DEGLACIATION OF THE POUCH COVE AREA, AVALON PENINSULA, NEWFOUNDLAND: A PALYNOLOGICAL APPROACH

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by

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Abstract

Recent studies (Ives 1978) have suggested that a re-evaluation of the earlier theories of the maximum extent of late-glacial ice in eastern Canada is necessary. The late-Wisconsinan glaciation of Newfoundland has been the subject of much speculation and debate but with recent field-work primarily centred along the west coast of the island and the Burin Peninsula.

The maximum limit of the late-Wisconsinan ice on the Avalon Peninsula, Newfoundland, is uncertain. Divergent opinions have been expressed in the literature by Henderson (1972) and Grant (1977a) as to whether glacial ice covered the northern extremity of the St. John's Peninsula (Figure 1.1 p. 15). The objective of the research was to clarify its position by establishing a minimum date for deglaciation, absolute or relative.

The geomorphology of the study area suggests that two recognizably different glacial landscapes exist north and south of Pouch Cove. Two subglacial tills are exposed by a quarry to the north of "Birch Hill's Pond". In the south-east of the study area a group of well defined meltwater

channels suggest that meltwater drained eastward from an ice margin within a trough to the west. However the presently available evidence does not suggest whether or not these observations are a product of different glaciations or reflect the oscillations of an ice margin during the last glaciation.

The lowest portions of three cores, one from "Birch Hill's Pond" and two from Northeast Pond, were subjected to palynological analysis and the basal organic sediments were submitted for radiocarbon dating. The pollen assemblages indicate changes in the regional vegetation during the early Holocene. Initial assemblages (8500 BP) suggest a shrub-sedge tundra vegetation which gave to a shrub tundra by 8300 BP, succeed in turn by boreal woodland similar in composition to that found in the area today. None of the basal pollen assemblages resemble the spectra collected by Pennington (1977) from recently deglaciated terrain, or a basal assemblage dated 9270 BP from near St. John's (Lowdon and Blake 1978; Macpherson 1980). The basal dates recorded in this study are therefore minimum dates for deglaciation, and appear too young to date ice retreat.

Evidence from glacial landforms and till analysis is also inconclusive. The results of this study neither confirm nor refute the "maximum" glacial hypothesis of Henderson (1972) or the "minimum" glacial hypothesis of Grant (1977a). It may be stated with certainty, however, that the northern extremity of the St. John's Peninsula was free of glacial ice some time before 8500 BP.

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Chapter 1

Literature survey and the aims of the study.

1.1 Introduction.

Aspects of the Pleistocene glaciations of Newfoundland have been discussed since 1843 (Jukes) and from then the extent and form of the land ice has been the subject of much debate. Initially the Pleistocene of North America was generally regarded as an undivided period of continental glaciation. By the 1880s evidence was found suggesting that there had in fact been several periods of glacial expansion and also times, now known as interglacials, when the climate in the Pleistocene had been as warm or warmer than today and there had been a reduction in size or a complete disappearance of continental ice in temperate latitudes. The readvance of ice following the final interglacial was called the Wisconsin Glaciation. More recently it has become apparent that this cold period can be divided into a series of stadials and interstadials relating to the major advances and retreats of ice on land during this period. In this thesis the term "late-Wisconsinan" will refer solely to the last expansion of ice recognized in Newfoundland. The term Wisconsinan will refer to the whole period post-dating the Sangamon Interglacial up to the beginning of the Holocene, about 10,000 BP (Hedberg, 1972).

Recent work has centred upon the Wisconsinan glaciations of the island since it is generally believed that much of the erosional and depositional evidence of glacial and proglacial conditions relates to these events. Grant (1976, 1977a, 1977b) and Brookes (1977, 1979) from evidence gained primarily from the west coast of Newfoundland, have suggested that the late-Wisconsinan maximum was of limited extent, in that many high-land areas were probably not covered by ice during this period and in several areas glacial ice most likely failed to reach the coast. Grant has produced two versions of a map (1976: p 290; 1977a : p 252) showing that the tips of the Avalon Peninsula lay beyond the late-Wisconsinan ice margin. By contrast, Henderson (1972), Vanderveer (1975) and Alam and Piper (1977) are of the view that the last ice was not of such limited extent and extended to at least the present coast of the Avalon Peninsula. It was the intention of the present research to find evidence on the northern tip of the St. John's Peninsula relating to the limit of late ice.

At several localities on the island there is evidence of a readvance or pause in the ice retreat ascribed to a climatic deterioration following the initial deglaciation, (Grant 1969a, 1969b; Brookes 1970, 1971, 1975; Rogerson and Tucker 1972; Eyles 1977 and Tucker 1979). Research on the northeastern promontory of the Avalon Peninsula would also allow the hypothesis of a late-glacial oscillation to be tested in this locality.

The aim of the research was therefore to establish a chronology for the final deglaciation of the northern tip of the St. John's Peninsula. The methodology followed involved the radiocarbon dating and pollen analysis of basal lake sediments from two ponds and an analysis of the gross morphology of the study area. It was hoped from this that the minimum date for deglaciation could be obtained and also that any oscillation in the retreat of the last ice could be identified.

1.2 Previous work.

a. Purpose of the literature survey.

In order to relate the present research to other work on the glacial chronology of Newfoundland a brief review of the literature is necessary. Emphasis will be placed upon the evidence advanced in the recent literature in support of what may be termed the "minimum" and "maximum" viewpoints of the late-Wisconsinan ice advance on the Avalon Peninsula and in particular that of the St. John's Peninsula. Extensive reviews of the literature pertaining to the historical progress of glacial studies in Newfoundland have been undertaken by Tucker (1976) and Brookes (1977) while Ives (1978) has reviewed work along the east coast of Canada and therefore gives a broader perspective to ideas prevalent in past glacial studies.

b. Early studies in Newfoundland.

During the nineteenth century studies in Newfoundland were largely concerned with investigation into and defence of the applicability of the hypothesis of former continental glaciation (Jukes 1843, Kerr 1870, Milne 1876, Murray 1883 and Wright 1895). Glacial studies entered a second phase at the end of the nineteenth century with Chamberlin's work on the Avalon Peninsula (1895). His studies were not motivated by a desire to defend the principle of continental glaciation but rather to examine the morphology and distribution of glacially related features, which he in turn used to infer the former distribution of local glaciers.

c. "Minimum" Wisconsinan glaciation.

The first general hypothesis to emerge from twentieth century research suggested that during the last glaciation Newfoundland had supported an ice cap of insufficient thickness to over-top certain coastal summits, notably along the southern Long Range Mountains. Coleman's (1926, 1930) investigations provided geomorphic evidence in support of this hypothesis. The botanical investigations of Fernald (1925, 1930), concerned with plant refugia on the Long Range Mountains and the investigations of marine features by Fairchild (1918) supported the conclusions of Coleman, as with certain reservations did Daly's observations on crustal warping (1921). Despite difficulties of access Coleman made studies of the southern Long Range Mountains as far north as Gros Morne, and also of central Newfoundland from along the railway track and the Avalon Peninsula in the vicinity of St. John's. His conclusions were based primarily on three types of evidence which were and remain the focus of much debate on the island's glacial history: distribution and direction of striae, distribution of erratics and differential weathering.

Observations of striae across the island led him to confirm Bell's (1884) earlier observation that "glaciation appears to have been from the centre towards the sea on all sides," (Coleman, 1926: p. 37). His studies on the Avalon Peninsula confirmed his opinion that the Pleistocene glaciation had been in two stages. He suggested from his island-wide observations that during an early Pleistocene glaciation an ice cap had extended over the whole island (apart from the southern Long Range Mountains) and was followed by deglaciation and a period of intensive weathering which preceded the development of local ice sheets and ice caps. This second expansion of ice during the Wisconsinan failed to form a complete island ice cap although ice flow was again coastward.

The intensively weathered summits of the southern Long Range Mountains and their apparent lack of erratics and striae convinced Coleman that they had never been glaciated. He recognized well weathered erratics on summits further north along the Long Range Mountains and also on the summits of some hills on the Avalon Peninsula, (Butter Pot 7 km from Fermeuse and the Hawke Hills 32.5 km southwest of St. John's). These he suggested had been glaciated once during a glaciation more ancient than the Wisconsinan. Other areas appeared to have less modified erratics and striations which he suggested were the result of the extension of Wisconsinan ice. His conclusion that less than half of the island had been covered during the Wisconsinan glaciation, is the first statement of the "minimum" Wisconsinan theory.

Investigations into postglacial isostatic warping over eastern North America by DeGeer (1892), Fairchild (1918), and Daly (1921) provided additional support for the theory of an ice dome over Newfoundland. However Daly felt the primary influence on isostatic warping in the area had been the Laurentide ice sheet.

Botanical evidence, provided by Fernald's studies (1925, 1930), supported the hypothesis of ice free areas. Summits of the Long Range Mountains appeared to contain a restricted relic Cordilleran flora which Fernald suggested demonstrated its antiquity by the high incidence of endemism and the localization of species. Such plant assemblages could only have survived had the habitats remained free of ice during the Pleistocene. Subsequent inability to colonize other areas following deglaciation was seen as a product of the long isolation and stability of the vegetation stock.

d. "Maximum" Wisconsinan glaciation.

All lines of evidence used to support the "minimum" hypothesis were being re-evaluated by 1940. The workers most responsible for the re-evaluation and later rejection of the former hypothesis were Wynne-Edwards (1937), Flint (1940), Twenhofel and MacClintock (1940) and MacClintock and Twenhofel (1940).

Flint's (1940) examination of the marine features of western Newfoundland led him to conclude that crustal warping was the result of the invasion of at least western Newfoundland by Laurentide ice flowing from the northwest, and that local Newfoundland glaciers were not massive enough to interfere seriously with the regional crustal influence of the Laurentide ice. The rise in elevation of marine features toward the northwest of the island appeared to be in conflict with the radial glacial flow indicated by striae. Flint suggested a hypothesis by which both sources of evidence were reconciled, "that the Labrador ice sheet invaded part or all of Newfoundland in Wisconsin time and that, as the ice sheet shrank, local snowfall on the Newfoundland plateau maintained an independent glacier mass which flowed radially outward and persisted after the Cabot Strait and parts of the Gulf of St. Lawrence had been deglaciated," (1940: p. 1761-2). Hence once the Laurentide ice had withdrawn the island's ice took up a radial flow, as recorded by numerous striations.

Fernald's and Coleman's observation sites, as well as additional sites to the north along the Northern Peninsula and in the interior of the island, were visited by MacClintock and Twenhofel in 1939. They disputed Coleman's claim that some areas of Newfoundland had not been glaciated and reported "convincing evidence of very recent and complete glaciation of each region studied," (Twenhofel and MacClintock 1940: p. 1668). They suggested that the island had been invaded by "Labrador ice during an early phase of Wisconsin glaciation". During a late phase Newfoundland had supported a local ice cap which extended beyond the present shoreline and during some phase of ice retreat a subsidiary ice cap covered the Avalon Peninsula. Preliminary retreat of the ice margin to within the present coastline was followed by a slight readvance in the Bay St. George area and in some parts of the Northern Peninsula. Final deglaciation was preceded by the shrinkage of the ice sheet into separate ice caps and valley glaciers, (MacClintock and Twenhofel, 1940: p. 1755-1756).

Wynne-Edwards (1937) disputed the botanical evidence offered by Fernald. He suggested that the primary control on the location of the Cordilleran flora was geology, since they had a marked preference for certain soils. He offered an alternative explanation for all the attributes imputed by Fernald to the "relict" flora.

By the time Flint suggested a mechanism for the growth of ice sheets (1943) the "maximum" hypothesis of the Laurentide ice sheet's invasion of Newfoundland had gained general acceptance.

e. Recent work: excluding the Avalon Peninsula.

Since the 1960s evidence has accumulated which suggests there is a need for a re-evaluation of the earlier theories of Coleman and Daly. Much of the impetus for such a project for Newfoundland has come from field-work on the west coast by Grant and Brookes.

Grant (1969a, 1969b, 1972, 1973, 1974, 1975, 1976, 1977a, 1977b) provides evidence for a restricted late-Wisconsinan glaciation of Newfoundland and the Maritime Provinces. His map of the inferred limit of late-Wisconsinan glaciers in this area (1977a) fails to support Coleman's contention that over half the island remained ice free, but does suggest that substantial areas lay beyond the ice margin as coastal nunataks: coastal enclaves along the west and northeastern coast, the Burin Peninsula and the extremities of the Avalon Peninsula, or as interior nunataks: the Buchans plateau and the Topsail Hills, (1977a: p. 252).

Grant relies heavily on field-work on the west coast and the Burin Peninsula, and extrapolates his theories to the whole island using air-photo coverage. The delimitation of the proposed late-Wisconsinan ice in his field areas is based on the mapping of morphological features such as moraines, marine features, meltwater channels, differential weathering zones and stratigraphic exposures. Although Grant had noted evidence of several ice advances (1969a, 1969b, 1972, 1974, 1975) it was not until 1977 he suggested their possible correlation with features elsewhere in eastern Canada and their possible chronostratigraphic status.

Three weathering zones were recognized in the Long Range Mountains and he suggested that the lowest Zone C correlated with the late expansion of glacier ice as similarly recorded in the Saglek zone of the Torngats of northern Labrador (Ives, 1976) and Zone III of Baffin Island (Boyer and Pheasant, 1974). Grant thereby discarded his former interpretation that the features in his Zone C correlated with a phase of deglaciation when local ice predominated following the withdrawal of the Laurentide ice (i.e. Grant 1969a).

The work of Brookes (1969, 1970, 1975, 1977, 1979) has generally supported Grant's conclusions and extended the findings to the southwest of Newfoundland. Minimum dates for the initial retreat of coastal ice have been obtained from the southwest (GSC - 2113: 13,800 ± 260 BP) as well as dates for the readvance of ice in the region, (GSC - 868: 12,600 ± 170 BP).

It has been suggested (Grant, 1977a) that the island's last ice sheet possibly consisted of several ice domes which were independent of the Laurentide ice sheet. This reflects a modification of Grant's earlier (1974) shrinking multiple ice caps theory. He originally envisaged the separation of an island ice-sheet into at least fifteen dispersal centres during the disappearance of glacial ice from Newfoundland. If Grant's correlation of the Zone C with the last expansion of ice is accepted, it follows that during that episode ice only partially covered the island. The ice sheet varied locally in thickness with ice flow controlled largely by the underlying topography but with an overall movement outward to the coast. It is suggested that this period may (if correctly identified) correlate with the activity of the dispersal centres previously recognized by Grant in 1974.

Jenness (1960) and Lundqvist (1965) accepted Flint's hypothesis of the extent of the last ice. However a re-appraisal of the evidence they present shows them in retrospect to offer support to Grant's restricted ice hypothesis. For instance, Jenness identified in the eastern part of the main island an inner and outer drift zone which he suggested related to the deglaciation of the coastal area; the outer drift zone being the land uncovered when the ice front stabilized for a period further inland during deglaciation. If Grant's analysis of the weathering zones along the west coast is accepted then Jenness' drift zones may perhaps be interpreted as features produced by the differing extent of former glaciations. He also recognized two directions of ice flow within his study area; one where ice invaded from the west and the other from the south. These may also record two glaciations when the direction of ice flow varied.

During Lundqvist's study of the northeastern coastal area of Newfoundland around Notre Dame Bay he found sets of crossed striae. Many of these he attributed to the increasing importance of local topography during a late phase of glaciation, while an ice cap was centred over the Long Range Mountains and the Topsails Plateau: a view countered by Grant's interpretation (1977a) of the Plateau as a nunatak. Lundqvist could not so interpret occasional striations orientated southeastward. He therefore tentatively assigned them to invading Laurentide ice and cited as support the 1960 work of Jenness and MacClintock and Twenhofel (1940), but as Brookes (1970) points out found no unassailable evidence of invasion by Laurentide ice in his own study.

More recently Tucker (1979) has supported Grant's (1975) interpretation of limited ice in the Burin Peninsula area. Tucker concluded that the main body of late-Wisconsinan ice did not advance south or east of the Terrenceville-Swift Current area, and was influenced in its flow by the underlying topography.

f. Evidence of readvance and a cold period following the initial retreat of the last ice from the main part of Newfoundland.

Grant (1969a) reported a moraine at Ten Mile Lake, Northern Peninsula which he suggested marked the culmination of a readvance. A maximum age of 10,900 BP (GSC - 1277) was assigned to this event.

Investigations by Brookes (1969, 1970, 1971, 1975, 1977) into the glaciation of southwestern Newfoundland revealed evidence of a readvance of glacier ice by 12,600 ± 170 (GSC - 868) the event being recorded notably in the long-known cliff exposure at Robinson's Head, St. George's Bay. Brookes (1971) reported the presence of fossil ice wedges in western Newfoundland formed in "marine sediments deposited in close temporal association with an active ice front", (1971: p. 121), subsequent to initial deglaciation of the coast at St. David's and York Harbour between 12,500 and 11,500 BP. He suggests that the ice-wedge casts probably developed within 1000 years of when sediments were first elevated. The ice-wedges are formed in marine sediments and beach gravels, respectively, and date from a period of active permafrost subsequent to the regional deglaciation of the west coast of Newfoundland.

