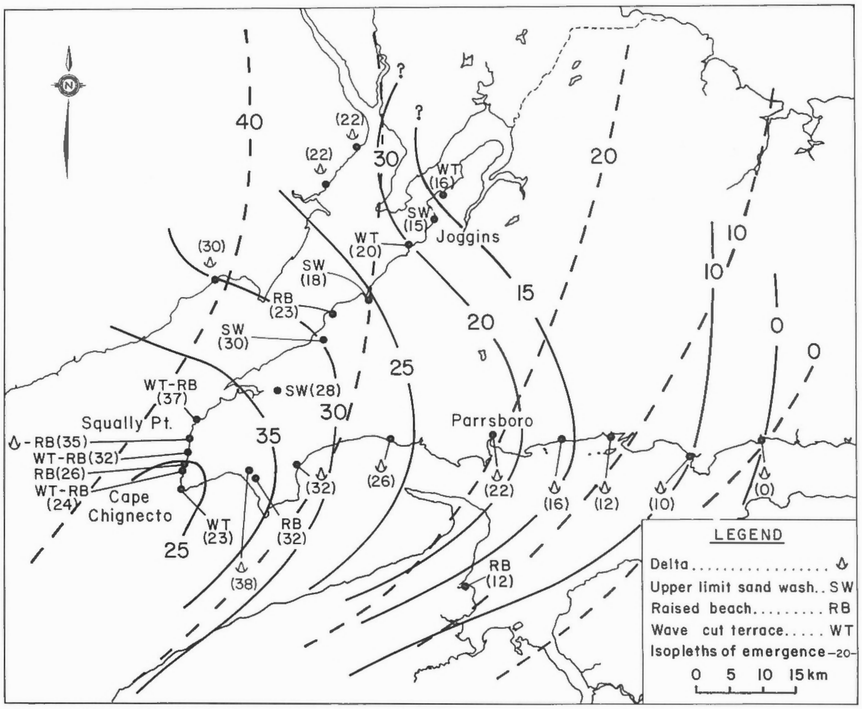


Figure 28. Isopleths of marine emergence in the Chignecto Peninsula (solid lines) compared with previous concepts (dashed lines) after Swift and Borns (1967), and Wightman (1980).

represent the limit of Shulie Lake Phase ice. He believes that the basal date of 15 900 ± 1200 years BP (GSC-2880) is too old based on the possibility of old carbon contamination from carbonaceous Carboniferous bedrock (see Appendix 4). The authors, however, have examined the outwash and ice contact stratified drift in the Leak Lake region and have found that it is composed primarily of Cobequid Highland igneous and metamorphic lithologies devoid of carbonaceous material. Mott states that the date of 12 900 ± 160 years BP (GSC-2728), just above the base may be correct as the pollen signature of that zone correlates with the boundary between pollen zones 8 and 9 at Basswood Road Lake in New Brunswick (Mott, 1975). The organic site at Lower Cove (Map 1630A; Appendix 4), north of the Shulie Lake Phase limit consists of a peat layer overlain by 40 cm of sand and underlain by a diamicton. The peat was dated at 11 400 ± 100 year BP (GSC-3550) and revealed shrub-tundra conditions at the time of deposition. This and other buried late-glacial organic sites in Nova Scotia attest to a climatic oscillation equivalent to the Allerod/Younger Dryas of Europe (Mott, et al., 1984).

If the diamicton at Lower Cove is glacigenic, then the 1500-year or greater discrepancy between the Lower Cove and Leak Lake dates indicates the persistence of ice north of the Shulie Lake Phase Limit, verifying the geomorphological data. A more direct indication of the age of the end of the Shulie Lake Phase comes from a cored bog north of the limit near Sand River that bottomed in the Shulie Lake Till (Appendix 4). Palynomorphs from the base of this bog revealed a truncated sequence correlative with pollen zones 6 and 5 of the Leak Lake and Basswood Road Lake cores. Mott estimates that the basal sediment started to accumulate about 10 000 years age (unpublished report, 1984; Appendix 4). The date of 9830 ± 100 years. BP (GSC-2772) on peat lying above outwash at West Brook (Appendix 4; Map 1630A) is another indication of late northern ice.

Ice may have also been persistent in the areas south of Minas Basin. Evidence of marine overlap is lacking in the areas along the south shore of Minas Basin east of the Avon River (Fig. 2). Hadden (1975) invoked a persistent ice cover in the Hants-Colchester Lowlands (Fig. 1) to explain a relatively young bog-bottom date of 9187 ± 255 years BP (I-7080).

Summary

In summary, deglaciation occurred in stages with the melting of remnants of Eatonville Phase ice. The first region to become ice free was the western Cobequid Highlands. Marine incursion affected the deeper parts of the Bay of Fundy, but may have been blocked in Minas Basin and the south coast of Chignecto Bay by eastward-receding grounded ice. Reactivation of the ice north of the Cobequid Highlands during the Shulie Lake Phase may have interrupted the deglaciation process at an early stage. Shulie Lake Till and the moraine at Gilbert Lake were then created. Meltwater was cut off to the emerging outwash deltas after the formation of the moraine. Subsequently, the Shulie Lake Phase ice stagnated, forming the Boars Back esker and the Joggins-Amherst Moraine. The ice behind the Joggins-Amherst Moraine may have been briefly active.

Figure 29 presents an interpretation of the time and space relationships of glacier ice over Nova Scotia during the Wisconsinan Stage. Included are the lithostratigraphic units described in this text and correlative units in southern, central mainland Nova Scotia described by Stea (1982b; c), Grant (1975) and Grant and King (1984).

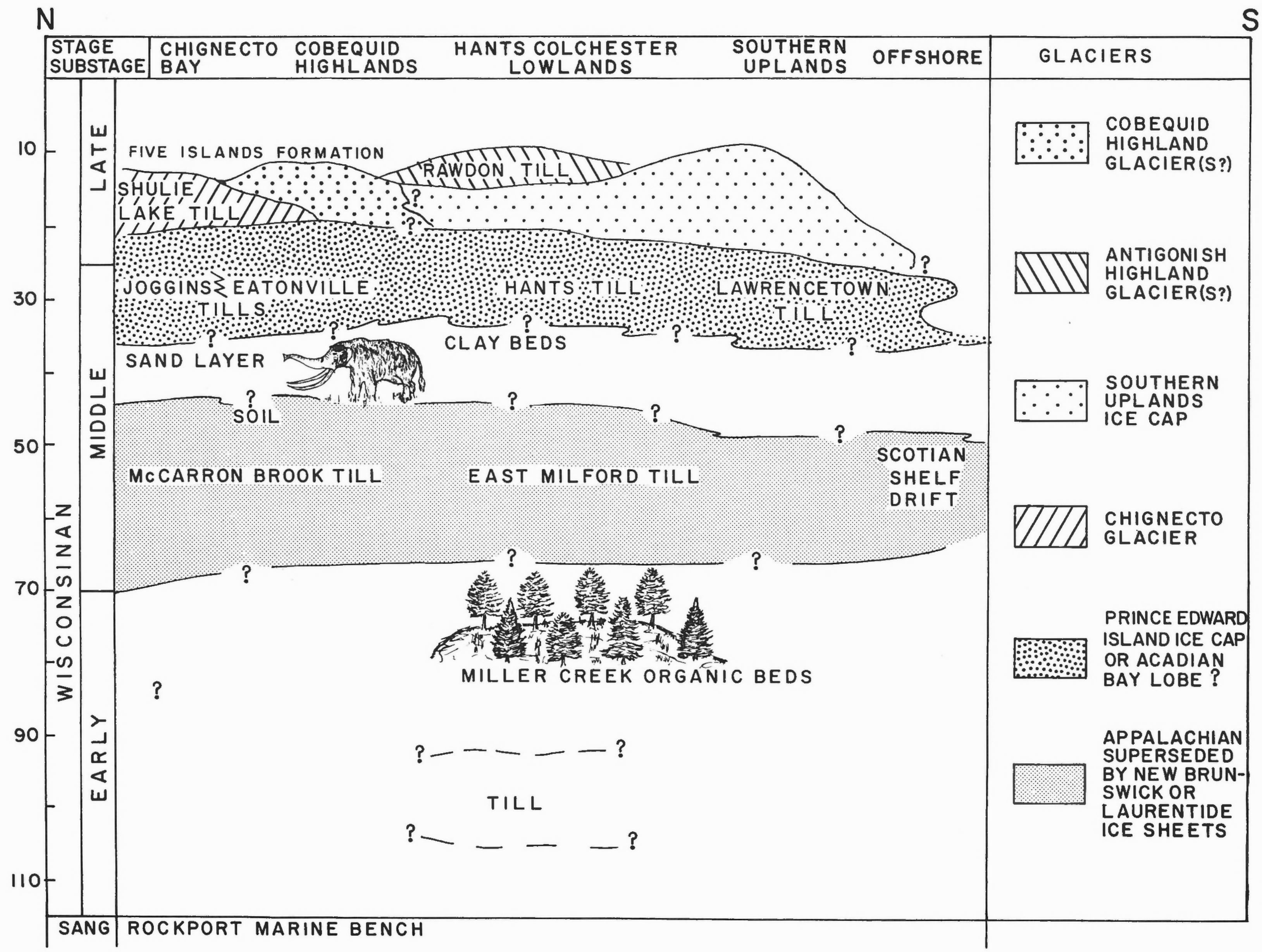


Figure 29. Time and space diagram of ice cover in central Nova Scotia during the Wisconsinan Stage.