Eyles (1977) also records a cold period which he very tentatively brackets between 12,000 and 10,000 years ago, as there is no radiometric dating control. He assigns his identified ice-wedge casts to this age span on the basis of a possible correlation with a similar period identified in Cape Breton by Livingstone and Livingstone (1958), Livingstone (1968) and in northern Nova Scotia by Borns (1965). Tucker (1979) reports evidence of permafrost activity on glacio-marine deltas subsequent to the deglaciation of the Burin Peninsula.

1.3 The Avalon Peninsula.

Little recent work has been done on the final Wisconsinan glaciation of the Avalon Peninsula. A conflict of opinion as to the extent of the ice exists: Henderson (1972) suggests that the last ice extended beyond the present coastline whilst Grant (1976, 1977a) suggests that the ice was more restricted and failed to cover the extremities of the Avalon Peninsula. Vanderveer (1975) produced a map of surficial deposits and landforms of the St. John's Peninsula which can be interpreted as showing a regional distribution on the northern portion of the St. John's Peninsula which might relate to different ice expansions. The glacial limits suggested by Henderson, Grant and by an interpretation of Vanderveer's map for the St. John's Peninsula are shown in Figure 1.1.

Implicit in Henderson's description of the glacial features of the Avalon Peninsula is his belief in a single

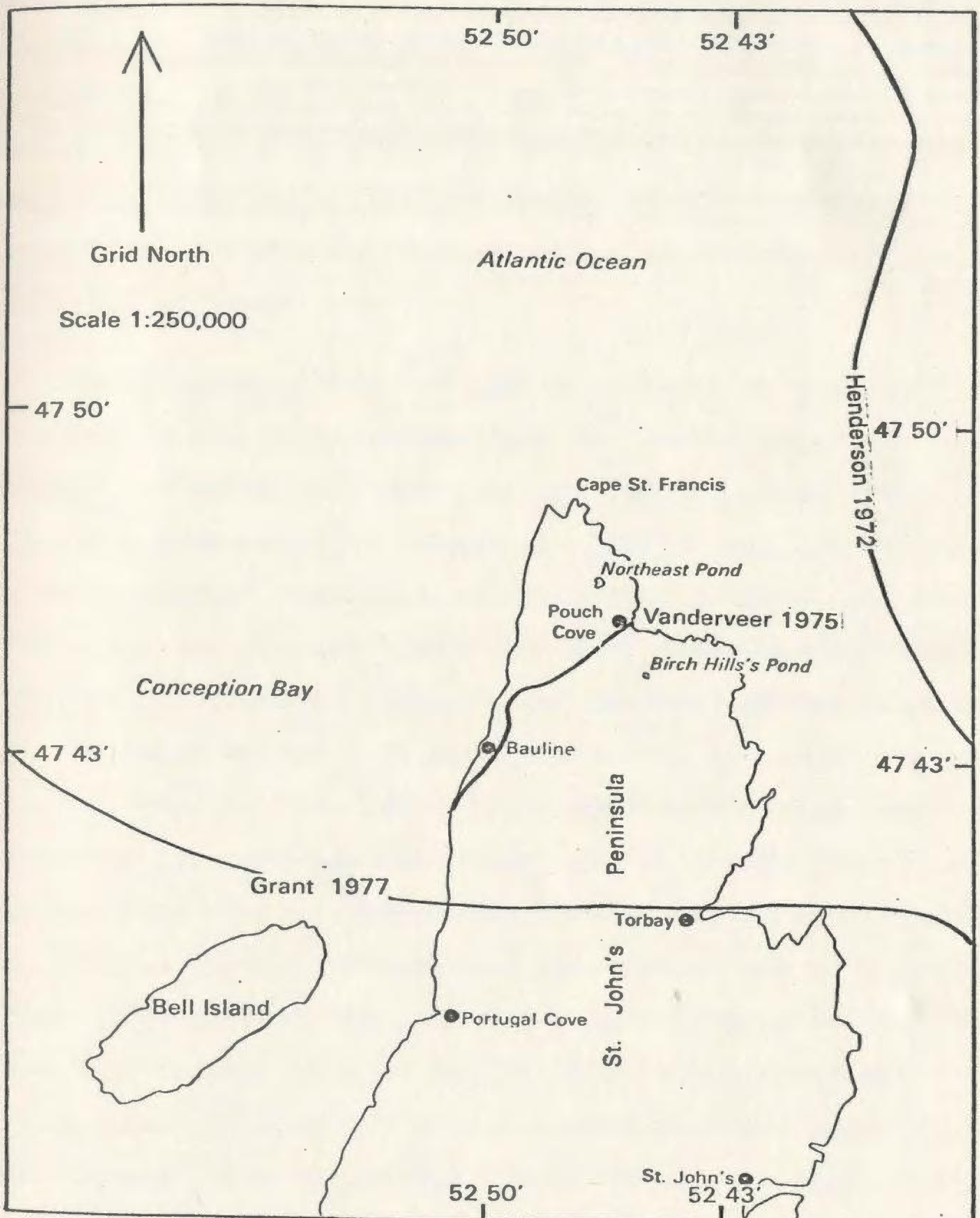


Figure 1.1 Suggested limits of late glacial ice on the St. John's Peninsula, Newfoundland.

Wisconsinan event. It is unclear whether he means to imply only the final Wisconsinan expansion or whether he views the Wisconsinan period as a continual glaciation. He suggests (following Chamberlain 1895, Summers 1949) that during this period the Avalon Peninsula developed a separate and vigorous ice cap, whose radial outflow dominated all the peninsula except the northern extremities which maintained thin local coverings of their own.

He postulates that the initial buildup of the ice occurred on the hills surrounding St. Mary's Bay. Subsequently ice moved east and west off the Trepassey and Placentia peninsulas to invade St. Mary's Bay. According to the "maximum" viewpoint of Henderson, outflow from St. Mary's Bay was at this time blocked by ice draining east from the St. Lawrence lowlands and the rest of Newfoundland via the Cabot Strait. In consequence the ice in St. Mary's Bay continued to rise until it assumed radial flow, and then this ice-dome dominated most of the Avalon Peninsula and the surrounding continental shelf. At its maximum, the ice drained through Trinity and Conception bays with sufficient escaping to prevent the main ice centre from advancing far along the central axis of the St. John's or Carbonear peninsulas. Preliminary pollen analysis of sediments from Bell Island leads Macpherson (pers. comm.) to suggest that this island in Conception Bay was glaciated during the last period of ice expansion; perhaps overridden by the ice draining from the main ice cap through this bay. Henderson suggests that the St. John's and Carbonear peninsulas were covered by local ice which was confluent with the main ice cap and "extended along their central ridges to their northern tips," (1972: p. 21). The local ice drained at right angles from their central ridges.

Henderson therefore maintains that the whole of the St. John's Peninsula was covered by glacial ice although he does suggest that generally glacial erosion on the northern peninsulas was feeble, except along the coast. As the ice cover was thin the direction of ice flow was generally determined by the underlying topography.

Henderson suggests that deglaciation began by a cessation of ice flow from the main ice centre draining through the bays of Conception and Trinity. If the ice blocking the Cabot Strait thinned, ice would have been able to escape south from St. Mary's Bay. The thinned ice-dome moved then from the head of St. Mary's Bay to the Trepassey Peninsula. Ice retreated first from coastal areas with the reduced flow concentrated into ice tongues extending seaward down major valleys probably to beyond the general ice margin. Henderson suggests from the distribution of supposed recessional moraines in the central Avalon, and the St. John's and Carbonear Peninsulas that deglaciation of the Avalon Peninsula was punctuated by pauses and slight advances.

Henderson's theory is largely based on the interpretation of the surficial deposits and glacial landforms of the Avalon Peninsula. Some of his interpretations have been questioned: notably by Rogerson and Tucker (1972). These writers maintain that the parallel moraines of the central Avalon Peninsula are not the ice marginal features known as Cross Valley moraines alluded to by Henderson but are more probably the subglacially formed Rogen or Ribbed moraines. If one accepts this identification then their distribution cannot be used to infer the position of a former ice margin since they are not marginal features and are more likely to be formed during the active dispersal of ice. Rogerson and Tucker further suggest that it is more likely that the residual ice retreated to areas of high elevation, such as the Hawke Hills where a topography reminiscent of ice stagnation exists.

A report of evidence of an ice advance after the initial deglaciation of the coast near St. Stephen's, southwest coast of the Trepassey Peninsula, is made by Rogerson and Tucker in 1972. However Eyles and Slatt (1977) have re-evaluated this sequence in light of Boulton's (1972) theoretical work based on the evidence from Spitsbergen glaciers. They conclude that the sequence represents a tripartite till similar to those now being formed by these subpolar glaciers. If such an interpretation is correct it leads to the suggestion that the Avalon Peninsula's ice cap complex was in part subpolar. As yet there is little evidence to support this and Sugden's 1977 review of the Laurentide maximum suggested that the Avalon Peninsula was covered by warm melting ice although on theoretical grounds he does suggest that the Long Range Mountains may have been capped by cold based ice.

Support for a more extensive Avalon ice complex has come from analysis of ocean sediments off the Grand Banks, (Alam and Piper, 1977). Although sedimentation in their study area has been primarily affected by conditions on the Grand Banks and in the Laurentide Channel, Alam and Piper suggest that the sediments also contain evidence of terrestrial glaciations. During the late-Wisconsinan glaciation much of the Grand Banks would have been exposed as land if sea-level fell the suggested 115 m (Alam and Piper, 1977). Their seamount cores reveal that the precipitation during this period was dominated by sediments supplied from the Laurentide Channel; Piper and Slatt (1977) discuss the probable origin of these ocean sediments. If ice on Newfoundland has been restricted then the Avalon Channel would have supplied sediment from the island while the Labrador Current advected sediment westward. However, if the Avalon Channel were blocked by ice and the Grand Banks emergent, the Labrador Current would be forced east away from the seamount area. From the deposition of reddish muddy foram-nanno ooze with the red mud originating from the Carboniferous and Triassic redbeds of the Maritime Province and the Gulf of St. Lawrence, they conclude that the Avalon Channel was either blocked by ice or that sea-level was so low as to block the Labrador Current from this region. Alam and Piper (1977) favour the former interpretation and therefore the "maximum" hypothesis in their model of Pleistocene sedimentation on the seamounts.

Vanderveer (1975) mapped the surficial deposits of the St. John's area primarily from airphoto interpretation. He accepted Henderson's (1972) theory on the limit of late-Wisconsinan ice and was primarily concerned with classifying and mapping surficial deposits as sources of aggregates for local industry. However his 1975 map suggests that there is a marked regional variation in deposits in the north of St. John's Peninsula.

Studies on the final deglaciation of the Avalon Peninsula are being carried out by Macpherson. Results from the Hawke Hills region suggest the Avalon was completely ice free before 8500 BP (Macpherson 1980).

1.4 The present study.

a. Reasons for the choice of the study area.

The St. John's Peninsula was chosen as the site for further investigations into the extent of last ice due to its ambiguous position in previous works.

It is suggested by Grant (1977a) that the northern extremity of the peninsula lay beyond the late-Wisconsinan margin. Also Vanderveer's (1975) surficial geology map suggests a broad change in the type and distribution of surficial deposits north and south of the "Bauline-Pouch Cove trough". However, Henderson's (1972) reconstruction suggests that the area was completely covered by a thin local ice sheet which was confluent with a major ice centre to the south. The argument for extensive glaciation has been supported by the work on oceanic sediments by Piper and Slatt (1977).

Henderson (1972: p. 67) describes two stony moraines south of Pouch Cove. These he considers to mark still stands or slight advances during the last deglaciation of the coast.

In either case the northern part of the St. John's Peninsula contrasts with the main body: - either it was not glaciated in the last expansion of ice or if it was, then it was ice free earlier. Therefore possible evidence of late-Wisconsinan or of the early post-glacial environment should be present in lake sediments dating from the final deglaciation of the area, whenever that occurred.

b. Aim of the study and choice of methodology.

The main thrust of the study was to examine the evidence for the existence of late Wisconsinan ice on the northern extremity of the St. John's Peninsula. It was proposed that two main tools would be employed: pollen analysis and radiocarbon dating, the former as a relative dating tool and also an indicator of gross environmental conditions, the latter to provide a minimum date for site deglaciation. Basal lake sediments would be used for the analyses since if a lake remained outside the ice margin it would likely contain a sedimentary sequence pre-dating the glaciation of the adjacent area. Had the last glacial ice advanced across the site then it is likely that any previously deposited sediments would be disturbed, distorted or removed. The basal organic material, dated using radiocarbon, would provide a minimum date for deglaciation while the pollen analysis would allow study of any stratigraphically older minerogenic sediment.

Other workers (notably Grant and Brookes in Newfoundland) have used differential weathering to delimit the extent of former ice expansions. This is most successfully applied where two conditions exist: uniform lithology and a large range in altitude over a comparatively short horizontal distance. As will be described in Chapter Two the solid geology of the area is complex both structurally and lithologically and the range in elevation is under 274 m. Also the identification of weathering zones carries the implicit assumption that weathering processes are uniformly active over the whole exposed area. Within the present study area no such realistic assumption can be made. For instance the effectiveness of weathering in the study area may vary according to the proximity to the sea or with the incidence of rapid heating of surface rock in the course of repeated vegetation fires.

A reconnaissance survey was made of some possible sites but this method of delimiting the last ice was rejected as the results were likely to be inconclusive as there are too many factors complicating weathering rates in the region. Tucker in his Burin Peninsula study (1979) demonstrates the unsatisfactory and inconclusive nature of weathering studies which lack suitable conditions.

It was proposed to obtain sediment cores from two ponds: Pouch Cove Northeast Pond (in future referred to as Northeast Pond in the text) and "Birch Hill's Pond" (which is an unofficial local name). From the basal sediments radiocarbon ages, pollen profiles and stratigraphic descriptions would be made and used to determine the early sedimentological/environmental histories of these ponds. Northeast Pond was chosen as a site since it was the most northerly accessible pond on the St. John's Peninsula and seemed likely to have accumulated more sediment than adjacent ponds, where exploratory probing had indicated shallow sediment. "Birch Hill's Pond" was sampled because it was believed to be a moraine-dammed lake, lying behind what is believed to be one of the features recognized by Henderson (1972) as an end moraine. If this interpretation was correct it had the potential to provide a minimum date for deglaciation of the area.

Both ponds lie north of Grant's (1977a) limit and if his hypothesis of a restricted ice cover is correct both ponds have the potential to contain sediments deposited during the late-Wisconsinan. "Birch Hill's Pond" is within the limit suggested by Vanderveer's 1975 map but the potential for older sediments in Northeast Pond remains. If late ice covered the whole peninsula neither pond should contain such sediments but if the last ice retreated as Henderson suggests the potential for evidence of the pauses or readvances in the last ice retreat remains. Similar analysis of some Scottish lake sediments has provided valuable evidence of the last ice expansion and retreat in Scotland (Loch Lomond Advance).

Radiocarbon dating of the lowest suitable (organic) sediments and pollen analysis of the early core would reveal irregularities in the depositional history of the lake and information about the surrounding contemporary vegetation of the lakes. If the basal sediments proved unsuitable for radiocarbon dating then the pollen record would provide an alternative relative dating technique.

Palynological studies on the Avalon Peninsula have been limited to three diagrams compiled by Terasmae (1963) and to the work in progress by Macpherson. None of these sites are from the northern St. John's Peninsula but it may be possible to correlate tentatively the undated portions of the pollen profiles of Northeast and "Birch Hill's Pond" with an absolute chronology of the vegetation change established by Macpherson for Sugar Loaf Pond, near St. John's (pers. comm.) and Terasmae's (1963) Goulds and Whitbourne bog sites, near St. John's and in the central Avalon, respectively. The sediments analysed by Macpherson and Terasmae recorded only variations in Holocene pollen production. The oldest pollen spectra for the Avalon were obtained from Sugar Loaf Pond (GSC - 2601: 9270 ± 150 BP for the lowest gyttja). The profile continues for approximately 40 cm below this and Macpherson (1980) suggests the site was not deglaciated before 10,000 BP. The sampling sites chosen in this study were potentially available for accumulation during the late-Wisconsinan if the speculations of Grant were correct. A few lake sequences pre-dating the Holocene have been discovered for Nova Scotia (Livingstone 1968), southern Labrador (Lamb, 1980) but correlations with these and other sites would have been more speculative because of the distances and variations between sites.

The finding of a pre-Holocene sediment sequence on the Avalon Peninsula would have demonstrated there had been an ice-free enclave, at least, along the east coast of Newfoundland. It would also provide a longer record of vegetation changes including the glacial and early post-glacial period.

As much of the previous work has involved the interpretation of geomorphic features it was decided that an examination of the study area's glacial geomorphology would be in order. However, the main thrust of the research was if possible to establish a chronology (absolute or relative) for the deglaciation of the northern tip of the St. John's Peninsula from analyses of basal lake sediments using the techniques of radiocarbon dating and pollen analysis.

Chapter 2

The study area.

2.1 Location.

The St. John's Peninsula (Figure 2.1) is the northeasterly limb of the Avalon Peninsula, Newfoundland. It is bounded by the North Atlantic Ocean to the east and north and to the west by Conception Bay.

The study area is the section of the St. John's Peninsula north of latitude $47^{\circ}\ 44'$N. Within this 56 km^2 area, field research was concentrated in the vicinity of "Birch Hill's Pond" ($47^{\circ}\ 44'\ 49''$N, $52^{\circ}\ 45'\ 31''$W) and Northeast Pond ($47^{\circ}\ 47'\ 44''$N, $52^{\circ}\ 46'\ 48''$W).

Settlement is largely restricted to the coastal centres of Pouch Cove, Bauline and Shoe Cove. Highway 18 connects Pouch Cove with the provincial capital, St. John's 25 km to the south. Access to Cape St. Francis is via a gravel road continuing from Pouch Cove, whilst Bauline is linked by a paved extension of Highway 18 to both Pouch Cove and Torbay. Northeast Pond is joined to the Cape St. Francis road by a forest track while "Birch Hill's Pond" is on a gravel road which links Miles Pond to Highway 18. Numerous forest tracks of varying quality are to be found in the forested valley troughs, generally these provide occess on foot to lakes.

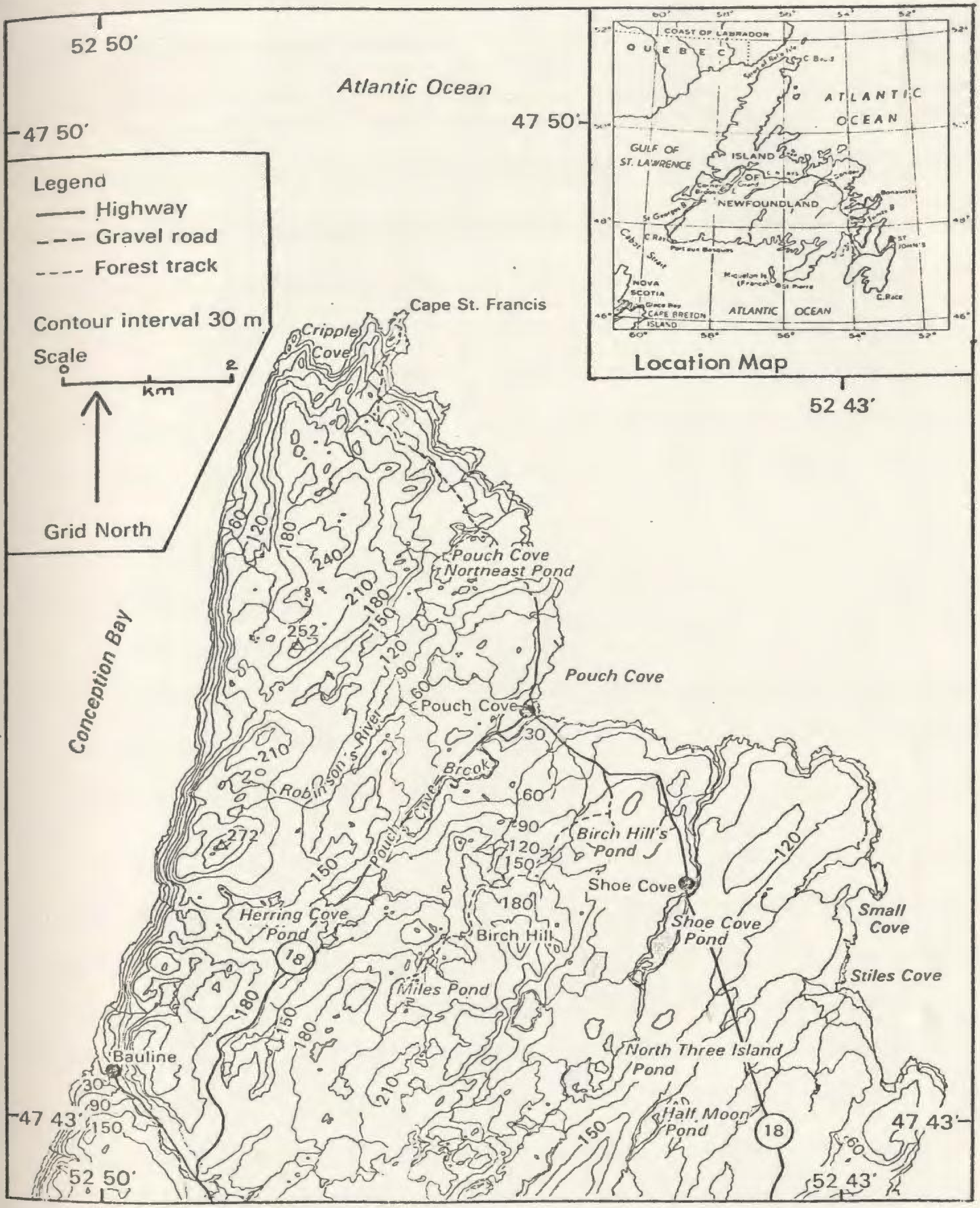


Figure 2.1 Map of the study area, St. John's Peninsula, Newfoundland.

2.2 Physical environment.

a. Introduction.

The physical environment will be described under the broad headings of geology, topography, drainage, climate and vegetation. Although for simplicity's sake these factors are dealt with separately they obviously cannot be regarded as independent of one another. For instance, vegetation is an expression of all the other factors affecting the distribution of plants including human interference as well as the characteristics of the plants available for colonization.

b. Geology.

i. Solid geology.

This aspect of the physical environment has had probably the greatest impact on the landscape of the study area. The coastline and relief are strongly influenced by the solid and structual aspects of the geology.

According to Rose (1952) the area is underlain by two bedrock groups: the Harbour Main Group (mainly schists and volcanic rocks) and the Conception Group (mainly siltstone, sandstone and slate). Figure 2.2 summarises the major features of Rose (1952) with modifications after the work of Maher (1973), and King (1977). Maher's study (1973) of the area north of the "Bauline-Pouch Cove trough"(term used in this text to refer to a major trough between these settlements) is based on detailed mapping of late Precambrian

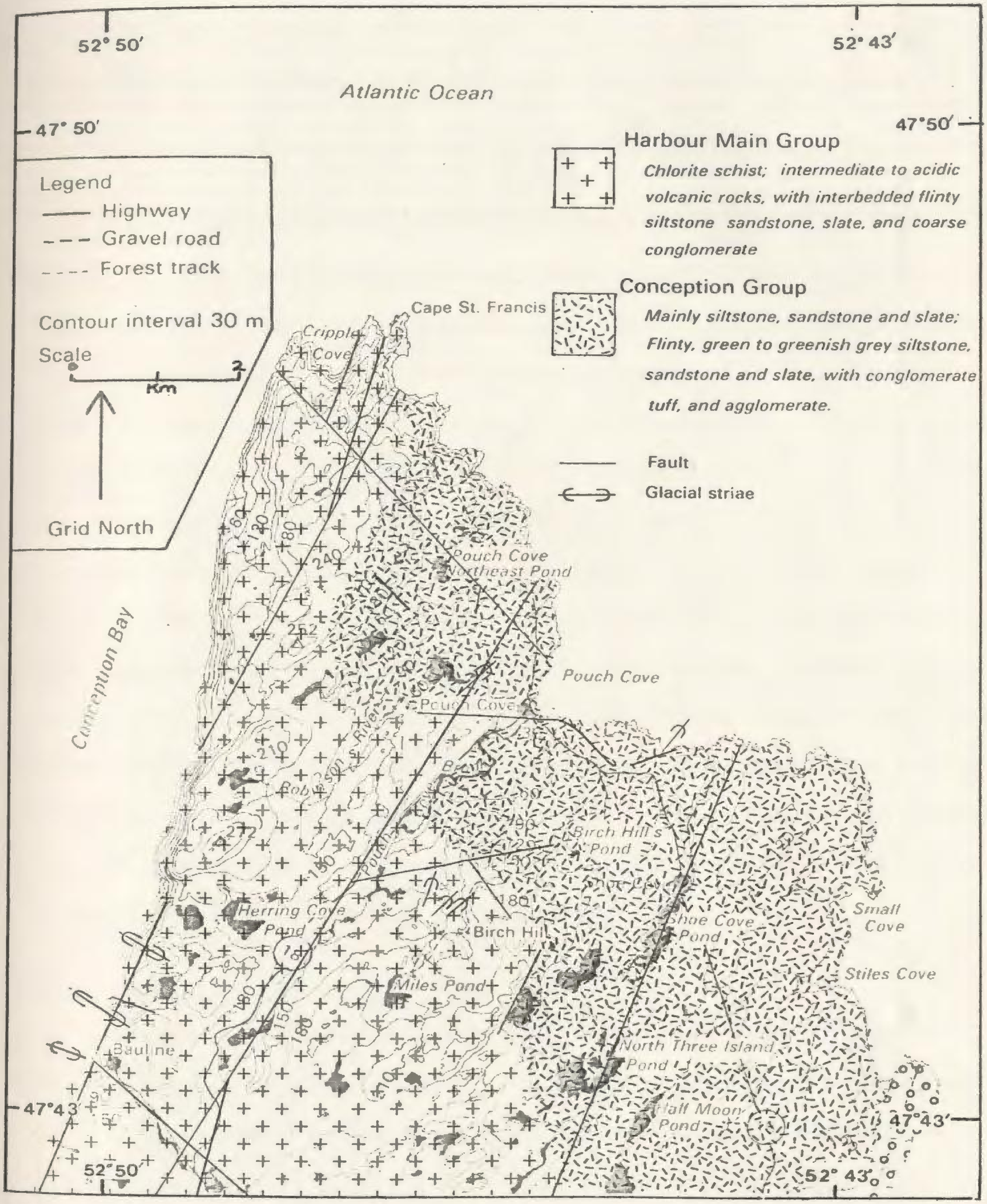


Figure 2.2 Map of the geology of the northern St. John's Peninsula, Newfoundland (after Rose 1952).

volcanic and sedimentary rocks. He states (1973: p. i) the Conception Group consists of "turbidite sandstones with subordinate cherts, shales and conglomerates." The Harbour Main Group comprises "numerous acidic and basic flows and tuffs inter-layered with sediments from the volcanic units." Maher also recognized glacio-marine and tillite formations within the Conception Group. Intrusions of quartz diorite, rhyolite and diabase were reported in the western part of area and may relate to the emplacement of the Holyrood granite batholith to the southwest (Maher, 1973). King (1977) in a recent geological map of the Avalon Peninsula confirms the earlier work and suggests the position of some major faults and folds south of Maher's field area. It appears that the sequence of rocks in the field area forms the western flank of a major anticlinal zone (Rose 1952, Keats 1968, and Maher 1973). The associated folds are of small scale but their axes generally trend northeast. Both thrust and normal faults are numerous. Exposures of solid rock occur on many summits as well as along the coastline.

ii. Surficial geology.

Roadcuts, quarries, building fountains and lake and stream channels expose varying depths of surficial material to field examination. A patchy veneer of till, of variable thickness, is largely confined to the northeast trending valleys. Henderson (1972) describes this veneer as ground moraine of local origin. The term "till" will be used in the

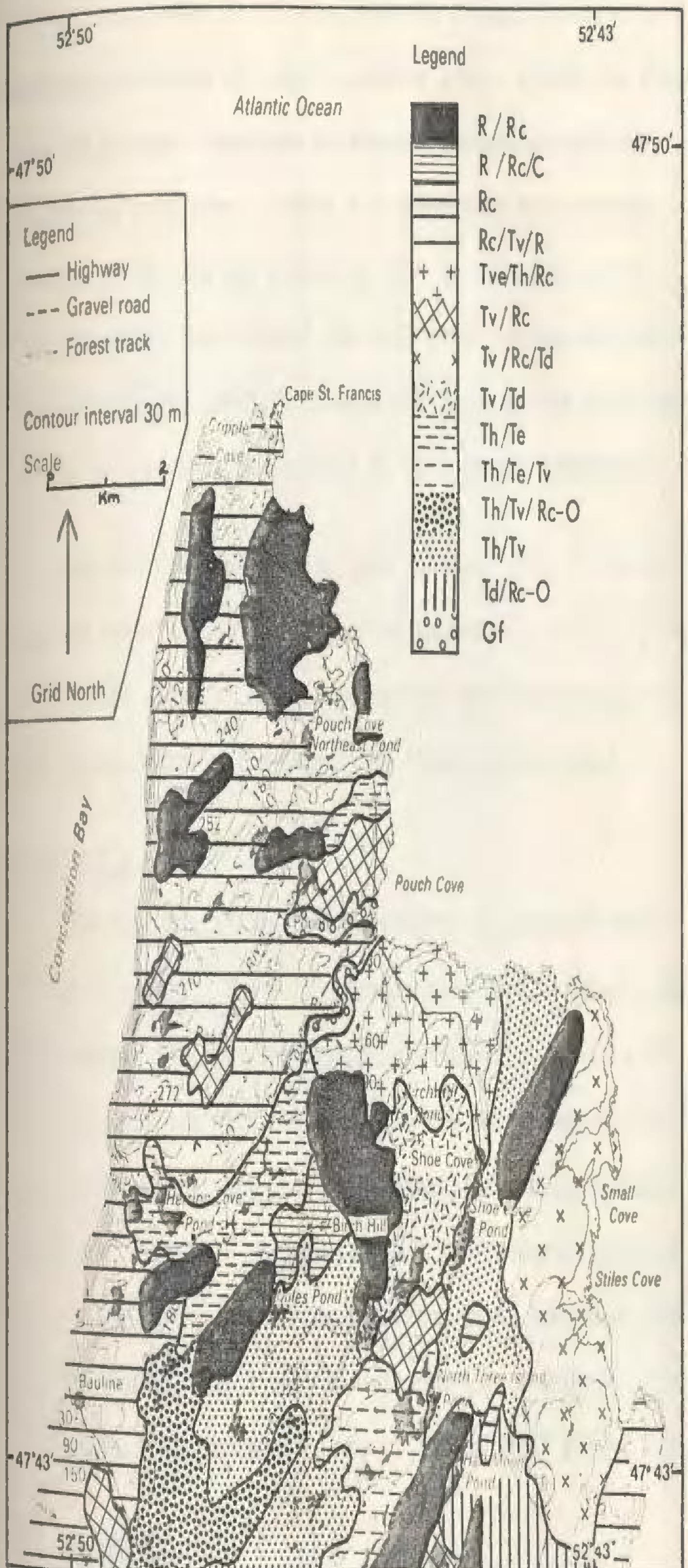


Figure 2.3 Map of the surficial geology of the northern St. John's Peninsula (Vanderveer 1975).

Key to the symbols used on Figure 2.3

Morphological Modifier	Genetic Category	Morainal T	Glacio-fluvial GF	Colluvial C	Organic O	Rock R
drumlinoid	(d)	Td				
plain	(p)	Tp	Gfp		Op	
hummocky	(h)	Th	Gfh			
ridged	(r)	Tr			Or	Rr
veneer	(v)	Tv				
eroded and dissected	(e)	Te		Ce		
concealed by vegetation	(c)			Cc		Rc

place of "ground moraine" in this thesis, after Boulton (e.g. 1976). Vanderveer (1975) has produced a classification of surficial deposits for the St. John's area. Within the field area he assigned landforms to genetic categories with morphological modifiers. Figure 2.3 summarises the relevant portion of his map and indicates that to the north of the "Bauline-Pouch Cove trough" the till cover becomes thinner and increasingly patchy. Towards the south of the study area landforms and deposits increase in variety and complexity.

Bog has developed in isolated patches. One of the largest of these is located at the headwaters of the Pouch Cove West Brook. East of Bauline bog growth has occurred around some lakes (notably for this study "Birch Hill's Pond").

III. Soils.

The cool humid climate has resulted in podsolic soils of low fertility. The soils contain many rock fragments and are strongly acidic. The organic content of such soils is typically low and with the generally low percentage of fine rock detritus the water holding capacity of the soils tends to be low. Drainage through the soil is frequently impeded by the development within the B horizon of an indurated layer of iron salts. Such a typical soil profile is exposed near the gravel road, northwest slope of "Birch Hill" Figure 2.4.

c. Topography.

Relief is dominated by a spine of highland extending along the western coastline formed predominantly of the

Figure 2.4 Soil profile, northwest slope of "Birch Hill".