ECONOMIC GEOLOGY

Till anomalies and their significance

Anomalous values of a trace element are taken to be any values equal to or greater than the 95th percentile of the cumulative frequency distribution for that element (Fig. 31). These 95th percentile or threshold values are determined for each mapped till unit. Table 1 shows that average trace element values differ between till types, especially between Shulie Lake Till and the other till types. Correlation matrices for each till unit (Fig. 10, 11, 16, 17) demonstrate that they have distinct geochemical signatures, largely related to their bedrock sources, whether local or distant. Instead of many single element maps, the geochemical data is summarized on Figure 31 by plotting all the anomalous elements of each sample site. The rest of the data are given in a table on the map. This approach allows for ther evaluation of elemental relationships in anomalous samples. The number and geochemical relations of anomalous elements can be an important indicator of mineralization.

The significance of multi-elemental anomalies are assessed using an anomaly-value concept (Sainsbury, et al., 1970). The actual value is divided by the threshold value (95th percentile) to obtain a ratio. The sum of these ratios for multi-element anomalies is an indication of the significance of the sample and are presented on Figure 31 as various size triangles.

There are several patterns of anomalous samples on Map 9b. Samples 99 and 127 have total anomaly values greater than 5. Sample 99 has an anomalous Pb value of 379 ppm while 127 shows anomalous values for Cu, Pb, Zn, and Mn. There appears to be a string of sample anomalies in Cu, Pb, Zn and Mn oriented parallel to strike overlying bedrock unit LCCc (Cumberland Group, upper coarse facies) in the northern part of the map area (Fig. 31). These samples are from Shulie Lake Till, largely composed of grey sandstone clasts of local derivation.

The association of Pb-Zn anomalies and the grey sandstones evident on Figure 31 and shown in Figure 16, may reflect mineralization present in the Cumberland Group in this area. Bjorykke and Sangster (1981) envisioned a mechanism of groundwater transport and precipitation of Pb and Zn in locally reducing areas, such as organic zones. Cumberland Group arenites have abundant plant debris. Plant-rich zones such as channel-lag beds could serve as a loci for Pb-Zn percipitation. Ryan (1984) has noted Pb occurrences in channel-lag deposits of the Pictou Group.

Manganese occurrences are common in the Cumberland Group (Fig. 31), in the form of disseminated manganite on bedding plane surfaces. This mineral may be associated with Pb and Zn occurrences.

Samples of residuum developed from the Greville River Formation (Samples 339; 63, Fig. 31) show anomalous values of Cu, Co, Mn and As. Sample 339 is especially significant with a copper value of 406 ppm Cu. These anomalies, and known occurrences of chalcopyrite and arsenopyrite in the Greville River Formation (Donohoe, 1982, p. 79) suggest widespread copper mineralization in the Greville River Formation, perhaps related to the Glooscap Fault.

Tin anomalies are found at several localities in the map area, but only two samples; 62 and 114 are considered significant because of the amounts of sand used to concentrate the heavy minerals from the till. Appendix 2 shows the raw analytical and the 'weighted' values of Sn and W based on the amount of sand used in the heavy mineral extraction and the weight of heavy minerals (Toverud, 1982). Sample 62 (5.29 ppm – Sn weighted value) and 14 (1.17 ppm – Sn weighted value) are both in Eatonville Till. Sample 62 is down-ice of volcanic rocks of the Hadrynian Jeffers Formation (HJ). The occurrence of cassiterite in Devono-Carboniferous volcanic rocks of the eastern Cobequid Highlands (Chatterjee, 1983) suggests the possibility of this type of mineralization in other volcanic terranes. Sample 114 rests on Carboniferous Windsor Group rocks and down-ice of the Parrsboro Formation, both which may have supplied some detrital cassiterite to this sample.

Till units; local vs regional input

It is apparent from the lithology of the till units that the bulk of the coarse matrix and clast fractions are derived from local bedrock areas; <1 to 5 km up-ice of the sample site. The pebble fraction of the Eatonville Till appears to reflect changes in underlying bedrock better than Shulie Lake Till which may have derived a substantial percentage of its clast from grey sandstone ridges in the northern part of the map area (Map 9a). The clay fraction geochemistry of Shulie Lake Till is strongly related to the amounts of local grey arenites in the clast fraction.

The matrix of the Eatonville Till has a reddish hue everywhere it is found. Averages of Cu, Pb and Zn suggest a shale source. The paucity of red mudstones or shales in the map area (J. Calder, personal communication, 1984) suggests that sources for much of this red fine material may be in the Amherst area underlain by Pictou and Windsor group rocks. Red sedimentary clasts in till samples 92 and 105 of the Eatonville Till (see Fig. 31) on grey sandstone terrain were probably transported from the Amherst area. Pb and Zn values in the clay fraction fluctuate sympathetically with the percentages of local grey arenites in the pebble fraction of the Eatonville Till (Fig. 16). It is apparent that both local bedrock (<1-5 km), distant bedrock sources (>10 km) and reworked older till material may have influenced the matrix geochemistry of the Eatonville Till. The clay fraction geochemistry of McCarron Brook Till, however, does not reflect a local source. A mafic source area is implied by strong Ni-Co-Fe correlations. Trace element values were significantly correlated with Caledonia Highland erratic percentages of the pebble fraction (Fig. 9, 10).

The extent and duration of the till-forming ice flows appears to have had a controlling influence on the amount of dispersal and disposition of material in the matrix and clast modes. This is essentially the concept of 'maturity' developed by Dreimanis and Vagners (1971, p. 246). McCarron Brook

Till, the oldest till in the map area, was produced by a relatively large ice sheet. This ice sheet comminuted and transported fine material as much as 50 km, while incorporating local material in the clast sizes. The smaller, local ice caps and glaciers that produced the Eatonville and Shulie Lake tills comminuted and transported fine material, but not as efficiently as the McCarron Brook Phase ice sheet. More material was supplied to the clast modes than was comminuted over a period of time, hence Shulie Lake Till contains a predominance of coarse gravel and boulders (see Fig. 13). A relative maturity index for the major till units based on the clast to matrix ratio would be:

McCarron Brook Till > Eatonville Till > Shulie Lake Till

Sources of aggregate

Surficial deposits mapped as residuum on Map 1630A, underlain by slate of the Greville River Formation, have been used as a sub-base for road building (Fig. 30)

The Saints Rest Member and Apple River Member (glacio-deltaic facies) (Map 1630A) can also be used for a road base, but are unsuitable for cement or asphalt grade aggregate as they contain 40 per cent or more soft Carboniferous sandstones (Fig. 21). The best source of cement and asphalt-grade aggregate west of Parrsboro is in the Advocate Harbour Member (glacio-littoral facies (-AHb); Map 1630A) which contain far less Carboniferous sandstones (Fig. 21). Recent beach deposits (Mb) are protected under the Beach Protection and Preservation Act.

Sources of clay

The bottomset beds of the Advocate Harbour Member, glacio-deltaic facies (AHa; Map 1630A) can provide a source of clay for brick, tiles and sewer pipe. There are outcrops of this clay along the Parrsboro River, at the mouth of Swan Creek near Greenhill, and along the shore at Spencers Island (Fig. 31).

Fuel peat

The average depth of peat suitable for fuel in 15 selected bogs of the map area (O; Map 1630A) is 1.08 m with an average humification index of 5.8 (Broughm and Anderson, 1984). The high average depths of the surficial layer (1.65 m of unhumified peat), in all of the bogs, however, makes the economic prospects dim (W. Broughm, personal communication, 1984).

Figure 30. Residuum of the Greville River Formation being removed for road fill near Parrsboro. Light area in the foreground is a yellowish, chemically-altered phyllite.

REFERENCES

Amos, C.L.
1978: The postglacial evolution of the Minas Basin, Nova Scotia — a sedimentological interpretation; Journal of Sedimentary Petrology, v. 48, no. 3, p. 965-981.

Bjorlykke, A. and Sangster, D. F.
1981: An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits; Economic Geology, v. 75, p. 179-213.

Blake, W. Jr.
1983: Geological Survey of Canada, Radiocarbon Dates XXIII; Geological Survey of Canada, Paper 83-7, 33 p.

Boulton, G. S.
1979: Processes of glacier erosion on different substrata; Journal of Glaciology, v. 23, no. 89, p. 15-38.

Boulton, G. S., Dent, D. L. and Morris, E. M.
1974: Subglacial shearing and crushing, and the role of water pressures in tills from South-East Iceland; Geografiska Annaler, v. 56, Ser. A, p. 135-145.

Broughm, W. and Anderson, S.
1984: BREGION; computer output of data for bogs in Cumberland County; unpublished report, Nova Scotia Department of Mines and Energy.

Calder, J. H.
1983: Interpretation of vertical pebble lithology variations within a Pleistocene multiple till sequence at Joggins, Nova Scotia; unpublished report, Nova Scotia Department of Mines and Energy.

Chalmers, R.
1895: Report on the surface geology of eastern New Brunswick, northwestern Nova Scotia, and a portion of Prince Edward Island; Geological Survey of Canada, Annual Report 1894, v. vii, pt. M.

Chatterjee, A. K.
1983: Devono-Carboniferous magmatism and epithermal U-Th-Mo-Ag-F mineralization in the Debert Lake area, Eastern Cobequid Highlands; *in* Program and Summaries, Seventh Annual Open House and Review of Activities, Nova Scotia Department of Mines and Energy, Information Series, no. 6, p. 81-82.

Cornish, R. A.
1980: Report on geology and overburden drilling; Base Metals, Noel Lake, Hants County, Nova Scotia, Shell Canada Resources Limited, Nova Scotia Department of Mines and Energy Assessment Report, 11E/05A, 07-l-29(01).

Crowl, G. H. and Sevon, W. D.
1980: Glacial border deposits of Late Wisconsinan age in Northeastern Pennsylvania; Pennsylvania Topographic and Geologic Survey, General Geology Report 71, 68 p.

Dilabio, R. N. W. and Shilts, W. W.
1978: Compositional variation of debris in glaciers, Bylot Island, District of Franklin; *in* Current Research, Part B, Geological Survey of Canada, Paper 78-1B, p. 91-94.