Harbour Main rock Group. The maximum elevation of the highland is over 272 m north-northwest of Herring Cove Pond. The steep west coast is the fault-line scarp slope of this highland and lacks any bays or coves.

From this spine of highland a series of ridges extends to the northeast and is attributable to the general northeast to north-northeast trend of major fold axes and a set of thrust faults (Maher, 1973). The broadest of these northeast trending valleys is the "Bauline-Pouch Cove trough". Northeast Pond is found within a parallel trough to the north of this trough. The second highest summit in the region (252 m) is on the ridge 1.4 km to the west-northwest of this pond.

The eastern coastline is indented with frequent bays and coves (eg. Cripple, Pouch, Small and Stiles Coves.)

d. Drainage.

The major drainage divide in the study area lies near the west coast due to the position of the spine of highland. Consequently westward flow is negligible with most drainage confined to the northeasterly trending valleys and flowing eastward. The area's valleys have been glacially deepened and shaped. A series of rock basin or moraine-dammed lakes occupies the major troughs (eg. Northeast Pond, North Three Island Pond and Shoe Cove Pond). The ponds are generally connected by a series of misfit streams. The "Bauline-Pouch Cove trough" contains the area's largest stream: ie. the Pouch Cove Brook. Generally streams are small and because of the width of the peninsula, short.

e. Climate.

The sea is the dominant local influence on climate in Newfoundland. The configuration of the Avalon Peninsula exaggerates this further with its deep inlets of Conception, St. Mary's, Trinity and Placentia bays. The maximum distance from an appreciable body of water as a result is less than 20 km. In consequence the climate of the peninsula is equable since the surrounding water body reduces the range of temperatures and the cool waters of the Labrador Current reduce the maximum summer temperatures in comparison to those recorded in the continental interior at similar latitudes. In the winter the saline water is relatively warmer than other water bodies and the continental landmasses. Consequently temperatures do not fall to those experienced at similar latitudes in the interior of Canada. During the period June to October southerly airstreams are influenced by the warm Gaspé Current off the southwest coast of Newfoundland. The notorious coastal fog of Newfoundland can result from the condensation caused by the topographic influence on this moist airstream as it passes over the island, or cyclonic conditions or during the June to October period as the warm air comes in contact with the cold Labrador Current.

The nearest official meteorological observations recorded for the study area are from the St. John's airport, Torbay (47° 37'N, 52° 45'W). The meteorological station is 16 km south of Pouch Cove and is 141 m amsl. Within the study area meteorological conditions will vary from those observed at the airport due principally to differences in elevation and distance from the coast. These variations in conditions are probably negligible but general tendencies should be borne in mind when reviewing the airport's data. Absolute temperatures at the airport will generally be lower than those experienced within the study area since a substantial portion is below 140 m. The observation site is approximately 5 km distant from the sea at Middle Cove while the maximum distance in the study area is less than 5 km. As already suggested the sea has an important modifying influence on climate. Therefore it would seem that temperature variations in the study area might have a slightly smaller range than those of the airport. Observations concerning precipitation will probably not differ significantly in quantity although the generally lower elevation of the study area might promote more precipitation to fall as rain rather than snow during the winter months. It is possible that there is a higher incidence of coastal fog which probably penetrates inland along the "Bauline-Pouch Cove trough." There is no evidence to suggest either wind or relative humidity are appreciably different from those recorded at the St. John's airport. If the study area has more fog than the airport then sunshine hours would presumably be reduced accordingly. Table 2.1 presents mean monthly averages based on meteorological observations between 1941 and 1970 at the St. John's airport, for: temperature, precipitation, sunshine, wind, relative humidity and fog.

period (1941-1970). Source: Environment Canada, Atmospheric Environment Service)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Ju.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature (°C)												
Maximum	13	13	18	22	25	29	31	30	28	23	20	16
Minimum	-23	-23	-21	-14	- 7	- 3	1	3	- 1	- 6	-10	-17
Average	- 4	-4	- 2	1	6	10	15	15	12	7	3	- 1
Precipitation (cm/mo)												
Rain	6.9	7.4	6.6	7.62	8.9	8.9	8.4	11.4	11.2	13.5	14.2	10.2
Snow	79	86	69	36	10	Trace	0	0	Trace	3	18	66
Total	14.5	15.7	13.2	11.4	9.9	8.9	8.4	11.4	11.2	14	16.3	16.8
Sunshine (Hrs./mo)	57	75	93	116	152	176	212	176	149	117	59	53
Wind												
Speed (m.p.h.)	18.5	17.5	16.7	16.1	14.3	13.5	13.0	12.9	14.2	14.9	16.0	16.6
Direction	W	W	W	SW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	W
Relative Humidity (%)	85	86	88	83	78	78	78	81	80	83	86	85
Fog (% hrs./mo)	18	20.7	24	32	33	29	25	24	23	22	23	17

The growing season as defined by Hare (1952) is when the mean air temperatures are above 6.11°C. He suggests that the season is generally of over 160 days in the northern region of the Avalon Peninsula, beginning in mid-May and extending to late October. Snow has been recorded throughout the year and frosts have occurred in every month with the exception of July and August. The frost free season of the study area is normally longer than two months although the proximity during the spring and summer to the ice floes on the Labrador Current may encourage cooler temperatures and delay the onset of the growing season by a few days.

Damman (1975) investigated the importance of summer temperature in controlling plant distribution in Newfoundland. He recognized four groups of arctic-alpine species in Newfoundland with geographic patterns controlled by climate. Damman was interested in variations in the growing season defined by temperatures measured using the sucrose inversion method. His results indicate that temperatures in the study area are generally lower and are cooler during the growing season (14°C) than the central Avalon (above 16°C). Winter temperatures on the Avalon Peninsula do not fall as low as those of the central Newfoundland area. Frequent winter thaws are likely with the passage of cyclones to the north bringing warmer southwesterly airstreams which are accompanied by heavy rain and wind. One of Damman's groups of arctic-alpine species required deep winter snow cover and another is restricted to areas without frequent winter thaws and so are not found in the study area. Hare (1952) notes that half of the Avalon Peninsula's precipitation during the winter falls as rain, which results in numerous crusts being built up within the snow as the result of water freezing on the snow cover. Diurnal melting and freezing of the snow cover would produce the same affect.

Precipitation is abundant throughout the year. It is primarily the result of the passage of fronts associated with the numerous cyclones approaching from the southwest and south. Other forms of rainfall do occur but are generally less significant.

The average relative humidity is high throughout the year with the mean monthly figures from the St. John's airport ranging from 78% to 88%. According to Hare (1952) absolute humidity is greatest in the summer and early autumn. This occurs with the presence of the very humid tropical air from the southwest.

Winds during the spring, summer and fall are predominantly from the west-southwest at the St. John's airport but in the winter westerly winds predominate. If similar winds predominate in the study area then the major regional and long distant contributions to the pollen rain will be from the central Avalon and the southerly portion of the main island. Exotic pollen may also be blown from the mainland of Atlantic Canada although it is suggested its contribution to the pollen sum is generally small. Precipitation associated with these winds occurs throughout the year and is most commonly in the form of rain. Northerly winds predominating for a day or less during winter months bring cold moist air, which can bring snowfall.

The lowest percentage of sunshine hours recorded at the airport is during the winter months (December to March). This reflects the increased relative humidity and coincides with the predominance of the cold westerly winds. Although foggy weather occurs throughout the year it is most frequent during April, May and June. During these months the contrast between the warm-moist southwesterly air mass and the Labrador Current is strongest. As the year continues the Gaspé Current becomes colder; it is as cold as the Labrador Current by November (Hare 1952). During these months the air mass is not warmed to such a degree and less moisture is absorbed during its passage. When the contrast between the two currents is reduced so is the tendency for advection fog to form.

f. Vegetation.

The whole of Newfoundland falls within the boreal forest region of Canada (Rowe 1977). Vegetation studies on the Avalon Peninsula have been directed towards the distribution of forest with concern focused largely on determining the commercial viability of stands (eg. Kennedy 1955, Wilton 1956, Rowe 1977). Such vegetation surveys are very generalised with the maps indicating only the major components of interest to the compiler.

Studies have shown the Avalon Peninsula to have a relatively large percentage of heath and disturbed forest. Kennedy (1955) attributes this to the repeated forest fires and cutting which have led he suggests to a heath-like vegetation. The frequent formation of an iron pan in the upper soil horizon impedes surface drainage and can to some extent promote bog formation whilst discouraging recolonization by trees. Terasmae (1963) suggests that recolonization by trees would be less effective on the Avalon Peninsula than on the mainland of Canada due to the restricted range of species present and to a suggested diminished ability of those that are present. He cites the absence of jack pine (*Pinus banksiana*) from Newfoundland which is an important element in the primary succession of recently fired areas on the mainland. Terasmae also notes the "less aggressive behaviour in colonizing" of poplar (*Populus*) compared to elsewhere in Canada. Damman (1975) suggests that aspen (*Populus tremuloides*) can be found only as a stand-forming species where root sucker development is induced by high soil temperatures. In Newfoundland such temperatures are confined to the north-central region and to burnt or cutover sites. Page (1972) correlates its distribution with mean July temperatures above 15.6°C and mean annual precipitation less than 1250 mm. These restrictions on the distribution of one variety of poplar may explain Terasmae's observation. Macpherson (pers. comm.) notes that poplar clones effectively on disturbed sites around St. John's.

The dominant tree species on the Avalon Peninsula are balsam fir (Abies balsamea) and spruce (Picea: P. glauca, P. mariana). These are generally part of a mature stage of forest development but in the absence of the more usual colonizers become part of the initial succession. These species seem to be less able to successfully regenerate in areas formerly burnt over. Birch (Betula: B. papyrifera, B. cordifolia) and the shrub mountain alder (Alnus crispa) prosper on disturbed sites where there is plenty of light, moisture and little competition. Periodically the northern tip of the St. John's Peninsula has been swept by fire. A major fire occurred in the early 1940s affecting the area south of the "Bauline-Pouch Cove trough". Subsequently smaller fires have destroyed parts of the vegetation in the study area and these plus the wood clearing associated with the areas of settlement have given the vegetation a very patchy appearance.

An estimate of the proportion covered by vegetation types has not been made for the study area. However Table 2.2 (after Wilton 1956) provides an estimate of the areal distribution of vegetation types over the Avalon Peninsula. Values in Table 2.3 are estimates of the gross merchantable

Table 2.2: Areal distribution of vegetation types, Avalon Peninsula (after Wilton).

Vegetation type	Percentage distribution
Heathland	47.8
Swamp	1.9
Cleared land	4.6
Inland water	8.1
Productive forest[1]	21.6
Non-productive forest	16.0

[1]An area is classified as forest if the tree-crown closure is 5% or greater.

Table 2.3: Gross merchantable volume of timber species; the Avalon Peninsula (except the southern barrens) and the Bonavista Peninsula. (After "1969 Inventory Statistics of Forests and forest lands on the Island of Newfoundland").

Species	Percentage distribution
Black spruce (*Picea mariana*)	32.3
White spruce (*Picea glauca*)	2.3
Balsam fir (*Abies balsamea*)	55.1
White pine (*Pinus strobus*)	0.03
Larch (*Larix laricina*)	2.2
Birch (*Betula*)	6.9
Other hardwoods	1.3

volume of timber species on the Avalon Peninsula (excluding the southern barrens) and the Bonavista Peninsula by the provincial Department of forestry and Agriculture for 1969.

The study area lies beyond the main area of productive forest on the Avalon Peninsula, a triangle of land between the heads of Trinity, Conception and St. Mary's bays. Smaller areas of productive forest are found in sheltered bays and inlet locations. Wilton (1956) suggests as a rough guide, that productive forest is not to be found above an elevation of 152 m. Above this scrub softwoods are likely to predominate.

This has been confirmed during field-reconnaissance of the study area although many of the hill summits to the south support only heathland (eg. "Birch Hill"). The densest forests of the field area occur in the "Bauline-Pouch Cove trough" and the other valleys. Balsam fir generally predominates with spruce more numerous on the better drained sites. Recently disturbed ground has frequently been colonized by mountain alder. The hill slopes to the south of the "Bauline-Pouch Cove trough" have only occasional stunted trees including shrub sized conifers or small occasional copses within more favoured locations. The slopes surrounding Pouch Cove have been cleared for cultivation. Disused fields may also be found further north near the abandoned Cape St. Francis village. The fields are generally small in extent (less than 0.2 ha) cleared of forest with the larger surface boulders removed.

Chapter 3

Methodology

3.1 Introduction.

The objective of all field and laboratory work was to determine when the northern most portion of the St. John's Peninsula was deglaciated. The limits of last expansion of Wisconsinan ice as suggested by the published works of Henderson (1972); Vanderveer (1975) and Grant (1977a) are shown on Figure 1.1, p. 15. The studied area lies within the limit proposed by Henderson in 1972 but outside that suggested in 1977 by Grant. The surficial mapping of Vanderveer (1975) suggests that the ice margin may have lain within the study area. The techniques used to investigate the position in this study are pollen analysis, radiocarbon dating, and the occurrence and distribution of certain morphological features.

3.2 Collection of samples for pollen analysis.

a. Sites.

Two lakes were chosen as sampling sites. These were used in preference to bog sites as those have a tendency to be affected by local pollen suppliers (Faegri and Iversen 1975, Moore and Webb 1978) and the study necessitates an analysis of the regional pollen rain. The selection of lake sites was also influenced by the logistical problems of taking the equipment in by foot.

"Birch Hill's Pond", (47° 44' N, 52° 45' 31" W) is surrounded by bog. The decision to core here was made on the basis of the recognition of what is believed to be an end-moraine identified by Henderson which he does not precisely locate. He suggests it was formed during a pause or readvance during final deglaciation. The end-moraine is believed to be the feature blocking drainage to the northeast of the pond.

"Birch Hill's Pond" (Figures 3.1 and 3.2) is not fed by any defined streams nor is there evidence that it is spring fed. Water draining directly from the slopes (in the form of through and overland flow) is probably the major supply of water to the lake. One small stream drains from the pond to the northwest and some water may seep through the marginal bog to the northwest and northeast.

Two sediment cores were obtained using a modified Livingstone corer through ice on 24.2.79 and 3.3.79. Coring sites were located in the deepest part of the lake, which was found by plumbing the water depth through holes drilled in the ice along north to south and east to west axes of the pond. Depths to the sediment/water interface were 1.65 and 1.75 m at the coring sites.

Figure 3.1 "Birch Hill's Pond": view ENE showing quarry, left.

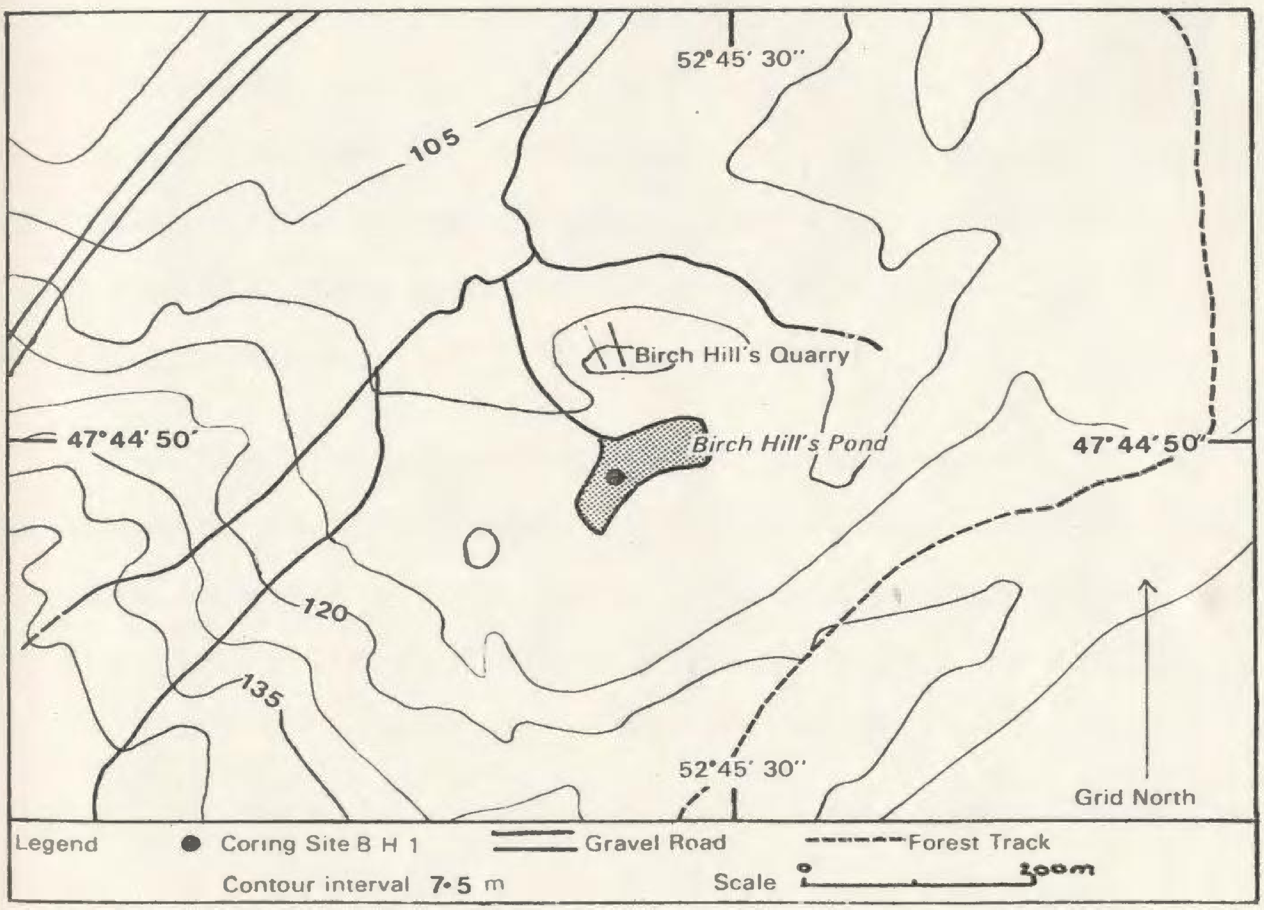


Figure 3.2 Map of "Birch Hill's Pond".

Northeast Pond (47° 47' 44" N, 52° 46' 48" W) occupies a rock basin with limited marginal bog development. Its position, not too far distant from the other sampled pond, was desirable for purposes of comparison while being beyond the limits suggested by Grant (1977a) and the work of Vanderveer (1975). Although the margins of the pond are floored with angular boulders, some of which protrude above the water, local information that the south arm of the pond was floored with soft sediment proved to be correct.

The steeper northern arm is free of sediment. Sediment accumulation may have been prevented by the continual through flow or periodic flushing of water draining into and from the lake in the northern basin. These streams and the general relief are shown in Figure 3.3. Intermittent drainage may also occur towards the north-northeast where a stream coalesces before draining into another pond whose waters drain into the Atlantic Ocean.

Sampling was restricted to the southern arm of the pond where the deepest water depths of this portion of the pond were observed. Four cores were taken using boats and from ice with the modified Livingstone corer. Expeditions were on 25.6.79, 2.7.79, 25.2.80 and 3.3.80.

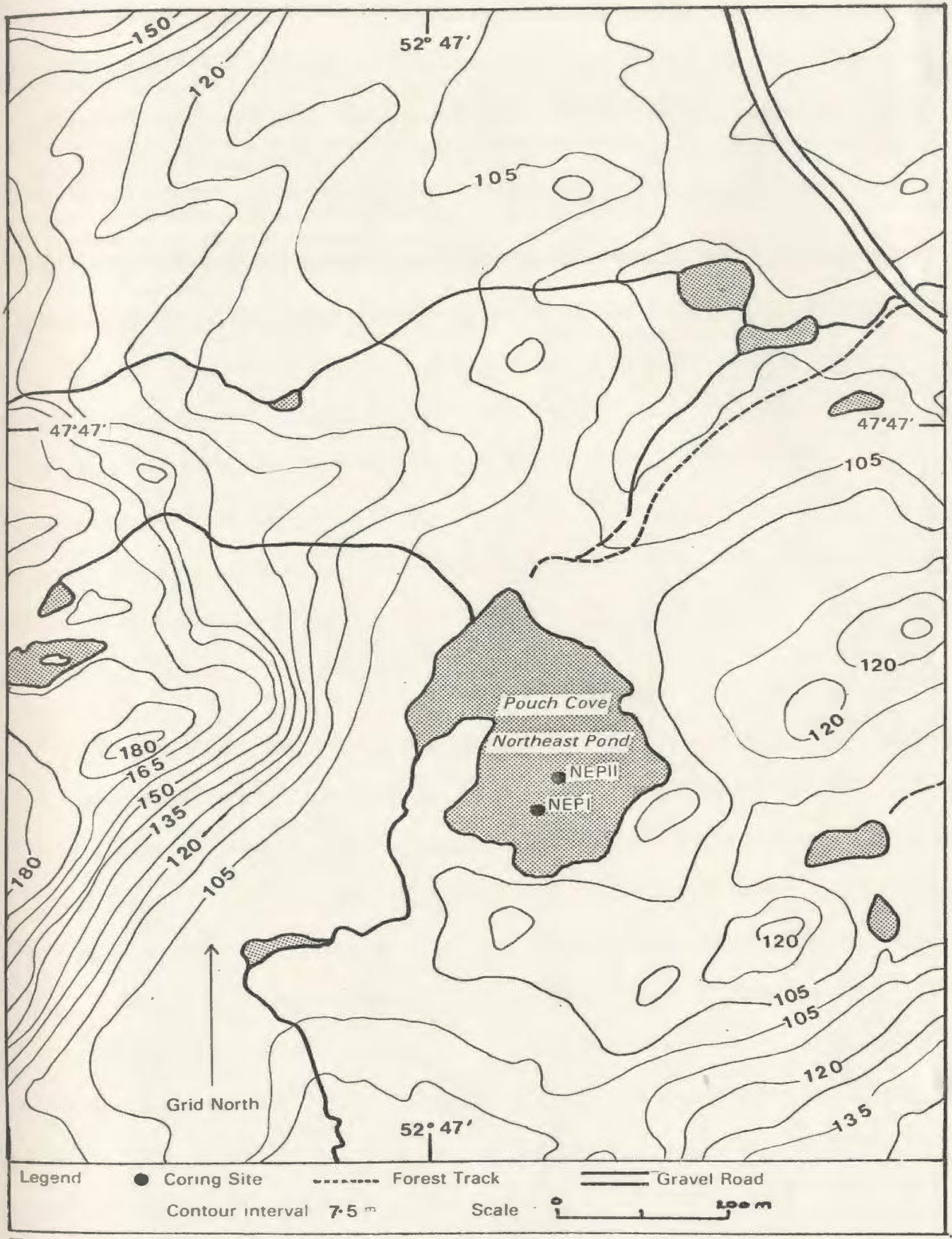


Figure 3.3 Map of (Pouch Cove) Northeast Pond.

b. Coring.

Sampling was done following the standard procedures outlined by Faegri and Iversen (1975) for lake sampling using a modified Livingstone corer, with chambers of 5 cm diameter. At Northeast Pond during the summer a pair of boats was locked together to form a suitable platform for the drilling operations. Once the sampling site had been chosen the boats were firmly anchored until the sampling was complete. During the winter the frozen lake surface provided a secure drilling platform at both Northeast Pond and "Birch Hill's Pond". The basic sampling procedure was followed from both platforms except that holes in the ice had to be drilled prior to sampling during the winter.

To prevent bending of the extension poles a casing tube was anchored from the drilling board to immediately above the sediment/water interface. The sediment cores of between 4.53 m and 5.26 m were collected from Northeast Pond while between 4.00 m and 4.38 m were retrieved from "Birch Hill's Pond. Each coring chamber could recover a maximum of one metre of sediment at each drive. On extraction of the sampler the coring chamber was disengaged from the piston and extension rods. The chambers were then plugged, sealed and transported horizontally to the laboratory for extraction. The piston was then scrupulously cleaned before being attached to a new chamber. The reassembled device was then lowered through the casing tube and into the same boring hole so that the next metre of sediment could be recovered. Care was taken throughout to record the proper notations for tubes and occurrences which might help during the analysis and interpretation of the core, (e.g. difficulties in the penetration of sediment and the likely cause of termination of the sequence).

3.3 Laboratory.

a. Extrusion.

In the laboratory the cores were extruded into clean plastic eaves-troughs. To ensure that the cores remained in a moist condition and to prevent contamination from exotic pollen sources they were covered in a plastic wrap. A further wrapping of aluminium foil prevented contamination of the sample from cosmic radiation and the production of radiocarbon within the sediment.

b. Stratigraphy.

Notes on the stratigraphy of the cores were made following the cleaning of their face by the removal of a portion of the surface perpendicular to the motion of coring. A record was made of the major sediment types (clay, gyttja, telmatic peat) and the depth of any transition. Variations within the sediment were recorded as were any marked concentrations of macrofossils. The colour of the moist sediment was described using a standard Munsell Soils Color Chart (1975). The length of the extruded cores were reconciled with the depth taken during field-work using the standard methods (i.e.

distribution of the loss or gain throughout the segment unless a compression or extension of a portion was obviously localized).

c. Sampling for pollen analysis.

A number of cores had been taken from each pond but only a few were analysed for pollen. The coring at each pond was done over a period of months due to the length of time the coring takes, the availability of sample chambers and the desirability of good weather conditions.

The first core from Northeast Pond penetrated a layer of stiff clay to reach underlying gyttja. The force necessary to penetrate the clay and to retrieve the sampler broke the coupling between the two boats, preventing further sampling that day. On returning to the laboratory the extruded basal core appeared to be badly contaminated by clay smeared along its surface. It was decided that another core was desirable although the core segments making up the first lake sequence were extruded and their stratigraphy noted. Subsequent coring parties from the boats and ice failed to penetrate the clay layer but encountered greater thicknesses of gyttja overlying the basal mineral sediment. The longest core of gyttja (NEP II: 5.26 m), from a point about 30 m distant from the first site, was used for pollen analysis as it was thought that this would allow a greater resolution of the early vegetation history. The basal section of the first core (NEP I: 4 m to 4.53 m) was also analysed since it had proved impossible to retrieve another similar segment. This core proved not to be as contaminated as initially thought, although the surface of the core had to be removed and samples taken from near the centre of it. The two profiles would be correlated by their pollen spectra after analysis. Other cores not used for pollen analysis proved useful checks as to the general stratigraphy of the lake sediments.

Two cores were taken from "Birch Hill's Pond". Both were used to verify the stratigraphy of the organic sediments. The longest core (BH I: 4.38 m) was chosen for pollen analysis since it was likely to provide a greater time resolution.

Samples to be processed for pollen were taken at intervals of between 2.5 cm and 10 cm from the cleaned surface of the chosen cores. The sampling interval varied according to the degree of resolution desired in the pollen spectra. Generally a closer sampling interval was used in the lower portions of the core or where stratigraphic changes occurred.

A sample of between 1 cm^3 to 2 cm^3 of sediment was removed from each level using a clean metal spatula, placed in a plastic vial, labelled with the core designation and the depth, and the lid sealed with wax to prevent the deterioration of the sample through moisture loss. Samples were taken from the whole core although not all samples were processed. This was because the study was concerned with the early postglacial period and consequently only the lower portion of the lake sequences were of interest. The higher samples were taken in case it was later decided these were necessary to the study.

d. Processing.

i. General Method.

The methods used to concentrate pollen grains for counting were determined by sediment type and were a combination of the procedures outlined by Faegri and Iversen (1975), Moore and Webb (1978), Bates, Coxon and Gibbard (1978) and Cwynar, Burden and McAndrews (1979).

ii. Processing for the calculation of pollen concentrations.

A known volume of sediment was processed so that following counting pollen concentrations could be calculated. Where sufficient sediment was available 1 cm^3 was processed. Exceptions where 0.5 cm^3 was processed are NEPI: 437.5 m, NEPI: 4.34 m and BHI: 4.38 m.

Prior to processing 0.5 cm^3 of a suspension containing a calculated quantity of *Eucalyptus* grains was added. Hence the exotic grains were subject to all the hazards experienced by the fossil grains during processing and it may be assumed that the grains were lost or destroyed in the same proportion. The suspension of exotic pollen was calibrated so that the approximate number of grains per ml of suspension was known (215.7 X 10^3 grains cm^{-3}). By the counting of *Eucalyptus* grains on each slide the concentration of the other pollen grains were calculated using the following formula

$$\frac{EX}{EX^1} \cdot n = N^1$$

where EX is the average number of exotic grains added,

EX^1 is the number of exotic grains observed in the sample's slides,

n is the number of observations per taxon,

and N^1 is the concentration of taxon per sample.

Values were corrected to 4 S.F. and are recorded in Appendix A, page 167.

iii Processing of organic sediments.

Samples from the cores designated NEPII and BHI were deemed sufficiently rich in pollen to make unnecessary the additional measures outlined by Bates et al. (1978) and Cwynar et al. (1979). Therefore the samples were concentrated using the standard techniques of KOH deflocculation to remove extraneous matter and humic acids; the HF treatment to remove siliceous matter and acetolysis using H_2SO_4 to destroy the cellulose of moss, leaves, rootlets etc. These techniques are standard and outlined by Faegri and Iversen (1975).

iv Processing of NEPI

The sediment of core NEPI was in part clay-rich. Such sediments are often poor in pollen and therefore it was decided to employ a further process to increase the concentration of pollen in the final residue. The procedure used is outlined by Cwynar et al. (1979) and Bates et al. (1978) and involves disaggregation with sodium pyrophosphate, and the discarding of material, including clay-sized particles which will pass through a fine screen. A 7 μm screen was used to collect the smaller pollens, as recommended by Cwynar et al. (1979).

v Mounting of samples.

All samples were mounted in silicone oil on precleaned microscope slides following the washing out of all reagents used during the preparation of samples and the final de-hydration with tertiary butyl alcohol and staining of pollen samples with safranin.

e. Microscopic technique.

Slides were examined using a binocular Zeiss Jena XaOC5 microscope with an ocular power of X8 and an objective power of X 40 giving a total magnification of X 320. Traverses were made at regular 2 mm intervals across the slide to avoid differences in grain dispersal beneath the cover glass. Determinations were made using a reference collection together with the keys from Kapp (1969), Richard (1970), McAndrews et al.(1973), Punt (1976), Moore and Webb (1978) and Bassett et al. (1979). An ocular micrometer was used to determine the proportions of certain pollen species distinguished on the basis of size.

The density of pollen grains varied between slides so that the number of slides counted per sample was not constant. With the exception of samples BH1: 3.70 m and NEPI: between 4.15 m and 4.34 m, counting continued until a minimum of 150 grains had been reached of both fossil land pollen grains and exotic marker grains. However complete slides were counted in all cases to counteract the sorting effect noted by Brookes and Thomas (1967). Samples BH1: 3.70 m and NEPI: between 4.15 m and 4.34 m were too poor in pollen for the normal pollen sum to be used. The pollen sum of BH1: 3.70 m was reduced to 100 fossil land pollen grains. The samples between 4.15 m and 4.34 m of core NEPI had very low quantities of pollen even though procedures were followed to concentrate that present. Only two slides from each of these samples were counted because of the disproportionately high amount of effort required to count even 100 fossil grains. The results are recognized as being less statistically significant than the results of other samples as generally less than 50 fossil grains were recorded.

The pollen sum includes all arboreal pollens plus those of the shrubs and herbs (including Cyperaceae). This sum was chosen because the purpose of the research was directed towards the study of the early post-glacial sediments and the early post-glacial pollen record has frequently an important non-arboreal pollen component. It is suggested that the regional pollen rain would be better represented by the three categories (tree, shrub and herb) than any one alone. The reconciliation of the demand for precision in identifying important pollen producers with the desire for speed in counting resulted

Counting continued over a period of five months and as the observer's experience increased the number of identifiable grains rose. In an effort to increase the compatibility of profiles and to avoid errors caused through erroneous identifications the counting of samples from core NEPI (the first profile worked on) was repeated.

The taxa were grouped into six major categories: tree, shrub, herb, aquatic, spore and the unknown with the indeterminable counts. Observations of Betula pollen were ascribed to either tree or shrub categories on the basis of measurements of grain diameter. Ives (1977) suggests that the majority of Betula pollen with a diameter less than 20 μm is that of the shrub B. glandulosa, with only minor amounts of B. nana and B. papyrifera. Substantial amounts of B. glandulosa pollen grains are found with diameters between 20 μm and 25 μm. Unfortunately there is an increasing proportion of grains of other Betula species with diameters above 20 μm. Therefore had all pollen grains with diameters less than 25 μm been assigned to "shrub" birch the count would most likely have included many "tree" birch taxa. Therefore it was decided that only those grains with a diameter of or below 20 μm would be recorded as "shrub" birch. In consequence the "shrub" birch component is probably under-estimated but the count is much more secure. Pollens with diameters greater than 20 μm were not differentiated but regarded as representing arboreal Betula sources. They are therefore referred collectively as "tree" birch but it must be noted that some larger "shrub" birch grains will have been accidentally included in this group.

The Coryloid category includes all triporate grains lacking a clear pore structure as well as Corylus grains. In the profile from NEPII Myrica gale was also included within the Coryloid category.

f. The calculation of pollen percentage values.

The results for each sample were translated into percentages of the pollen sum using the following standard formula

$$\frac{100}{Ps} \times n = N$$

where P_s is the pollen sum (ie. Σtree + Σshrub + Σherb)

n is the number of observations per taxon

N is the percentage contribution of n observations to the pollen sum.