Donohoe, H.V., Jr.
1982: Mineral occurrences in the Cobequid Highlands; *in* Mineral Resources Division Report of Activities 1981, ed. K.A. Mills; Nova Scotia Department of Mines and Energy, Report 82-1, p. 79-111.

Donohoe, H. V., Jr. and Wallace, P. I.
1978: Preliminary map of the Cobequid Highlands; Nova Scotia Department of Mines, Map 78-1.

1982: Geological maps of the Cobequid Highlands – Colchester, Cumberland and Pictou Counties, Nova Scotia; Nova Scotia Department of Mines and Energy, Maps 82-6 to 82-9.

Downey, N. A.
1979: Cobequid project: uranium assessment report, Cobequid IV, Nova Scotia; Nova Scotia Department of Mines and Energy, Assessment report No. 11E/12B 54-04-64(04).

Dreimanis, A. and Vagners, U. J.
1971: Bimodal distribution of rock and mineral fragments in basal tills; *in* Till: a Symposium, ed. R. P. Goldthwait; Ohio State University Press, p. 237-250.

Fader, G. B., King, L. H. and MacLean, B.
1977: Surficial geology of the eastern Gulf of Maine and Bay of Fundy; Marine Science Paper 19; Geological Survey of Canada, Paper 76-17.

Gillberg, G.
1967: Further discussion on the lithological homogeneity of till; Geologiska Foereningens, Stockholm Foerhandlingar, v. 89, p. 29-49.

Goldthwait, J. W.
1924: Physiography of Nova Scotia; Geological Survey of Canada, Memoir 140, 179 p.

Grant, D. R.
1963: Pebble lithology of the tills of southeast Nova Scotia; unpublished M.Sc. Thesis, Dalhousie University, Halifax, Nova Scotia, 235 p.

1975: Glacial style and the Quaternary stratigraphic record in the Atlantic Provinces, Canada; *in* Report of Activities, Part B, Geological Survey of Canada, Paper 75-1B, p.109-110.

1977: Glacial style and ice limits, the Quaternary stratigraphic record, and changes of land and ocean level in the Atlantic Provinces, Canada; Geographie Physique et Quaternaire, v. xxxi, no. 3-4, p. 247-260.

1980a: Quaternary stratigraphy of southwestern Nova Scotia: glacial events and sea level changes; Geological Association of Canada and Mineralogical Association of Canada Guidebook, 63 p.

1980b: Quaternary sea-level change in Atlantic Canada as an indication of crustal delevelling; *in* Earth Rheology, Isostasy and Eustasy, ed. N. A. Morner, p. 201-214.

Grant,D. R. and King, L.H.
1984: A stratigraphic framework for the Quaternary history of the Atlantic Provinces; in Quaternary Stratigraphy of Canada- A Canadian Contribution to IGCP Project 24, ed. R.J. Fulton; Geological Survey of Canada, Paper 84-10, p. 173-191.

Hadden, K. A.
1975: A pollen diagram from a post glacial peat bog in Hants County, Nova Scotia; Canadian Journal of Botany, v. 53, jp. 39-47.

Kauranne, K., Salminan, R. and Ayras, M.
1977: Problems of geochemical contrast in Finnish Soils; *in* Prospecting in areas of glaciated terrain, Institution of Mining and Metallurgy, p. 264-278.

Keppie, J. D.
1982: The Minas Geofracture; *in* Major Structural Zoens and Faults of the Northern Appalachians, ed. P. St-Julien and J. Béland; Geological Association of Canada, Special Paper 24, p. 264-278.

Kite, J. S., Lowell, T. V. and Nicholas, G. P.
1982: Quaternary studies in the upper St. John River basin: Maine and New Brunswick; New Brunswick Quaternary Association, Field Trip Guidebook, 54 p.

Koteff, C. and Pessl, F., Jr.
1981: Systematic ice retreat in New England; United States Geological Survey, Professional Paper 1179, 20 p.

Leggett, R. F.
1980: Glacial geology of Grand Manan Island, New Brunswick; Canadian Journal of Earth Science, v. 17, p. 440-452.

Levinson, A. A.
1980: Introduction to Exploration Geochemistry; Applied Publishing, Wilmette, Illinois.

MaClintock, P., and Dreimanis, A.
1964: Reorientation of till fabric by overriding glacier in the St. Lawrence Valley; American Journal of Science, v. 262, p. 133-142.

MacNeill, R. H.
1956: Surficial geology maps of Nova Scotia, 1:50,000; Nova Scotia Research Foundation, Dartmouth, Nova Scotia.

McKeague, J. A., Grant, D. R., Kodama, H., Beke, G. J., and Wang, C.
1983: Properties and genesis of soil and the underlying gibbsite-bearing saprolite, Cape Breton Island, Canada, Canadian Journal of Earth Sciences, vol. 20, no. 1, p. 37-38.

Morner, N. A.
1973: A new find of till wedges in Nova Scotia, Canada; Geologiska Foereningen i Stockholm Foerhandlingar, v. 95, p. 272-273.

Mott, R. J.
1975: Palynological studies of lake sediment profiles from Southwestern New Brunswick; Canadian Journal of Earth Sciences, v. 12, p. 273-288.

Mott, R. J., Stea, R. R., Occhietti, S., and Grant, D. R.
1984: The Allerod/Younger Dryas climatic oscillation in North America — Fact or Fiction, Paper presented to the Sixth International Palynological Conference Calgary, 1984.

Nielsen, E.
1976: The composition and origin of Wisconsinan tills in mainland Nova Scotia; unpublished Ph.D. Thesis, Dalhousie University, Halifax, Nova Scotia, 256 p.

North American Commission on Stratigraphic Nomenclature
1983: North American Stratigraphic Code; The American Association of Petroleum Geologists Bulletin, v. 67, n. 5, p. 841-875.

Nowland, J. L. and MacDougall, J. I.
1973: Soils of Cumberland County, Nova Scotia; Nova Scotia Soil Survey, Report no. 17, 133 p.

Podolak, W. E. and Shilts, W. W.
1978: Some physical and chemical properties of till derived from Meguma Group, southeast Nova Scotia; *in* Report of Activities, Part A, Geological Survey of Canada, Paper 78-1A, p. 459-464.

Prest, V. K.
1970: Quaternary geology of Canada; *in* Geology and Economic Minerals of Canada 5th edition, ed. R. J. W. Douglas; Geological Survey of Canada, Economic Geology Report no. 1, p. 676-764.

1973: Surficial deposits of Prince Edward Island; Geological Survey of Canada, Map 1366A.

Prest, V. K. and Grant, D. R.
1969: Retreat of the last ice sheet from the Maritime Provinces-Gulf of St. Lawrence region; Geological Survey of Canada, Paper 69-33, 15 p.

Prest, V. K., Grant, D. R. MacNeill, R. H., Brookes, I. A., Borns, H. W. Jr., Ogden, J. G. III, Jones, J. F., Lin, C. I., Hennigar, T. W., and Parsons, M. L.
1972: Quaternary geology, geomorphology and hydrology of the Atlantic Provinces; International Geology Congress, Guidebook, Session 24, Excursion A61-C61, 79 p.

Rampton, V. N., and Paradis, S.
1981a: Quaternary geology of Amherst map-area (21H) New Brunswick; New Brunswick Department of Natural Resources, Map Report 81-3, 36 p.

1981b: Quaternary geology of Moncton map area (21I) New Brunswick; New Brunswick Department of Natural Resources; Map Report 81-2, 31 p.

Rampton, V. N., Gauthier, R.C., Thibault, J. and Seaman A.A.
1984: Quaternary geology of New Brunswick; Geological Survey of Canada, Memoir 416, 77 p.

Ramsden, J., and Westgate, J. A.
1971: Evidence for reorientation of a till fabric in the Edmonton area; *in* Till: a Symposium, ed. R. P. Goldthwait; Ohio State University Press, p. 335-344.

Rogers, P. J., Stea, R. R., and MacDonald, M. A.
1984: A statistical investigation of the geochemical reflection of Au mineralization in the tills and lake sediments of the Eastern Shore of Nova Scotia; *in* Prospecting in Areas of Glaciated Terrain 1984, Institution of Mining and Metallurgy, p.137-152.

Ruitenberg, A. A., Giles, P. s., Venugopal, D. V., Buttimer, S. M., McCutcheon, S. R., and Chandra, J.
1979: Geology and Mineral Deposits Caledonia Area; Mineral Resources Branch New Brunswick Department of Natural Resources and Canada Department of Regional Economic Expansion, Memoir 1, 213 p.

Ryan, R. J.
1984: Upper Carboniferous strata of the east half of the Tatamagouche syncline, Cumberland Basin, Nova Scotia; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 493-504, 1984.

Sainsbury, C. L., Hudson, T.; Kachadoorian, R., and Richards, T.
1970: Geology, mineral deposits, and geochemical and radiometric anomalies, Serpentine Hot Springs Area, Seward Peninsula, Alaska; United States Geological Survey, Bulletin 1312, 19 p.

Shaw, W. S.
1951: The Cumberland basin of deposition; Unpublished Ph.D. thesis, Massachusetts Institute of Technology, 170 p.

Shilts, W. W.
1975: Principles of geochemical exploration for sulphide deposits using shallow samples of glacial drift; Canadian Mining and Metallurgical Bulletin, v. 68, no. 757, p. 73-80.

Siegel, S.
1956: Nonparametric statistics for the behavioral sciences, McGraw-Hill, New York, 312 p.

Stea, R. R.
1982a: Pleistocene geology and till geochemistry of south-central Nova Scotia (Sheet 6); Nova Scotia Department of Mines and Energy, Map 82-1.

1982b: The properties, correlation and interpretation of Pleistocene sediments in central Nova Scotia; unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 1217 p.