The sum for the calculation of spore percentages was the sum of land pollen plus the sum of spores. Aquatic pollen percentages were computed in a similar fashion, using the sum of land pollen plus the sum of aquatics. For the final category of pollen grains the sum of all indeterminable and unknown pollen was added to the land pollen sum. Calculations are to 2 d.p in Appendix A,page 167. Within the text figures are corrected to 2 S.F.

[illegible]. Construction of pollen diagrams.

Percentage and concentration diagrams were constructed using the figures in Appendix A, page 167. All taxa are recorded on the percentage diagram while only those taxa which contribute more than 5% of the pollen sum at some point in their profile are included in the concentration diagrams. The standard techniques and conventions described by Moore and Webb (1978) were used in drawing of the pollen profiles.

3.4 Radiocarbon dating.

Five samples from the lower portions of the cores analysed for pollen were radiometrically dated. One sample was from core BHI and was from between 4.33 m and 4.38 m. The purpose of this date was to establish a minimum date for the deglaciation of the "Birch Hill's Pond" site. It would also provide an initial point of reference when comparing it to the profiles of Northeast Pond, Macpherson (1980) and Terasmae (1963).

From Northeast Pond four samples were submitted for radiocarbon dating. The original reason for the submission of the sample from between 5.21 m and 5.26 m of core NEPII was to link the pollen profiles of cores NEPI and NEPII. However as will be discussed in Chapter Six this date provides the oldest minimum age for the deglaciation of Northeast Pond.

The whole of the datable portion of core NEPI has been submitted for radiocarbon dating. The lowest material (between

4.53 m and 4.48 m) was submitted initially to provide a minimum age for the deglaciation of Northeast Pond. Following an unexpectedly recent age determination the rest of the gyttja retrieved from beneath the clay was submitted for dating (4.35 m to 4.48 m). In an effort to clarify the position of the core NEPI further the sediment recording the transition from clay to gyttja (from between 4.00 m and 4.15 m of the NEPI core) was dated.

The procedures followed to avoid contamination of the cores with radiocarbon were outlined in section 3.3. a., page 52. Before the samples were shipped to other laboratories for the actual radiocarbon dating a preliminary stripping of the surface of the sample was done. This precaution was in case the outside of the core had been contaminated by its juxtaposition with the coring chamber.

3.5. Regional morphology.

The area's morphology was studied using three approaches. Evidence and conclusions drawn by previous workers (Henderson 1972, Maher 1973, and Vanderveer 1975) concerning the surficial and solid geology of the area were reviewed prior to an examination of the area using air photographs. Field reconnaissance of the local area provided an opportunity to verify and examine the morphology in more detail.

The airphotograph coverage at a scale of 1:161700 with a few enlargements of a scale 1:7800 was used to locate melt water channels, bedrock exposures, moraine-like features and as an indication of the easiest access to the area. During field reconnaissance selected features noted either during the airphotograph examination or by earlier workers were examined. Note was taken of the distribution, depth and appearance of till, the orientation of glacial striations, the appearance of exposed bedrock and quartz veins and other features which might suggest the area's late-glacial history.

The morainic feature believed to be an end-moraine mentioned by Henderson (1972) has been exposed through quarrying to the north of "Birch Hill's Pond". The excavations allowed an examination of the feature's stratigraphy and an analysis of the exposed till's fabrics and particle size ranges. Fabric analysis and wet sieving were done according to the standard methods described by Briggs (1977) and Bowles (1954) for three and eight samples, respectively. The position from which the eight wet sieved samples were taken is shown in Figure 4.8, page 73, as well as a description of the feature's exposed stratigraphy. It was believed that the information obtained about the fabric and particle size would be of help in determining the tills' geneses.

Chapter 4

Glacial Geomorphology.

4.1 Introduction.

The results will be examined in the following three chapters; Chapter 4: analysis of the region's glacial geomorphology, Chapter 5: analysis of the evidence from basal sediment from "Birch Hill's Pond", and Chapter 6: analysis of the evidence from basal sediments from Northeast Pond.

In this chapter a qualitative-descriptive approach has been adopted in discussing the observations of glacial and proglacial features. Throughout this chapter reference will be made to Figure 4.1 on which examples of the features discussed are located using symbols indicated in the text. Where appropriate other more detailed figures are included and are an integral part of the discussion. The second part of the chapter will examine the possible implications of the geomorphological evidence for the glacial chronology of the area.

4.2 Geomorphology.

a. Glacial erosion in the field area.

i Valley form.

As described in Chapter 2 the structural geology has

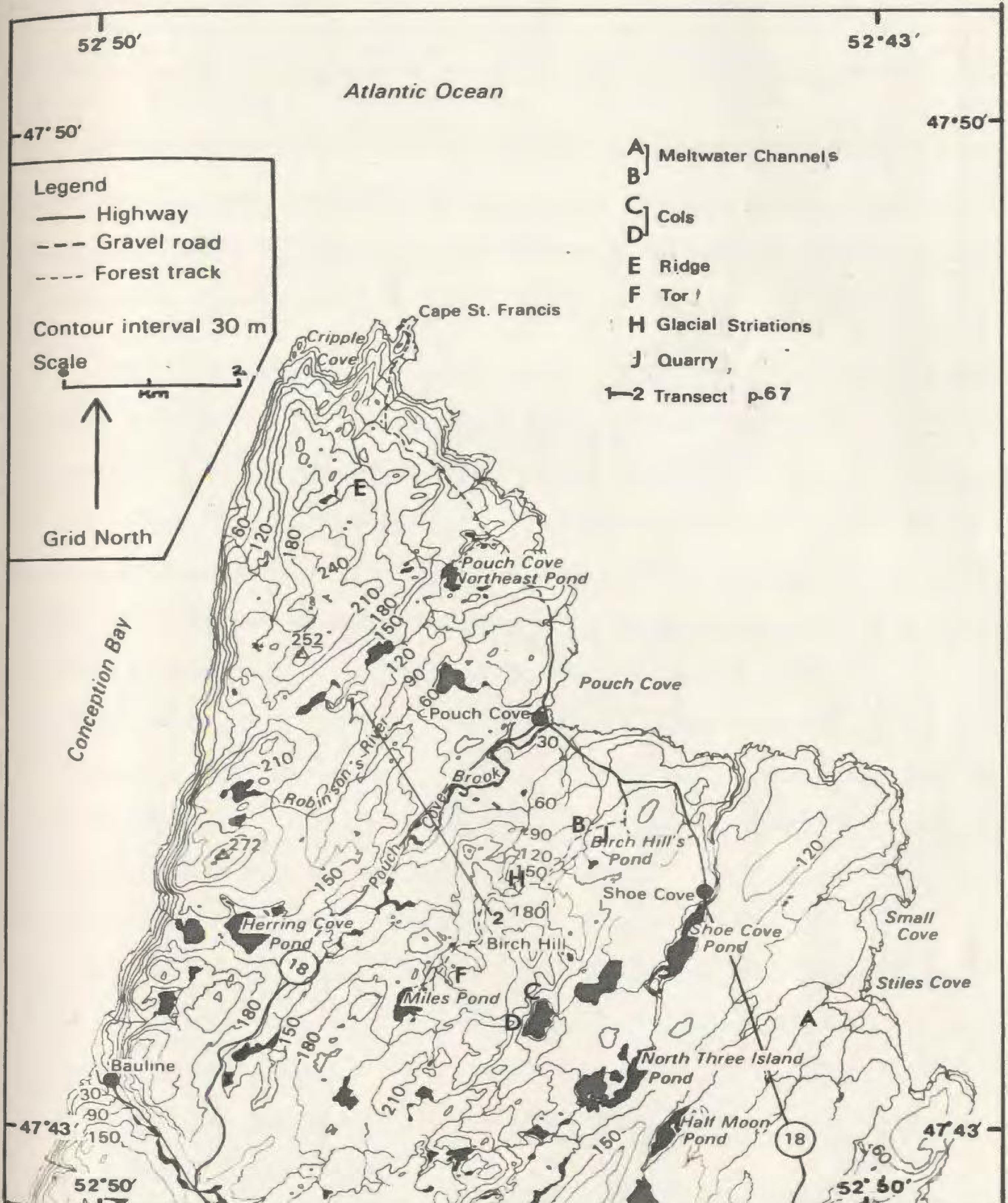


Figure 4.1 Map of the study area locating areas referred to in the text.

dominated the northeast to southwest orientation of the valleys in the area. The relief is dominated by a highland spine extending north-south along the western coastline from which occasional highland ridges extend northeast across the St. John's Peninsula; see Figure 2.1 page 28. These ridges are breached at various points by glacially shaped cols; such as C and D (Figure 4.1) southwest of "Birch Hill", suggesting that glacier ice overtopped the ridges.

The intervening valleys are characteristically U-shaped troughs with their walls rising steeply from the valley floors. Figure 4.2 is a cross section north-south across the "Bauline-Pouch Cove trough" with its position indicated on Figure 4.1. Valley shape may reflect the fault guided nature of the valleys. On occasion the valleys become more constricted in the centre of the Peninsula. In such locations the air photographs suggest a step in the valley floor but this could not be identified in the field. The width of the valley floors varies but is greater than the present drainage can account for. Numerous lakes and small streams occupy the trough floors. Generally the misfit streams have little modified their valleys although the lower courses of both the Pouch Cove and Shoe Cove brooks are incised. The trough floors are covered with a veneer of till. Those valleys south of "Birch Hill" appear to have a more hummocky uneven floor than those to the north.

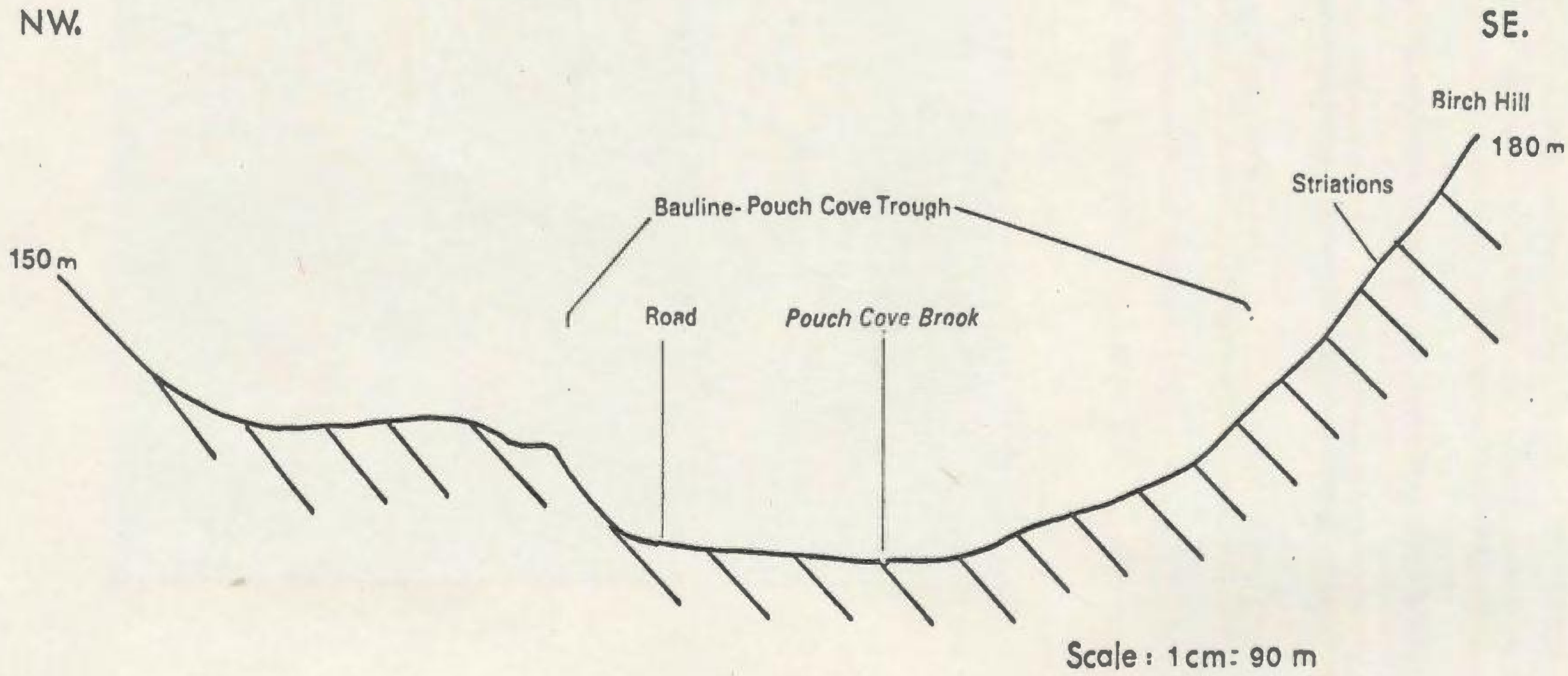


Figure 4.2 Cross-section of the "Bauline-Pouch Cove trough".

Figure 4.3 Roche moutonnée, south of Cape St. Francis.

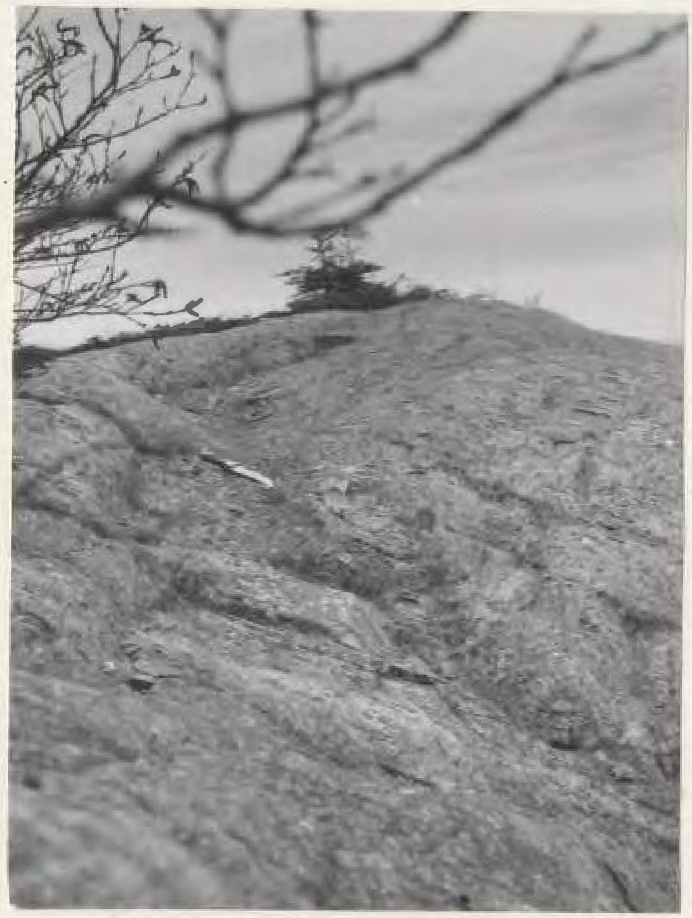


Figure 4.4 Glacial smoothing, south of Cape St. Francis.

ii Ice moulding.

Many of the rock surfaces have been glacially sculptured and the form of those found in valleys or along the east coast suggests that they were moulded by ice moving towards the coast in a northeasterly direction. Figures 4.3 and 4.4 are examples of glacially smoothed rock features found south of Cape St. Francis. Movement of ice down the slopes of "Birch Hill" is suggested by the glacial moulding and plucking of bedrock outcrops on its slopes.

The surfaces of many of these forms have a weathered appearance in that major joints are being exploited by weathering processes and that some surface mineral grains have been weathered out (Figure 4.3). As the occurrence of glacial till increases southward these forms are frequently veneered with till while elsewhere accumulations of till have been glacially shaped. For instance north-northeast of 'Birch Hill' there are elongated forms with a north-northeast orientation which are suggestive of drumlinoid deposits.

iii Glacial striations.

Two sets of glacial striations were found on a recently exposed rock surface, on the north facing slope of "Birch Hill" (Figure 4.1: H). The orientations of the sets are 50° for the stronger and 15° for the weaker and probably the more recent set (Figure 4.5). This suggests that movement was towards the northeast and north from the steep slopes of

Figure 4.5
Two sets of striations exposed on the NW slope of "Birch Hill".

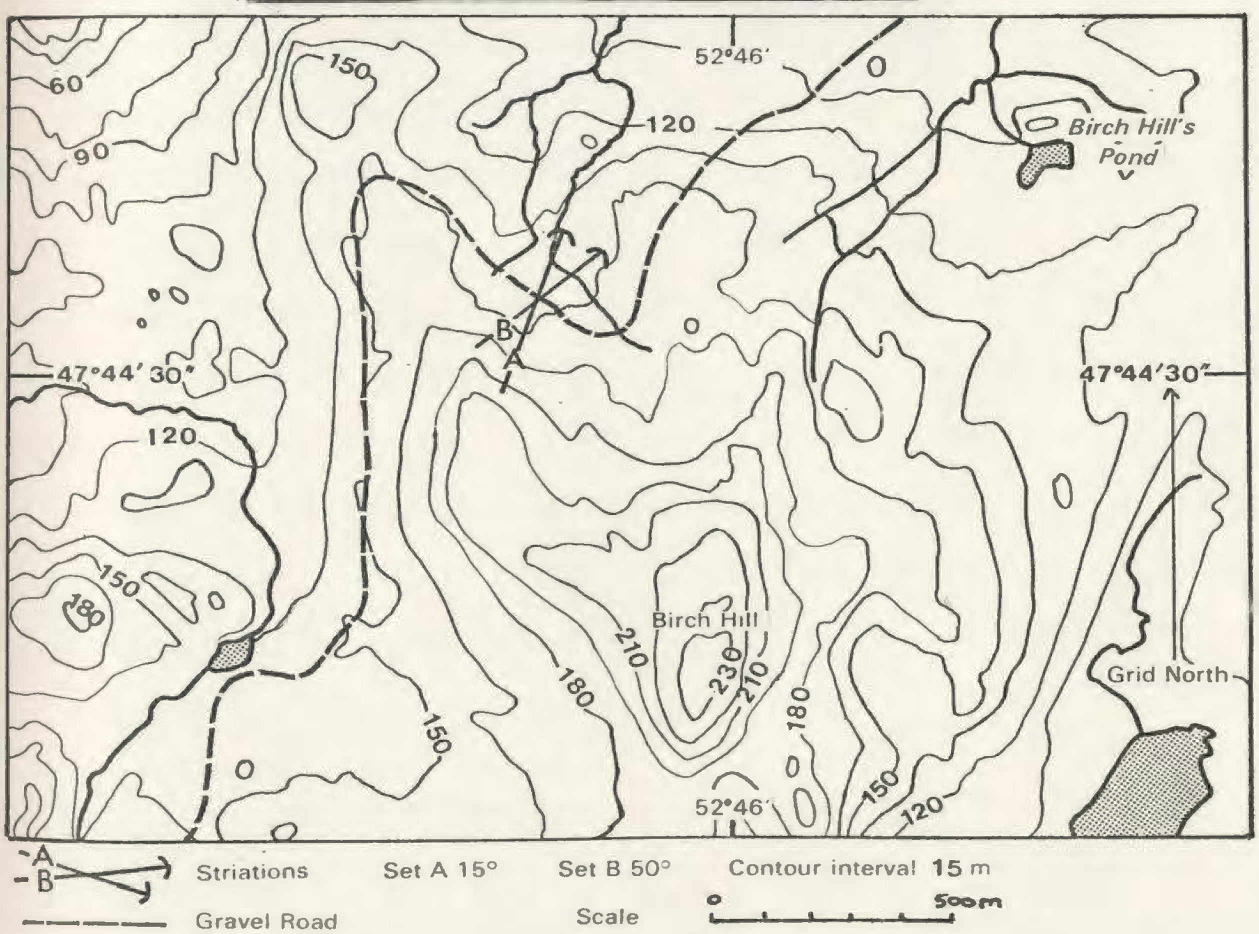


Figure 4.6 Map of "Birch Hill" with the location of the sets of striations.

"Birch Hill" (Figure 4.6). The glacial features north of Pouch Cove (whale backs, roches moutonnées etc.) are generally orientated between 50° and 60°, suggesting that ice moving in the same direction was involved.

b Glacial deposits.

i General distribution of till.

The depth and distribution of till varies within the study area. The troughs and coastal area have an inconsistent veneer of till, which locally increases in thickness to more than 4 m as in the quarry SSE of Shoe Cove Pond (Fig. 4.12, p. 80) but is elsewhere pierced by bedrock. The ridges to the north of Pouch Cove are bedrock, whilst less steep hillsides to the south are frequently covered by a thin veneer of till or colluvium, although the summits often expose fractured bedrock. Till is generally thin and patchy along the eastern coastline, from Cape St. Francis to the northern limit of the settlement of Pouch Cove. The reader is referred to Figure 2.3, page 32, which depicts the relevant portion of Vanderveer's (1975) study of the surficial geology of the St. John's area, which field checks have shown to be a fair general representation of the distribution of till within the area.

The till of the region is derived from the local rock. The surface till is stony, the clasts being of pebble to cobble size with occasional boulders. Often the upper till is washed with the matrix being largely composed of sand

and coarse silt with little clay or fine silt. Observations at road cuts and quarries suggest that the upper surface has been leached to depths of between 0.5 m and 1.0 m with an iron pan forming at approximately this depth.

The covering of till becomes more continuous towards the southern limit of the field area. South of 'Birch Hill', especially around North Three Island Pond, the trough floors have the appearance of a chaotic assemblage of low hills. These are emphasized in some instances by the shapes of lakes (eg. North Three Island Pond).

<u>ii Stratigraphy and deposits exposed by quarrying in the area.</u>

The quarry 1.3 km west-southwest of Stiles Cove (Figure 4.12: 1,page 80) exposes over 4 m of the stony surface till. The stratigraphy exposed in the "Birch Hill's Quarry" (Figure 4.1: J) is more complex. The quarry is cut into an asymmetrical arcuate moraine (Figure 4.7). To the south is "Birch Hill's Pond" and to the north a meltwater channel separating the feature from a linear till ridge. The quarry is still in use so exposures are constantly changing. The elongated ridge is in the process of being cleared in preparation for similar excavations.

A stratigraphic description of an east facing exposure in "Birch Hill's Quarry" will be given since it exhibits most of the features noted (Figure 4.8). The samples for wet sieving were taken from this face. The organic soil was removed prior to the commencement of quarrying. The

Figure 4.7 "Birch Hill's Quarry".

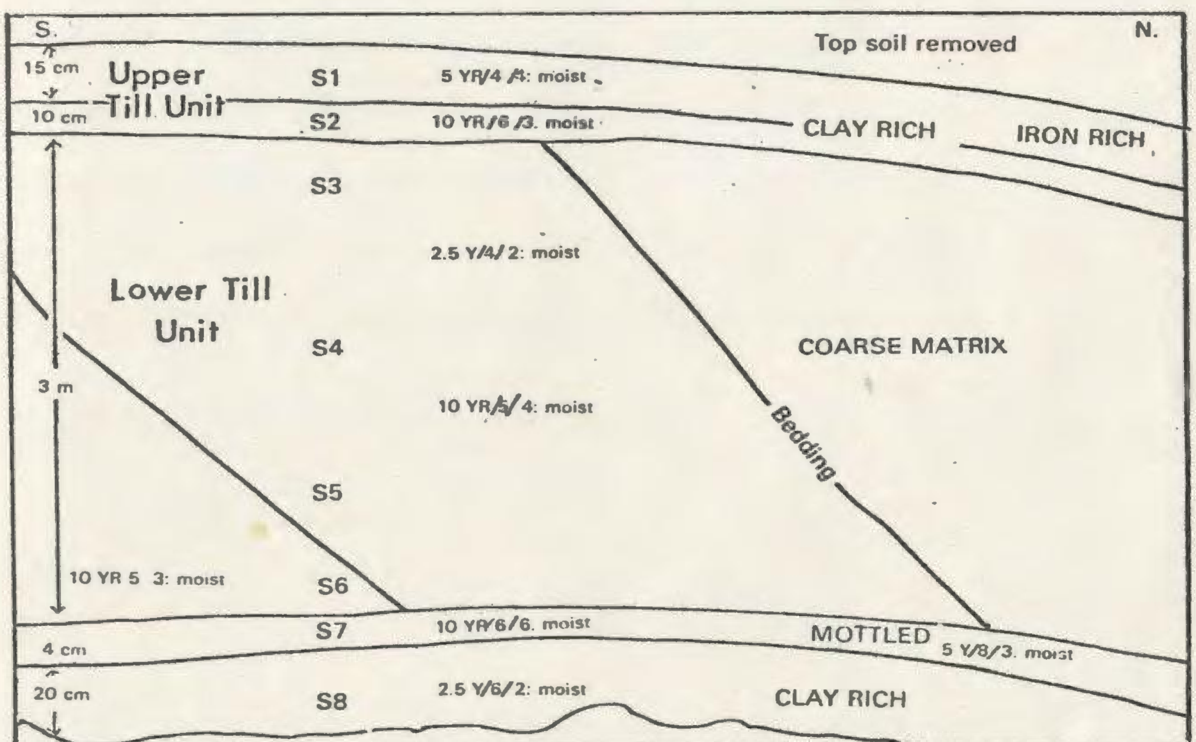


Figure 4.8 East facing exposure at "Birch Hill's Quarry".

face exposes two till units differentiated primarily by the bedding and highly fractured clasts of the lower till compared to that of the upper. The upper till is stony and extends in this exposure from the present surface to a depth of 25 cm with an iron rich layer below 15 cm. The lower till appears to be washed and to be composed of highly fractured stones ranging from pebble to cobble size with some boulders, also fractured. The lower till appears to be bedded in a southwest to northeast direction. The matrix is very coarse, (89% to 96% > 4 Ø) compared to the overlying till (63% to 74% > 4 Ø). The lower unit extends for 3 m. Below this there are two distinct layers which may represent eluviated horizons of transposed clay-sized particles from the till unit above. Wet sieving results indicate that 64% to 73% of the matrix is greater than 4 Ø which is comparable with the upper unit. Talus covers the lower slope of the face so that only 24 cm of the vertical extent of the lower beds is exposed. The layers are differentiated by colour differences. The upper bed is 10 YR 5/4 and mottled with 5 Y 8/3: moist, while the lower is 2.5 Y 6/2: moist.

Table 4.1 Wet sieving results

	Upper till unit		Lower till unit					
Sample No.	1	2	3	4	5	6	7	8
> 4 Ø	74.49	63.32	95.68	92.19	92.77	89.43	63.69	72.75
< 4 Ø	25.51	36.68	4.32	7.81	7.23	10.57	36.31	27.25

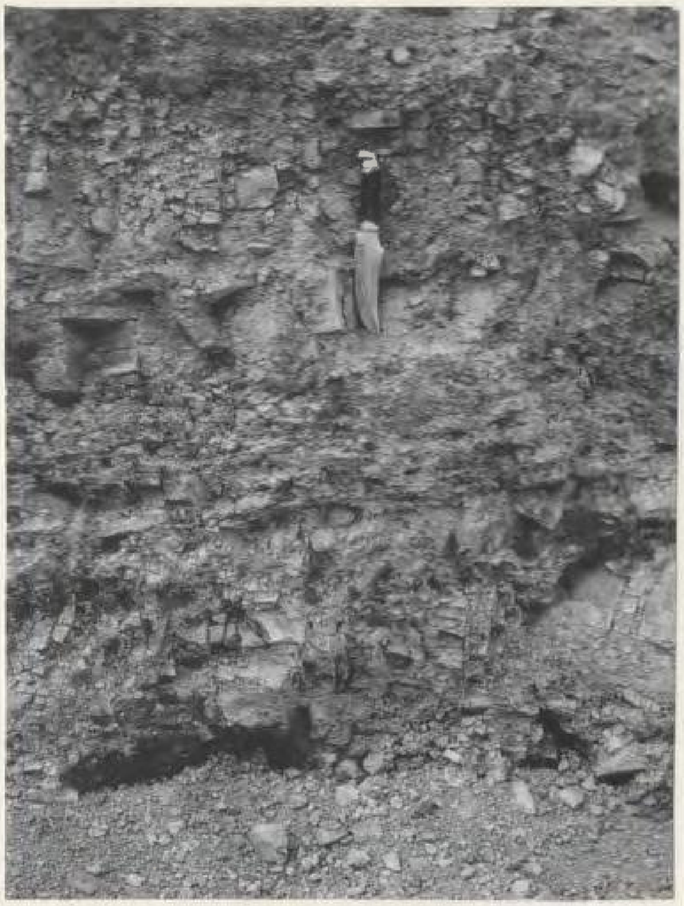


Figure 4.9 "Birch Hill's Quarry", lower till unit.

The two tills are exposed by the major cuts through the morainic feature but the amount of visible bedding varies. So far only the upper till unit with its iron pan has been exposed on the elongated ridge to the north.

A bedrock knob has been exposed about 1 m below the ridge in which the "Birch Hill's Quarry" has been cut. The lower slopes are generally mantled with talus but bedrock is not visible until outside the northern limit of the quarry. The identification of bedrock is complicated by the inclusion of large boulders in the lower till unit, the lower limit of which is obscured by talus and which appears to rest on highly fractured bedrock (Figure 4.9).

Three fabric analyses were done: one on the upper till and two on the lower. The results are plotted as Figure 4.10: a, b and c respectively and show significantly preferred orientations with modes of 95° N, 145° N and 35° N. There is no evidence to suggest that the upper till is of colluvial origin, since the fabric readings were taken below the summit of the ridge bisected by the quarry face and all were well within the interior of the feature.

One other feature, since destroyed, was an apparent ice-wedge cast. This extended from below the junction of the two tills for 0.5 m (Figure 4.11). The wedge was infilled with coarse pale rock fragments, some of which were shattered quartz. No other wedges were found.

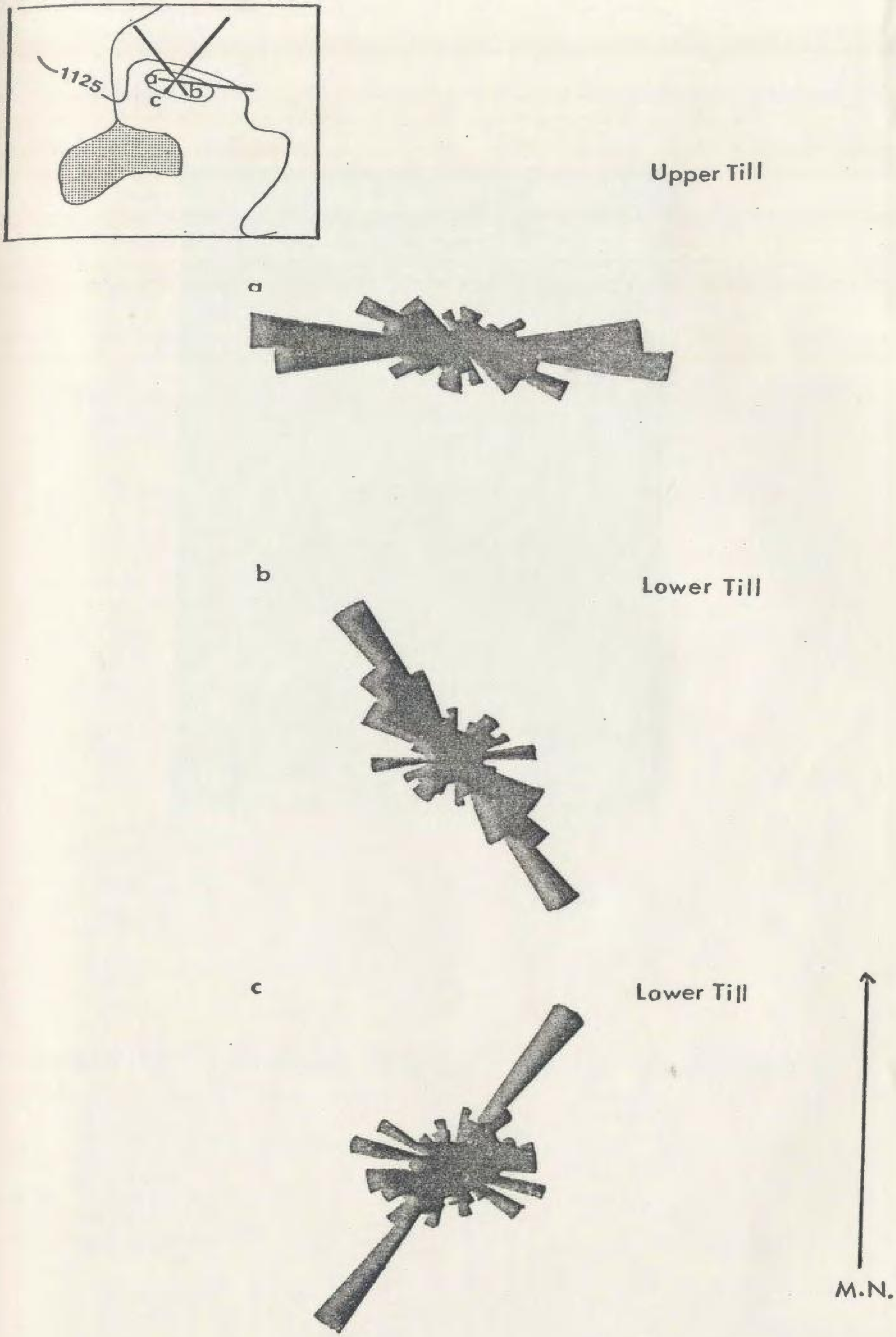


Figure 4.10 Fabric graphs from till exposure at "Birch Hill".