1982c: Pleistocene stratigraphy of central Nova Scotia; *in* Mineral Resources Division, Report of Activities 1981, ed. K. A. Mills, Nova Scotia Department of Mines and Energy, Report 82-1, p. 47-53.

1983: Surficial geology of the western part of Cumberland County, Nova Scotia; *in* Current Research, Part A, Geological Survey of Canada, Paper 83-1A, p. 197-202.

Stea, R. R. and Finck, P. W.
1984: Patterns of glacier movement in Cumberland, Colchester, Hants, and Pictou counties, northern Nova Scotia; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 477-484.

Stea, R. R. and Fowler, J. H.
1979: Minor and trace element variations in Wisconsinan tills, Eastern Shore Region, Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 79-4, 30 p.

Stea, R. R. and Grant, D. R.
1982: Pleistocene geology and till geochemistry of south-western Nova Scotia (Sheets 7 and 8); Nova Scotia Department of Mines and Energy, Map 82-10.

Stea, R. R. and Hemsworth, D.
1979: Pleistocene stratigraphy of the Miller Creek Section, Hants County, Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 79-5, 16 p.

Stea, R. R. and O'Reilly, G. A.
1982: Till geochemistry of the Meguma terrane in Nova Scotia and its metallogenic implications; *in* Prospecting in Areas of Glaciated Terrain, 1982, ed. P. H. Davenport; Canadian Institute of Mining and Metallurgy, p. 82-104.

Sugden, D. E.
1973: Landscapes of glacial erosion in Greenland and their relationship to ice, topographic and bedrock conditions; Institute of British Geography, Special Publication 7, p. 177-195.

Swift, D. J. P. and Borns, H. W., Jr.
1967: A raised fluviomarine outwash terrace, north shore of the Minas Basin, Nova Scotia; Journal of Geology, v. 75, no. 6, p. 693-710.

Toverud, O.
1982: Geochemical prospecting for tin in upper central Sweden using heavy-mineral concentrate of glacial till; *in* Prospecting in Areas of Glaciated terrain, 1982, ed. P. H. Davenport, Canadian Institute of Mining and Metallurgy, p. 204-212.

Turekian, K. K. and Wedepohl, K. H.
1961: Distribution of the elements in some major units of the earth's crust; Geological Society of America Bulletin, v. 72, p. 175-192.

Wagner,F.J.E.
1977: Report on samples from Cumberland County, Nova Scotia; Atlantic Geoscience Centre, Dartmouth Nova Scotia, fossil report, AGC-PI-2-1977.

Wang, C., Ross, G. J. and Rees, H. W.
1981: Characteristics of residual and colluvial soils developed on granite and of the associated pre-Wisconsinan landforms in north-central New Brunswick; Canadian Journal of Earth Sciences, v. 18, n. 3, p. 487-494.

Wickenden, R. T. D.
1941: Glacial deposits of part of northern Nova Scotia; Transactions of the Royal Society of Canada, Section iv, p. 143-149.

Wightman, D. M.
1976: The sedimentology and paleotidal significance of a late Pleistocene raised beach, Advocate Harbour, Nova Scotia; unpublished M.Sc. Thesis, Dalhousie University, Halifax, Nova Scotia, 157 p.

1980: Late Pleistocene glaciofluvial and glaciomarine sediments on the north side of the Minas Basin, Nova Scotia; unpublished Ph.D. Thesis, Dalhousie University, Halifax, Nova Scotia, 426 p.

Wightman, D. M. and Cooke, H. B. S.
1978: Post-glacial emergence in Atlantic Canada; Geoscience Canada, v. 5, p. 61-65.

APPENDIX 1

Sample comparisons

In order to test for the effects of sampling, sample preparation and analytical variation, adjacent drift samples were taken in the field, and splits were made, at random, before the sample preparation and analytical stages. These pairs of samples were compared element for element using the Wilcoxon matched-pairs signed-ranks test (Siegel, 1956). The results are given in the following table. The results show that there are no significant differences between any of the treatments using all the elements.

TESTED LEVELS / ELEMENT	SAMPLE SITE DUPLICATES N = 14		SAMPLE PREPARATION DUPLICATES N = 18		ANALYTICAL (BLIND) DUPLICATES N = 16	
Ag	*	*	-1.095	.273	-1.278	.201
		*		N.S.		N.S.
Cu	-.676	.499	.700	.484	-.338	.735
		N.S.		N.S.		N.S.
Ni	-.105	.917	-.761	.447	-.980	.327
		N.S.		N.S.		N.S.
Pb	-.507	.612	-.889	.374	-.980	.327
		N.S.		N.S.		N.S.
Zn	0	1.000	-.507	.612	-1.521	.128
		N.S.		N.S.		N.S.
Co	-.254	.800	-.948	.343	-.490	.624
		N.S.		N.S.		N.S.
Fe	-.845	.398	-.350	.726	-.943	.345
		N.S.		N.S.		N.S.
Mn	-.338	.735	-.280	.779	-1.677	.093
		N.S.		N.S.		N.S.
Ca	-.314	.753	-1.826	.068	-.183	.855
		N.S.		N.S.		N.S.
Mg	-.169	.866	-.140	.889	-.338	.735
		N.S.		N.S.		N.S.
Mo	-.135	.893	-.447	.655	-.267	.789
		N.S.		N.S.		N.S.
U	-.592	.554	-.980	.327	-.169	.860
		N.S.		N.S.		N.S.
As	-.169	.866	-1.050	.294	-.254	.800
		N.S.		N.S.		N.S.
Sn	-.524	.600	-.254	.800	*	*
		N.S.		N.S.		*
W	-.085	.933	-.560	.575	*	*
		N.S.		N.S.		*

Z STATISTIC	2-TAILED PROBABILITY y = .50	* NOT CALCULABLE
	SIGNIFICANCE N.S.=NOT SIGNIFICANT	

APPENDIX 2

Sample list

The following table is a list of the samples; the total sand weight used in the heavy mineral separation, the heavy mineral weight; the Sn and W raw values; and the weighted Sn and W values. The weighting formula is adapted from Toverud (1982).

SAMPLE	TOTAL SANDWT	TOTAL HVYWT	Sn(rv) (ppm)	W(rv) (ppm)	Sn(Wv)	W(Wv)
2	537.00	.88	45.00	10.00	.07	.02
3	513.00	12.20	15.00	10.00	.36	.24
31	544.00	17.09	5.00	4.00	.16	.13
32	168.00	3.80	15.00	8.00	.34	.18
34	110.00	6.09	10.00	4.00	.55	.22
38	208.00	1.45	10.00	12.00	.07	.08
39	270.00	3.78	10.00	1.00	.14	.01
40	570.00	8.40	5.00	2.00	.07	.03
43	298.00	8.73	30.00	16.00	.88	.47
44	215.00	.61	10.00	14.00	.03	.04
45	628.00	8.31	10.00	8.00	.13	.11
46	305.00	6.76	35.00	10.00	.78	.22
47	471.00	9.40	15.00	10.00	.30	.20
49	156.00	1.49	10.00	8.00	.10	.08
50	315.00	1.69	30.00	12.00	.16	.06
52	740.00	.83	45.00	14.00	.05	.02
53	345.00	.83	45.00	8.00	.11	.02
54	194.00	1.25	10.00	4.00	.06	.03
55	357.00	2.05	10.00	8.00	.06	.05
56	659.00	6.94	5.00	6.00	.05	.06
57	300.00	1.30	25.00	14.00	.11	.06
58	564.00	8.75	30.00	6.00	.47	.09
59	309.00	3.13	5.00	4.00	.05	.04
61	281.00	6.92	10.00	2.00	.25	.05
62	368.00	64.83	30.00	1.00	**5.29**	.18
63	516.00	2.51	30.00	12.00	.15	.06
64	412.00	3.95	15.00	8.00	.14	.08
65	475.00	.88	95.00	12.00	.18	.02
66	857.00	1.07	15.00	20.00	.02	.02
67	386.00	1.48	15.00	20.00	.06	.08
68	685.00	1.42	15.00	16.00	.03	.03
69	599.00	5.36	10.00	14.00	.09	.13
70	211.00	.52	50.00	20.00	.12	.05
71	581.00	1.29	20.00	20.00	.04	.04
72	401.00	1.21	15.00	24.00	.05	.07
73	620.00	1.81	5.00	18.00	.01	.05
74	368.00	3.06	10.00	14.00	.08	.12
75	451.00	2.80	5.00	10.00	.03	.06
76	504.00	1.13	5.00	10.00	.01	.02
77	700.00	6.80	5.00	8.00	.05	.08
78	423.00	1.62	35.00	24.00	.13	.09
79	363.00	5.47	20.00	10.00	.30	.15
81	160.00	9.27	5.00	1.50	.29	.09
83	480.00	15.01	5.00	14.00	.16	.44
84	324.00	7.65	5.00	4.00	.12	.09
85	305.00	7.13	5.00	2.00	.12	.05
86	520.00	5.35	45.00	6.00	.46	.06
87	274.00	1.13	20.00	2.00	.08	.01
88	722.00	1.00	15.00	16.00	.02	.02
89	849.00	1.65	10.00	28.00	.02	.05
90	153.00	8.26	5.00	2.00	.27	.11
91	210.00	1.00	20.00	4.00	.10	.02
92	576.00	2.61	50.00	10.00	.23	.05
94	444.00	2.10	10.00	12.00	.05	.06
95	523.00	2.05	40.00	20.00	.16	.08
96	672.00	2.27	25.00	20.00	.08	.07
97	367.00	1.19	15.00	6.00	.05	.02
98	440.00	1.38	10.00	50.00	.03	.16
99	957.00	1.24	5.00	14.00	.01	.02
101	599.00	2.12	20.00	20.00	.07	.07
103	226.00	1.80	5.00	4.00	.04	.03
104	248.00	2.93	10.00	12.00	.12	.14
105	493.00	1.70	20.00	8.00	.07	.03
106	289.00	.64	35.00	1.50	.08	.00
107	680.00	4.50	80.00	12.00	.53	.08
108	774.00	4.36	25.00	12.00	.14	.07
109	812.00	2.26	15.00	20.00	.04	.06
110	854.00	.62	75.00	10.00	.05	.01
111	566.00	1.61	25.00	30.00	.07	.09
112	901.00	1.90	10.00	14.00	.02	.03
113	647.00	4.07	15.00	10.00	.09	.06
114	570.00	7.82	85.00	10.00	**1.17**	.14
115	357.00	4.38	10.00	6.00	.12	.07
116	899.00	2.86	20.00	6.00	.06	.02
117	650.00	5.09	55.00	6.00	.43	.05
118	350.00	2.60	10.00	12.00	.07	.09
119	224.00	.06	10.00	10.00	.00	.00
121	474.00	1.42	10.00	10.00	.03	.03
122	309.00	2.86	25.00	10.00	.23	.09
123	316.00	2.26	25.00	20.00	.18	.14
124	908.00	2.08	10.00	8.00	.02	.02
125	394.00	1.60	10.00	24.00	.04	.10
126	760.00	1.33	45.00	10.00	.08	.02
127	1511.00	3.78	39.00	5.00	.10	.01
128	877.00	1.40	5.00	16.00	.01	.03
129	239.00	2.15	2.50	8.00	.02	.07
130	784.00	1.00	25.00	14.00	.03	.02
146	414.00	3.43	10.00	10.00	.08	.08
201	1061.00	6.29	25.00	6.00	.15	.04
217	441.00	21.77	5.00	6.00	.25	.30
218	325.00	5.30	5.00	4.00	.08	.07
237	512.00	3.25	45.00	6.00	.29	.04
239	642.00	13.18	10.00	6.00	.21	.12
244	215.00	1.57	15.00	6.00	.11	.04
333	226.00	2.51	5.00	2.00	.06	.02
334	597.00	4.84	5.00	10.00	.04	.08
335	250.00	13.54	5.00	2.00	.27	.11
336	284.00	1.64	30.00	4.00	.17	.02
337	462.00	8.40	20.00	4.00	.36	.07
338	487.00	6.76	10.00	2.00	.14	.03
339	141.00	.56	15.00	4.00	.06	.02
343	398.00	5.20	5.00	6.00	.07	.08

$$\mathrm{Sn(Wv)} = \mathrm{Sn(rv)} \times \frac{\mathrm{(TOTAL\ HVWT)}}{\mathrm{(TOTAL\ SANDWT)}}$$

$$\mathrm{W(Wv)} = \mathrm{W(rv)} \times \frac{\mathrm{(TOTAL\ HVWT)}}{\mathrm{(TOTAL\ SANDWT)}}$$

APPENDIX 3

Site descriptions and chemical/physical data

Site descriptions and chemical/physical data of the soil profiles of 23 sites. Figure 15 provides the locations of most of the sites. Soil development on the Eatonville Till (Westbrook soil catena) is deeper than on the Shulie Lake Till (Shulie soil catena); with the average depth of the B horizon on the Eatonville Till being 54.3 cm and on the Shulie Lake Till, 45.9 cm.

Cumberland County study of age of Shulie (Rodney) and Westbrook Soils.

Site 1. Westbrook, forested, upper slope, moderately well drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	9-0						
Ae	0-15						
Bf	15-42	3.8	3.12	0.61	0.015	2.00	0.62
BCxjgj	42-57	3.9	2.48	0.52	.013	1.14	0.51
IIC	57 plus	3.9	2.74	0.13	.003	0.17	0.16

Site 2. Westbrook (contains some coarse fragments of the Shulie), moderately well drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	5-0						
Ae	0-11						
Bf	11-28	3.7	4.52	0.55	.014	3.23	0.58
BCxj	28-50						
C	50 plus	4.0	1.37	0.15	.004	0.24	0.16

Site 3. Rodney (Westbrook-Shulie transition), imperfectly drained, lower slope, clear cut.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	10-0						
Ae	0-6						
Bfg	6-50	3.8	3.35	0.64	.016	2.20	0.55
Cg	50 plus	4.0	0.96	0.18	.005	0.44	0.21

Site 4. Shulie, imperfectly drained, forested.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	18-0						
Ae	0-6	3.2	0.34	0.03	.003	0.09	0.05
Bf	6-16	3.5	3.99	0.64	.016	2.86	0.56
Bfg	16-30	4.2	1.31	0.65	.016	0.90	0.65
BCx	30-40						
C	40 plus	4.1	0.68	0.17	.004	0.32	0.16

Site 5. Shulie

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	15-0						
Ae	0-4	3.2	0.28	0.04	.003	0.09	0.05
Bf	4-16	3.4	4.88	0.89	.022	3.07	0.74
Bg	16-29	3.9	2.32	0.78	.020	1.73	0.70
BCx	29-36						
C	36 plus	4.0	0.73	0.13	.003	0.26	0.15

Site 6. Shulie, poorly drained, undulating, clear cut, moderately mounded microtopography.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	20-0						
Aeg	0-28	3.4	0.13	0.03	.001	0.02	0.02
Bgf	28-41	4.1	1.42	1.04	.026	1.05	1.13
BCxg	41-50						
C	50 plus	4.4	0.47	0.29	.007	0.28	0.43

Site 7. Shulie, top of ridge, imperfectly drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	13-0						
Aeg	0-10	3.4	0.14	0.03	.003	0.03	0.02
Bhf	10-23	3.6	3.69	0.63	.016	2.37	0.58
Bgf	23-35	3.9	1.17	0.37	.009	0.84	0.35
C	35 plus	3.9	0.79	0.12	.003	0.29	0.14

Site 8. Shulie, top of ridge, imperfectly drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	10-0						
Aeg	0-20						
Bfg	20-38	3.8	2.53	0.69	.017	1.50	0.59
C	38 plus	4.0	0.83	0.19	.005	0.32	0.72

Site 9. Shulie, lower slope, imperfectly drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	10-0						
Ae	0-15						
Bfg	15-40	3.8	2.84	0.85	.021	2.21	0.76
BCx	40-48						
C	48 plus	4.0	0.71	0.14	.003	0.28	0.17

Sites 8 and 9 were a toposequence on a ridge and swale pattern. Approximately 25 m apart.

Site 10. Westbrook, crest, 13% slope, well drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	2-0						
Ah	0-3						
Bm	3-15						
Bf	15-36	3.9	2.55	0.62	.016	1.67	0.55
BC	36-49	4.1	1.37	0.06	.002	0.47	0.33
C	49 plus	4.0	1.62	0.21	.005	0.25	0.23

Site 11. Westbrook, crest, 2% slope, clear cut, well drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	6-0						
Aej	0-9	3.4	0.93	0.03	.004	0.04	0.00
Bf	9-32	3.8	3.06	0.64	.016	1.67	0.48
BC	32-48	4.2	1.20	0.22	.006	0.23	0.22
C	48 plus	4.0	1.30	0.08	.019	0.19	0.12

Site 12. Westbrook, lower slope, 2% slope, well drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	13-0						
Aej	0-8						
Bfh	8-28	3.6	2.31	54	.035	1.91	0.54
Bf	28-41	4.2	1.24	0.68	.020	0.58	0.63
BC	41-50	4.2	1.25	0.54	.020	0.70	0.61
Cx	50 plus	4.3	0.85	0.21	.048	0.23	0.28

Site 13. Westbrook, upper slope, 4% slope, well drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	15-0						
Bf1	0-15	4.0	1.99	0.66	.013	1.07	0.71
Bf2	15-38	4.2	1.53	0.42	.016	0.55	0.47
BC	38-55	4.2	1.36	0.30	.019	0.74	0.74
C	55 plus	4.1	2.52	0.18	.023	0.20	0.24

*pockets of Ae under Bf2

Site 14. Shulie-Westbrook, 2% slope, lower slope imperfectly drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	12-0						
Ae	0-4						
Bh	4-12						
Bfh	12-28	3.8	2.17	0.53	.007	1.74	0.58
BCgx	28-50	4.2	0.71	0.14	.022	0.74	0.17
Cxgj	50-58	4.2	0.69	0.13	.028	0.23	0.15
R	58 plus						

Site 15. Westbrook, imperfectly drained, mid slope.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	8-0						
Bf	0-5	4.0	3.15	1.01	.028	1.89	0.94
Bm	5-30	3.8	3.05	0.50	.024	1.49	0.42
Bgx	30-60	3.8	2.17	0.37	.013	1.24	0.34
C	60 plus	4.0	1.87	0.16	.016	0.23	0.17

Site 16. Westbrook, Red/Scotch pine, 4% slope, lower slope, moderately.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	8-0						
Aej	0-5						
Bf	5-30	3.9	2.76	0.86	.051	2.04	0.81
BCgx	30-60	4.1	1.29	0.82	.032	0.90	0.67
C	60 plus	4.2	0.64	0.15	.033	0.23	0.16

Site 17. Shulie, poorly drained, 4% slope, mid slope, clear cut.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	1-0						
Bfg	0-20	3.9	3.00	0.67	.015	2.00	0.51
Bg	20-42	3.9	1.13	0.23	.005	0.49	0.16
Cg	42-60	4.1	0.18	0.10	.003	0.09	0.06
C	60-70	4.3	0.39	0.10	.022	0.21	0.07
R							

Site 18. Shulie. Poorly drained, mid slope, 4% slope.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	10-0						
Aej	0-5						
Bfg	5-37	4.2	1.88	1.16	.053	1.66	1.17
BCxg	37-55	4.4	1.07	0.91	.036	0.84	1.04
C	55	4.4	0.53	0.30	.022	0.22	0.29

*a deeper deposit of ablation over lodgement till.

Site 19. Shulie, imperfectly drained, upper slope, 4% slope.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	10-0						
Ae	0-4						
Bhf	4-26	3.7	3.28	1.13	.013	2.12	0.99
Bfg	26-40	4.0	1.92	0.86	.011	1.43	0.75
BCxg	40-55	4.1	0.94	0.43	.011	0.50	0.44
C	55 plus	4.2	1.02	0.24	.026	0.58	0.47

*Ablation till phase of the Shulie?

Site 20. Shulie, slope 2-3%, crest, imperfectly drained.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	11-0						
Ae	0-7						
Bfh	7-28	4.0	1.60	1.03	.041	1.15	0.88
Bfg	28-52	4.3	0.85	0.59	.011	0.59	0.52
BCxj	52-60						
C	60 plus	4.4	0.65	0.35	.009	0.28	0.33

Site 21. Westrook, imperfectly drained, upper slope, 3% slope.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	14-0						
Ae	0-16	3.4	0.40	0.05	.004	0.19	0.07
Bfhgj	16-34	3.8	2.12	0.61	.015	1.81	0.56
BCxg	34-47	4.0	0.89	0.29	.006	0.57	0.27
Cg	47 plus	4.0	1.33	0.09	.129	0.22	0.08

Site 22. Westbrook, moderately well drained, 2% slope, mid slope.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	5-0						
Ah	0-3						
Ae	3-10						
Bf	10-28	3.9	2.88	0.60	.027	1.62	0.52
Aej	28-48						
BC	48-53						
C	53-68	4.1	2.98	0.51	.025	0.65	0.47
R	68 plus						

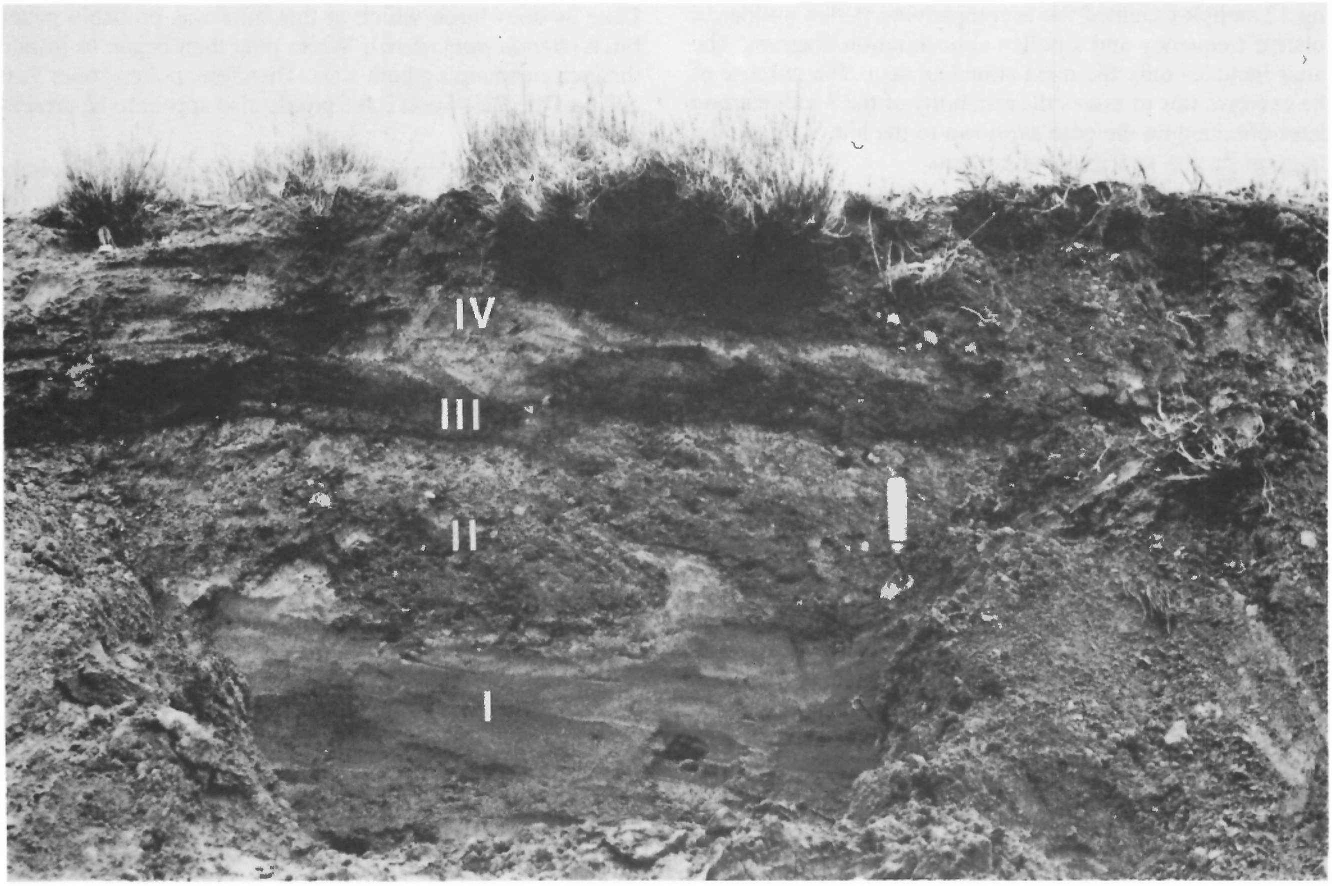
Site 23. Westbrook, well drained, lower slope, 11% slope.

Horizon	Depth (cm)	PH	Dithionite Citrate			Ammonium Oxalate	
			Fe%	Al%	Mn%	Fe%	Al%
LFH	7-0						
Ae	0-10	3.3	0.53	0.04	.003	0.07	0.04
LBf	10-40	3.9	4.88	1.07	.016	2.79	1.04
Bfg	40-52	4.1	1.92	0.61	.010	0.96	0.60
BC	52-64	4.2	1.37	0.30	.015	0.36	0.31
C	64-75	4.2	1.55	0.26	.028	0.41	0.30

APPENDIX 4

Palynological Reports: R.J. Mott, Geological Survey of Canada

Following is a photograph of the Lower Cove organic site and unpublished palynological reports on cores from Leak Lake, the Lower Cove organic site, a basal core of bog E-16-7 near Sand River, and a section drawing and palynological report on the West Brook organic site.



Unit IV Greenish medium to fine sand overlain by brownish, oxidized sand
Unit III Fibrous, compacted, fissile peat.
Unit II Reddish-brown gravelly-sand diamict
Unit I Yellow sand with red silt lenses.

PALYNOLOGICAL REPORT NO. 79-13

Date: June 11, 1979

Locality: Leak Lake, 2.5 km north of Parrsboro, Nova Scotia.

Lat.: 45° 26.2′ N **Long.:** 64° 21′ W

NTS: 21 H/8

Submitted by: Daryl Wightman

Field No.: Leak Lake Core 4

Lab No.: PL-78-71

Description of Sample: Lake sediment core

Results and Interpretation:

A preliminary analysis of Leak Lake Core no. 4 involving 12 samples yielded the accompanying pollen profiles: a relative frequency and a pollen concentration diagram. The latter includes only the most abundant taxa. The purpose of the exercise was to assess the reliability of the 3 radiocarbon dates obtained on the core as shown to the left of the pollen diagram on the stratigraphic column.

The basal red silt and clay has a very low pollen concentration with an assemblage dominated by diploxylon type pine *(Pine banksiana/resinosa)* pollen with smaller percentages of other tree pollen. Willow *(Salix)* pollen increases in abundance toward the upper boundary of this sediment.

In the overlying grey-green silty gyttja the pollen concentration is greater and pine pollen is less abundant. Willow and sedge (Cyperaceae) are abundant. Birch *(Betula)* pollen is present as are a variety of herbaceous types. Towards the top of this layer, birch and then spruce *(Picea)* pollen reach maximum values and shrub and herb pollen values decline.

Pollen concentration values decline again in the grey clay unit. Spruce and birch pollen percentages are lower whereas pine pollen increases slightly. Aspen or poplar *(Populus)* reaches a low maximum as do some of the clubmosses *(Lycopodium)* especially *Lycopodium annotinum*. Sedge pollen is more abundant and fern spores (Polypodiaceae) attain peak values. Most of the fern spores are oak-fern *(Dryopteris disjuncta)*.

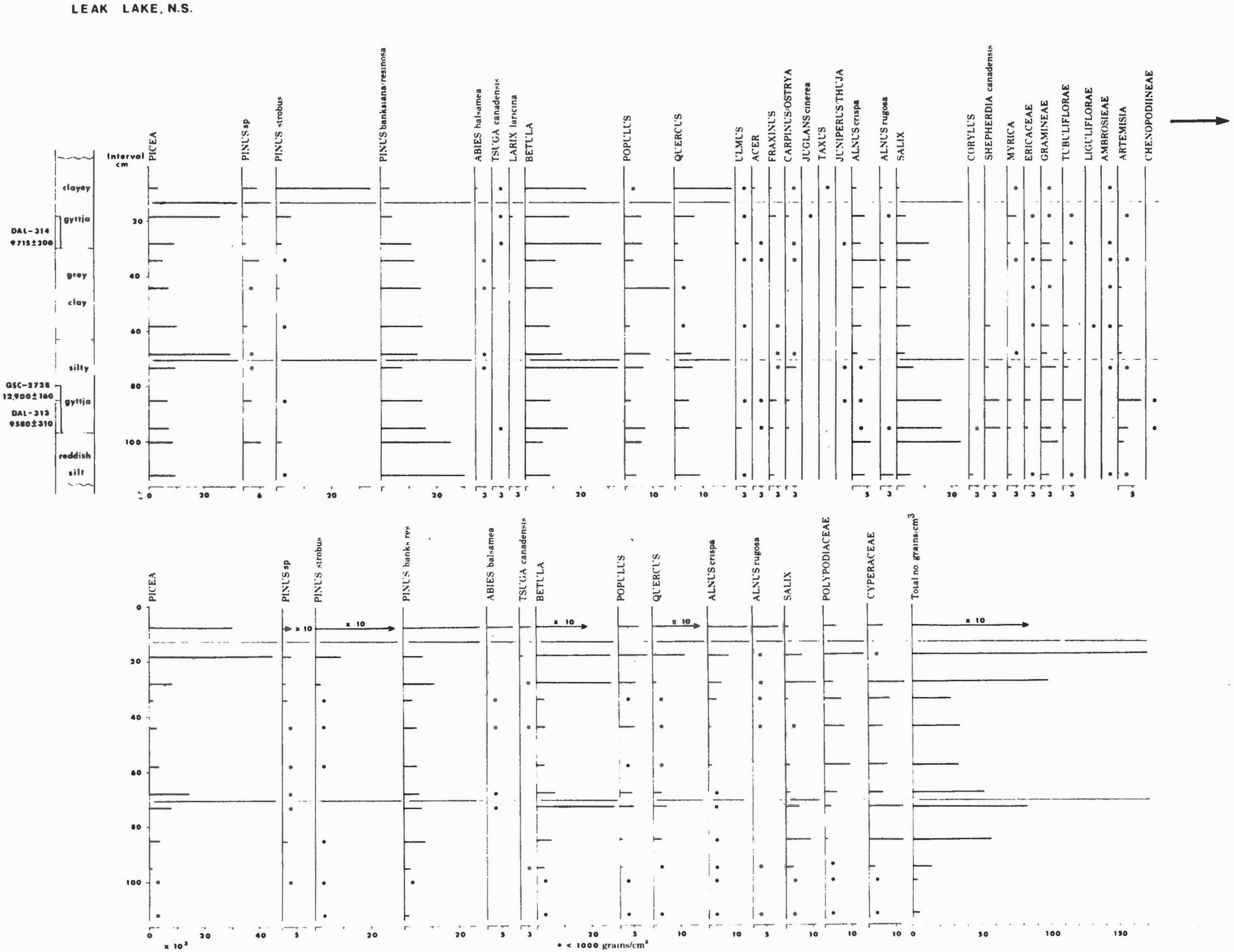
Spruce pollen increases again just above the base of the more organic upper clayey gyttja as does birch. Shrub and herb percentages decline to very low values. However, spruce is replaced by pine pollen of the haploxylon white pine *(Pinus strobus)* type accompanied by oak pollen. Pollen concentration values are very high in this lake sediment.

Comparison with other pollen diagrams from the Maritime Provinces reveals many similarities. This is especially true for the Basswood Lake profile from southwestern New Brunswick (Mott, 1975). The sediment stratigraphy of the two sites is also very similar. An herbaceous/shrub pollen zone is evident in the basal part of both diagrams with successive maxima in willow, *Artemisia* and sedge and declining amounts of jack pine type pollen. Very low pollen concentrations suggest an herbaceous tundra environment with concentrations of willow at suitable sites. Birch, probably shrub birch *(Betula glandulosa)* then became more plentiful, and pollen production in general increased. A prominent *Populus* pollen peak is not present at the Leak Lake site as it is at Basswood Lake. These pollen assemblages are delimited as Zones 9 and 8 in the New Brunswick profile.

Spruce trees then began to invade the area to some degree as evidenced by the increase in spruce pollen, but although pollen values increased generally, not enough is present to indicate closed forest conditions. An abrupt change in lithology with deposition of grey clay of low organic content then occurred at both sites and pollen values, especially spruce, decline considerably. The pollen assemblage in this clay unit is characterized by a dominance of sedge pollen and fern spores. Unfortunately, the fern involved at the New Brunswick site was not identified to species but it was a polypodiaceous type spore as is the case at Leak Lake. Above the clay layer spruce shows a resurgence especially at Leak Lake as does birch which at this time was probably paper birch *(Betula papyrifera)*. White pine then began to invade the area surrounding both sites. Therefore, pollen zones 7, 6 and 5 of the Basswood Lake profile also appear to be present at Leak Lake.

Since the pollen sequence and stratigraphy at Leak Lake are amazingly similar to the Basswood Road Lake site, the chronology at the latter can be used to assess the reliability of the Leak Lake radiocarbon dates, although it does not necessarily follow that pollen zones are of equivalent age at different sites. The radiocarbon date of 9715 ± 200 (DAL-314) for the base of the upper gyttja appears reasonable when compared with the date of 9460 ± 220 (GSC-1643) for the zone 5-6 boundary in New Brunswick. The date DAL-313, 9580 ± 310 for the base of the lower silty gyttja horizon containing a tundra type pollen assemblage is far too young for this level and is considered spuriously young. If the correlation between sites is valid, according to the New Brunswick profile an age of about 11,300 would be expected for the top of the lower silty gyttja horizon at the spruce pollen maximum. An age of 12 600 years B.P. was obtained at Basswood Lake for the zone 9-8 boundary which, if the correlation is correct, also occurs at Leak lake at about the depth of the 12 900 ± 160 (GSC-2728) year B.P. date. Therefore, given the statistical errors involved in the dates, they are equivalent. However, caution should be exercised in accepting these old dates at face value, especially in areas of Carboniferous age bedrock where the possibility of contamination by old carbon is great.

The significance of the grey clay layer is of interest because of the occurrence of such a layer at two widely separate sites. The clay layer at Basswood Lake was originally interpreted as a local phenomenon resulting from local erosion and washing of clay into the lake (Mott, 1975). A similar stratigraphic occurrence of Leak Lake and at other sites in New Brunswick (pollen not yet analyzed) suggests a regional phenomenon with climatic change implications. The well known Younger Dryas Stadial (10 950 to 10 000 years B.P.) of northwestern Europe (Mörner, 1970) and Britain (Coope et al, 1971) is a possible correlative judging by the dates obtained thus far. A climatic deterioration just as spruce trees began moving into the area with a consequent decline in vegetation cover and hence greater erosion, would cause



POLLEN DIAGRAM OF CORES BOTTOMED IN RED SILT AT LEAK LAKE deposition of a clay layer. When the climate warmed again, spruce continued to advance into the area followed eventually by more thermophilous trees.

More detailed pollen work and radiocarbon dating are required on this and other cores before the detailed fluctuations, if such did in fact occur, are worked out.

Coope, G.R., Morgan, Anne, and Osborne, P.J. 1971. Fossil Coleoptera as indicators of climatic fluctuations during the Last Glaciation in Britain. Palaeogeogr., Palaeoclimatol., Palaeoecol., 10: 87-101.

Mörner, Nils-Axel. 1973. Climatic changes during the last 35,000 years as indicated by land, sea, and air data. Boreas, 2: 33-54.

Mott, R.J. 1975. Palynological studies of lake sediment profiles from southwestern New Brunswick. Can. J. Earth Sci., 12: 273-288.

PALYNOLOGICAL REPORT NO. 83-5

Date: March 31/83.

Locality: Joggins Section, 2 km north of Joggins on road to Lower Cove, Nova Scotia.

Lat.: 45° 43′N. **Long.:** 64° 28′W.

NTS: 21 H/9 w.

Submitted by: Samples collected by R.J. Mott at site discovered by R. Stea. Results requested by R. Stea.

Field No.: MS-82-44.

Lab No.: -----

Description of Sample: Well-decomposed, somewhat fibrous peat overlying sand and diamicton and overlain by sand.

Results and Interpretation:

The accompanying table lists the palynomorph content of three samples from the approximately 10 cm thick organic layer at the Joggins Site.

Cypereaceae (sedge) pollen dominates all assemblages and is extremely high at the 10 cm depth. Other prominent taxa that are more abundant with depth are *Betula* (birch) and *Artemisia*, whereas *Shepherdia canadensis* and Tubuliflorae pollen and *Selaginella selaginoides* spores decrease with depth. *Salix* (willow) pollen and Polypodiaceae spores are fairly abundant but do not show any definite trend. *Pinus banksiana/resinosa* (jack pine/red pine) type pollen is abundant but may reflect long-distance transport rather than indicating the presence of pine trees in the area. *Picea* (spruce) values are not high enough to indicate the presence of spruce trees in any abundance in the area.

Considering the assemblages as a whole, a shrub tundra type of environment with willow, shrub birch and *Shepherdia canadensis* along with abundant sedge and other herbaceous plants characterized the area. If trees were present in the area they were not abundant.

	Depth of sample below top of peat		
	1cm	5cm	10cm
Picea	6.8	3.1	7.2
Pinus sp.	1.0	0.6	—
P. resinosa/banksiana	35.6	25.1	33.1
P. strobus	—	—	1.4
Larix laricina	—	0.6	—
Betula	5.3	6.9	21.6
Alnus sp.	1.0	—	1.4
Salix sp.	14.1	25.8	18.0
Shepherdia canadensis	27.7	24.5	4.3
Myrica	1.0	—	0.7
Ericaceae	—	0.6	—
Gramineae	2.1	0.6	2.2
Tubuliflorae	4.7	3.8	0.7
Artemisia	—	1.3	2.9
Caryophyllaceae	—	0.6	—
Unidentified	0.5	6.3	4.3
Lycopodium sp.	—	1.9	—
L. annotinum	0.5	3.1	1.4
L. lucidulum	0.5	—	2.2
Selaginella selaginoides	11.5	—	1.4
Equisetum	—	—	3.6
Pteridophyta	—	1.9	1.4
Polypodiaceae	8.9	6.3	7.2
Botrychium	0.5	0.6	—
Pteridium	—	0.6	—
Cyperaceae	53.4	75.5	372.7

Percentage are based on total pollen excluding spores and aquatics equalling 100.

PALYNOLOGICAL REPORT NO. 84-2

Date: April 19/84.

Locality: 4 km southeast of Sand River, Nova Scotia.

Lat.: 45° 30′ N. **Long.:** 64° 37′ W.

NTS: 21 H/10.

Submitted by: Ralph Stea.

Field No.: E-16-7.

Lab No.: PL-83-49.

Description of Sample: Core of basal sediment of peat bog.

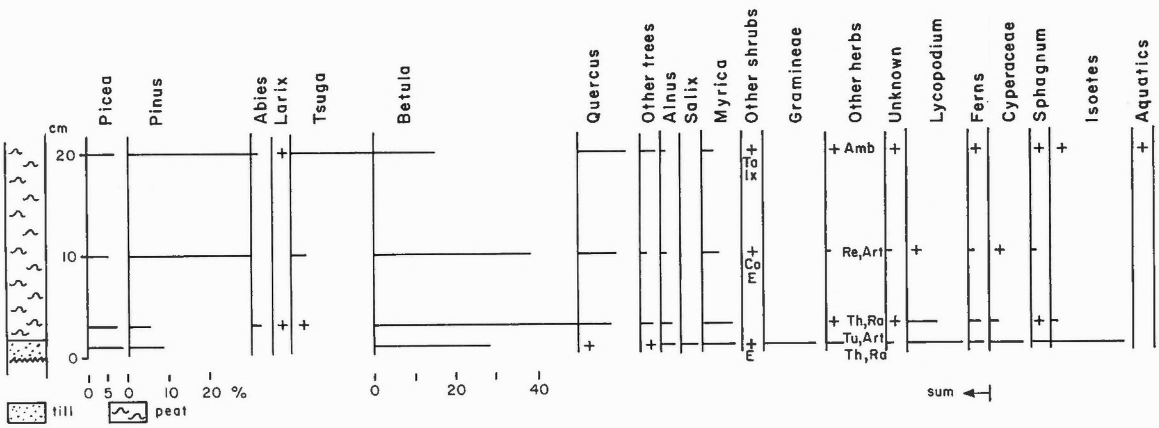
Results and Interpretation:

The accompanying pollen diagram for the basal part of a peat bog core reveals palynological changes related to the early history of the site.

The basal sand is characterized by an open shrub tundra type assemblage dominated by *Betula* (birch, probably shrub birch), Gramineae (grass), *Lycopodium* (clubmoss) and smaller amounts of *Myrica* and *Salix* (willow) pollen. *Isoetes* spores are prominent, indicating deposition in an aquatic environment. Birch pollen is more abundant in the next sample at the base of the peat, but these are mainly tree birch representatives. Note also the rise in *Quercus* (oak) pollen and the decline in open ground indicators. *Picea* (spruce) and *Pinus* (pine) pollen are still relatively sparse, although some spruce trees may have been in the area from the beginning. At 10 cm above the base of the core, pine (maily white pine type) pollen increases greatly, birch declines somewhat, and shrubs and herbs are much less abundant. At 20 cm above the base, pine remains abundant, but birch is replaced by *Tsuga* (hemlock) pollen.

Comparison with other profiles from Nova Scotia indicates that the basal sediment began accumulating about 10 000 or less, years ago. The basal spectrum is distinctly different from those typical of pre- 11 000 year B.P. spectra at some lake sites and from buried late-glacial deposit spectra. Early sedimentation rates were apparently very slow because at 20 cm above the base the abundant hemlock pollen indicates an age of 7000 years B.P. or less, based on the general age for incursion of hemlock into the Maritimes.

The results are what would be expected if accumulation of organic sediments were delayed until after about 10 000 years B.P. because of adverse climatic conditions or late ice cover in the area. If this site is within the area of youngest till coverage, it may be a good area for further study. A basal radiocarbon date on as narrow an increment as possible would be required to corroborate this interpretation.



BASAL CORE– SAND RIVER AREA, NOVA SCOTIA (R. Stea E-16-7) (PL-83-49)

PALYNOLOGICAL REPORT NO. 78-11

Date: Oct. 6, 1978

Locality: 0.5 km east of West Brook (settlement), Nova Scotia.

Lat.: 45° 33.5′ N **Long.:** 64° 17.5′ W

NTS: 21 H/9W

Submitted by: W. Blake Jr. for Daryl Wightman

Field No.: DW-76-2

Lab No.: PL-78-48

Description of Sample: Peat

Results and Interpretation:

Trees	%	Herbs	%
Picea	16.5	Ericaceae	3.8
Pinus sp.	1.9	Gramineae	4.7
P. strobus	0.9	Tubuliflorae	0.9
P. banksiana/		*Artemisia*	1.4
resinosa	14.4	Rosaceae	0.7
Abies balsamea	0.2	*Rubus chamaemorus*	0.2
Betula	30.0	Caryophyllaceae	0.2
Quercus	0.7	*Polygonum*	0.4
Fagus	0.2	*Lycopodium clavatum*	0.5
Shrubs		*L. obscurum*	0.5
Alnus	1.7	*L. complanatum* type	0.7
Salix	3.8	*L. annotinum*	0.9
Myrica gale	7.6	Pteridophyta	1.2
		Polypodiaceae	0.7
Aquatics		*Selaginella*	
Cyperaceae	283.7	*selaginoides*	2.4
Myriophyllum	0.2	*Botrychium*	0.2
Sphagnum	8.0	Unidentified	2.4

The assemblage noted above is similar in many ways to those found at or near the base of several profiles from Nova Scotia (Railton, 1972; Hadden, 1975; Livingstone, 1968) and to assemblages contained in other buried postglacial organic deposits (Gill, Internal Palynological Report, 1974-4).

The preponderance of sedge (Cyperaceae) pollen accompanied by *Sphagnum* spores, heath pollen types (Ericaceae), grasses (Gramineae), cloudberry *(Rubus chamaemorus)* and *Selaginella selaginoides* are characteristic of bog or fen environments indicating such conditions prevailed at the time of deposition. Some of the clubmosses *(Lycopodium annotinum; L. obscurum)* are also indicative of bog margins or wet woods. This wet or boggy area or its surroundings also supported such shrubs as sweet gale *(Myrica gale)*, willow *(Salix)* and alder *(Alnus)*.

Among the arboreal pollen types birch *(Betula)* is the most abundant but many of these may relate to the shrub birch *(Betula glandulosa)*. Spruce *(Picea)* pollen is less abundant but some spruce trees may have been present in the area or on the bog itself. Pine pollen is about as abundant as spruce with most of the pine pollen of the jack/red pine *(Pinus banksiana/resinosa)* type. The former was the most likely tree involved but it may not have been growing in the immediate area. Only a few grains of white pine *(Pinus strobus)* are present. Open treeless or sparsely treed tundra conditions are suggested by this pollen assemblage.

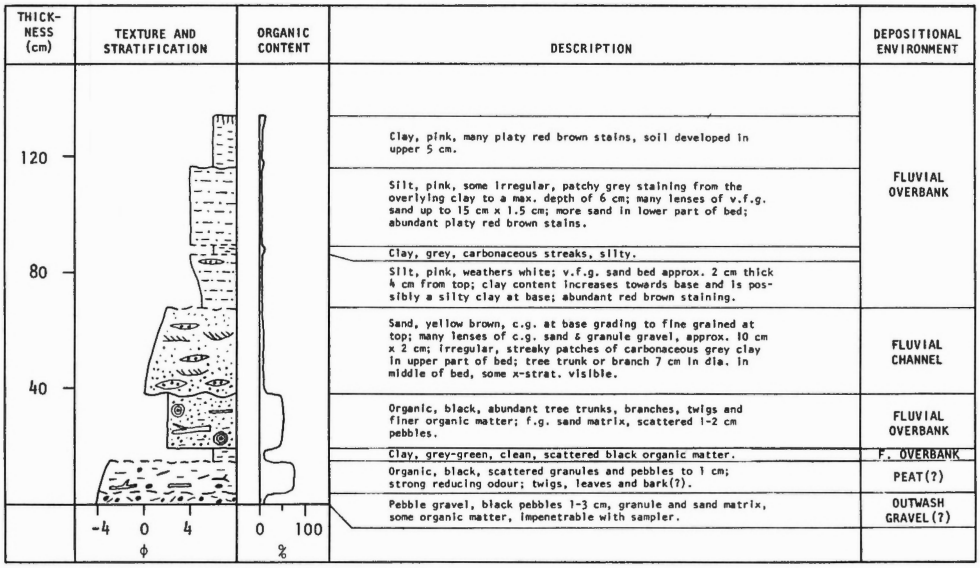
Comparison with other assemblages from Nova Scotia suggest an age of between 9 500 and 11 000 years B.P. or possibly as old as 11 700 years B.P.

The occurrence of white pine wood (see Wood Report No. 78-35) associated with this deposit is an enigma. The few grains of white pine pollen are probably attributable to long distance transport and white pine trees were not present until a much later time. Possibly the wood is stratigraphically higher in the section or may have fallen into an older peat deposit.

Hadden, K.A. 1975. A pollen diagram from a postglacial peat bog in Hants County, Nova Scotia. Can. J. Bot., 53, 1, 39-47.

Livingstone, D.A. 1960. Some interstadial and postglacial pollen diagrams from eastern Canada. Ecol. Mon., 38, 2, 87-125.

Railton, J.B. 1972. Vegetational and climatic history of south-western Nova Scotia in relation to South Mountain Ice cap. Dalhousie U., Ph.D. thesis, 146 p.



STRATIGRAPHY OF THE WEST BROOK SITE. DATED SAMPLE WAS FROM THE BASE OF THE PEAT