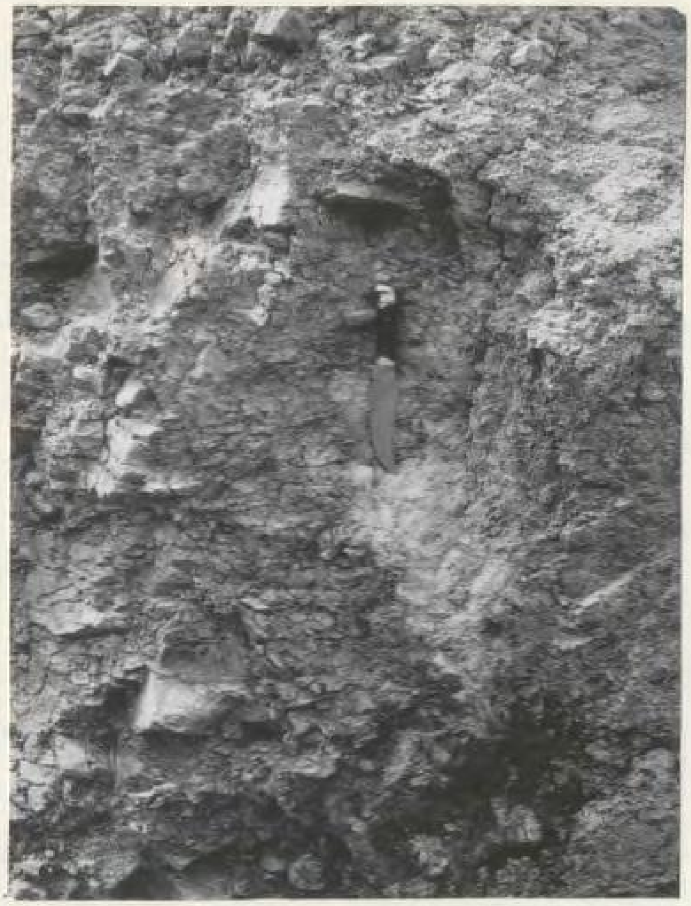


Figure 4.11 Ice-wedge cast exposed at "Birch Hill's Quarry".

c Meltwater Channels.

The best developed meltwater channels are in the southeast of the study area (Figure 4.1: region A). Five channels can be traced from the troughs now partly occupied by North Three Island and Half Moon ponds across a narrow dissected plain to converge (all except one) on Stiles Cove (Figure 4.12). The longest (3.9 km) and most northerly channel connects North Three Island Pond to a cove north of Small Cove. The inset in Figure 4.12 is a cross-section aligned north-south showing the valley's shape. There is no reason to suppose that these features were formed parallel to an ice front or subglacially. Their shape, distribution and location suggest that they were cut by meltwater draining away from an ice mass to the southwest across a plain veneered with till which they dissected. Two quarries demonstrate that the channels have been cut into till. The most northerly quarry is cut into the ridge separating the channel occupied by Half Moon Brook from the most northerly channel and it shows the till to be over 4 m thick in places.

In the west of study area distinct meltwater channels were not found. Along the Conception Bay coastline of the St. John's Peninsula the terrain is more hilly with the fault-line scarp forming the western margin of the hill range plunging to below sea level. Minor meltwater channels may be obscured by the forest vegetation whilst the general lack of surficial material along this coastline would mean

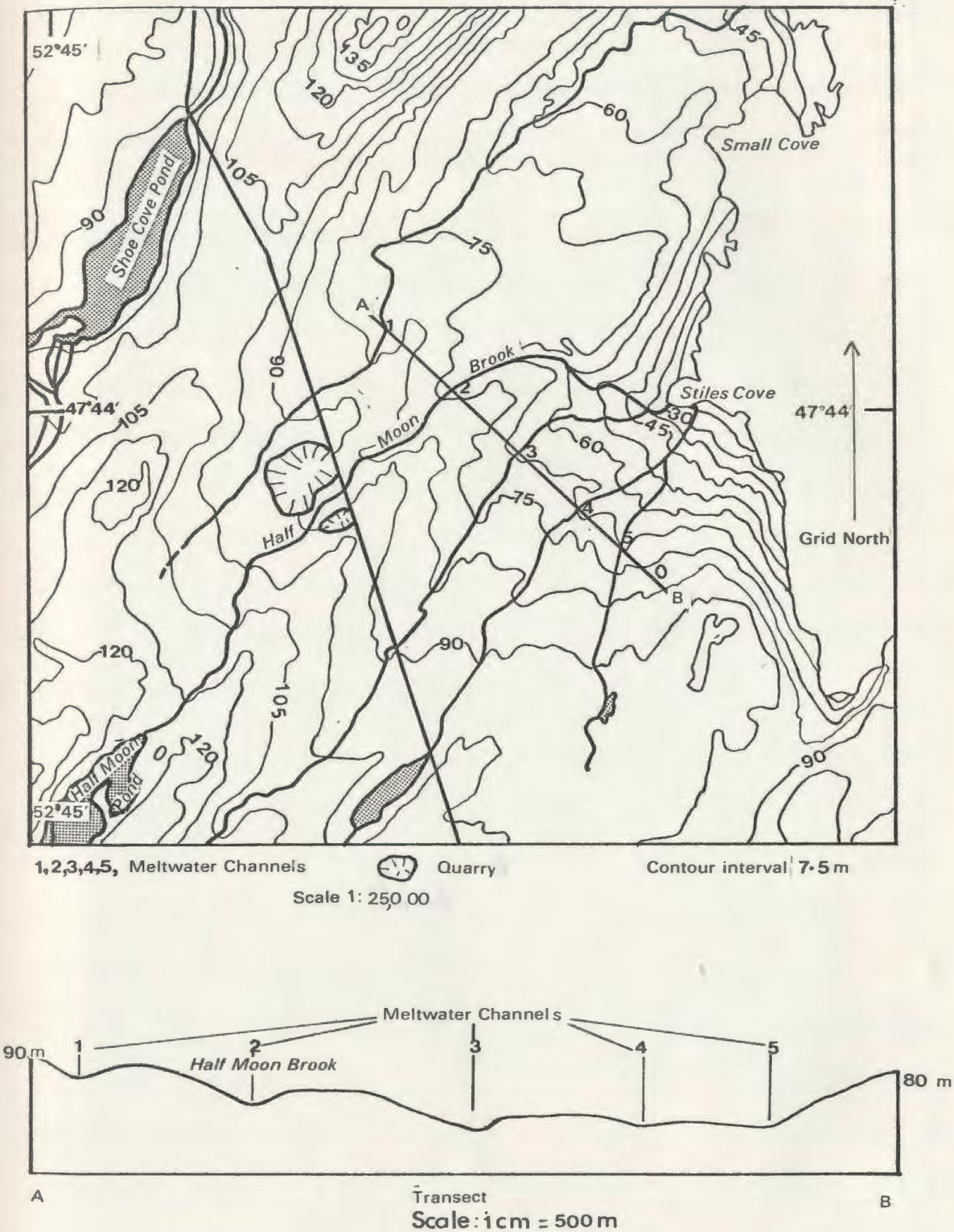


Figure 4.12 Map of the meltwater channels SE of "Birch Hill" Transect illustrates the position of the channels on the map.

that any meltwater channel similar to those in region A would be eroded into rock and would not be so highly developed.

Identification of channels just south of Pouch Cove (Figure 4.1: region B) is complicated by the structure of the bedrock which obscures such features. The complex relationship between bedrock spurs and glacially streamlined forms is illustrated near "Birch Hill's Pond". From airphotographs an apparent meltwater channel is cut north-eastward from the outlet of "Birch Hill's Pond". Field reconnaissance indicates that this identification is insecure since the "channel" is the valley between a glacially streamlined hill to the east and a bedrock spur to the west. It may have been used by glacial meltwater flowing from an ice margin but its form owes less to this function than do the features identified in region A.

The moraine to the north of "Birch Hill's Pond" may be separated from the glacially moulded till ridge to the north by a small (0.3 km long) meltwater channel. This channel, now occupied by a small stream, joins the features described in the previous paragraph.

The postglacial drainage (notably Pouch Cove Brook and the lower course of the Robinson's River) has occupied and modified old meltwater channels. Airphoto coverage of the area suggests that several less distinct channels converge at Pouch Cove from the "Bauline-Pouch Cove trough" and from Old Pond to the north.

Figure 4.13 Summit of "Birch Hill".

Figure 4.14 Summit of ridge E.

d Post-glacial weathering.

Exposed bedrock is generally well weathered. The summits of ridges to the north and south of Pouch Cove are bouldery where weathering has exploited the massive jointing of the rocks. Figures 4.13 and 4.14 allow a comparison of the summits of "Birch Hill" and the ridge northwest of Northeast Pond (Figure 4.1: E). Both are well weathered schists and volcanic rocks from the Harbour Main Group. The slopes of ridge E are very steep and boulder strewn (Figure 4.15). Ridges further south have generally less steep slopes (perhaps a function of the structural geology) and are veneered with till and colluvium except where minor bedrock ridges cut the surface or where slopes locally increase (Figure 4.16). Quartz veins commonly occur in the country rock. Boyer and Pheasant (1974) used the projection of quartz veins as an indicator of relative weathering rates. Although no systematic sampling was carried out, it appeared from random observation on the ridges that the majority of projections on the summits of "Birch Hill" and ridge F northwest of Northeast Pond were between 1.1 cm and 1.5 cm for both. This weathering parameter failed to indicate any difference between the summits. The appearance of surface boulders has been affected by fire which has caused the outer weathered layer to spall off. This further complicates observations on surface weathering of rocks.

Figure 4.15 Boulder strewn slope of ridge E.

Figure 4.16 "Birch Hill" with minor bedrock ridges exposed on the slopes

Bedrock is occasionally exposed on the floors of troughs. Such an apparent incongruity in the landscape occurs 1 km southwest of "Birch Hill" (Figures 4.1: F, 4.17). Here, from what appears to be a gently undulating plain of till, rises an angular "tor-like" structure of heavily faulted volcaniclastic rock incorporated with mudstone (R.J. Rogerson, pers. comm.). One explanation for the feature is that the till is locally very thin so that a bedrock knob has been left exposed to weathering since deglaciation. Any modification of the form of this structure by glacier ice has been obliterated by the effectiveness of post glacial weathering. A road cut near the base of the slope of 'Birch Hill' (south-southwest) shows the till at this locality to be at least 2.5 m thick. Above this a soil has developed on parent material of probably colluvial origin which overlies the till. Approximately 0.7 m of colluvium is exposed. As the "tor-like" feature rises above surface till the depth of till must be variable. The bedrock knob has been weathered along its joints and the rock is mechanically very weak in that it can be broken along its fracture planes with little effort. Why this bedrock knob was not removed by the glacier ice is open to speculation since it appears easily erodible. Perhaps this feature represents the only remnant of a formerly more massive projection which was greatly affected by a former ice cover. Another possibility is that the feature was previously mantled by a thin till layer which has during the postglacial been removed by weathering processes.

Figure 4.17 Tor-like feature SSW of "Birch Hill".

4.3 Interpretation of the evidence.

a. Reconstruction of glacial events from geomorphic evidence.

The distribution of geomorphic features has been used in reconstructions of the glacial history of eastern Canada (eg. Grant, 1977a, 1977b for Newfoundland and the Maritimes). The inferences drawn are most reliable when supported by an absolute or at least independent chronology, since features themselves do not necessarily indicate their relative ages. Interpretation of the glacial history of an area is complicated if features formed during different glaciations are present. The preservation of features formed during various phases of glaciation, (during advance or retreat under marginal and subglacial conditions) may also create a false impression of a series of advances over an area. It is suggested that the glacial geomorphology of the study area contains elements of more than one glaciation but also that some features may have been formed during the same glaciation but during its different phases.

b. Active glacial ice.

The valleys show strong glacial modification in their form (ie. Figure 4.2). The structural geology of the area has aided valley development but the dominant glacial shaping suggests that the valleys have been important channels for ice movement. Their orientation suggests such flow was northeastward toward the Atlantic coast of the peninsula. The bedrock forms found near Figure 4.1: E have a similar orientation as does the stronger set of striations (50° N) from "Birch Hill". Features veneered with till near "Birch Hill" show a similar orientation.

The existence of cols along the ridges bordering the troughs suggests that there has at some time been a more northerly component to flow. Glacial sculpturing apart from the cols does not record this event.

The less well developed striations from "Birch Hill" do record a movement toward 15° N. It is suggested that this most likely does not record the movement of ice which breached the ridges but rather a more feeble flow moving down the hill slope in response to gravity. This more feeble flow may have resulted from the accumulation of ice on summits and slopes which under the influence of the topography flowed into the "Bauline-Pouch Cove trough". The parallel ridges would tend to funnel flow into the troughs, which since their initial excavation would have presumably channelled subsequent ice flow.

Henderson (1972) records striations along the "Bauline-Pouch Cove valley" which suggests that the last ice movement was towards Pouch Cove. Other striations north and east of the major slipway of Pouch Cove also suggest a final north-easterly movement of ice. These striations are recorded on Figure 2.2: page 30.

If the striations orientated towards 15° N are attributable to the last glacial ice and those of Henderson record the same event then it is suggested that the last ice cover of the St. John's Peninsula was relatively thin. The ridges separating the troughs had a thin covering of local ice which under the influence of gravity flowed into the troughs and coalesced. The trough ice also took up a flow largely conditioned by gravity towards the Atlantic coast because of the drainage divide along the west coast. The ice in the "Bauline-Pouch Cove trough" could not have filled the trough since the younger striations of "Birch Hill" fail to record a strong easterly component to flow which they would surely have otherwise. The older striations orientated 50° N reflect a period when ice was much thicker and appears to have been less influenced by topographic control of "Birch Hill". These striations suggest that flow was being funnelled through the "Bauline-Pouch Cove trough" even at 110 m above the valley floor. It is open to speculation whether the two sets of striations are the product of fluctuating ice thicknesses during the expansion or thinning of the last ice or were the product of two distinct glaciations.

c. Passive or stagnant ice.

To the south of "Birch Hill" till deposits on the trough floors do not appear to be streamlined. The troughs are still aligned in a southwest to northeast direction but deposits on the valley floors are chaotic and lack the moulding of till and bedrock of further north. It is suggested the valley and coastal landscapes described for the south of the study area are the product of deglaciation or ice stagnation rather than the active processes as recorded in the north. The identification of a series of proglacial meltwater channels suggests that they drained away from an ice margin within the troughs. As the meltwater channels are cut into till it is probable that ice advanced across the area and most probably beyond the present coastline at some time. Evidence of an ice margin beyond or at the present coastline is supported by the glacially sculptured bedrock and till forms found all along the east coastline. Henderson (1972) suggests that many of the smoothed bedrock forms were produced by an increase in ice velocity as it plunged over the cliffs. In any event their presence does indicate that former ice sheets have extended to this point. However the question arises as to whether or not the glacially eroded forms and the ice stagnation features were formed by the same ice cover or during two different expansions of ice.

d. Glacial episodes.

Less debatable evidence as to the number of glacial episodes recorded within the region came from the observations of "Birch Hill's Quarry".

The "Birch Hill's Quarry" has exposed two till units in a feature believed to be the end moraine recognised by Henderson. Although further extensive research of a more specialised sedimentological nature is required in and around this area, sufficient preliminary analysis, (air photographic interpretation, stratigraphic descriptions, preliminary fabric analysis) has been concluded to shed doubt on Henderson's initial interpretation of the feature.

The present surface expression of the feature is reminiscent of an arcuate moraine (Figure 4.7). However, an original feature may extend towards the north-northeast and is basically drumlinoid in shape. The arcuate form has been produced by a subglacial meltwater channel bisecting the feature towards its southern limit.

The stratigraphic sections suggest that the initial feature may have been a crag-and-tail or rocdrumlin, since the lower till has been largely deposited in the lee of a bedrock protrusion. However, the bedding within this till and the fractured characteristic of the stones is reminiscent of the lee-side tills described by Hillefors (1974) from western Sweden. Fabric analysis indicates that the lower till shows a significantly preferred orientation (Figure 4.10:b,c), compatible with the stream-lining found in subglacially deposited tills.

The status of the upper till is unknown. It differs visibly from the lower unit in the less fractured appearance of its clasts, the lack of stacking or bedding and its generally more clay-rich matrix. The appearance of the surface till resembles that of other surface diamictons found within the area. There is an unconformity between the units, since the upper till has apparently been deposited subsequently to the removal of some of the lower till. This is inferred from the partial removal of some of the beds from the lower till (Figure 4.8). The upper till is significantly orientated 95° N which suggests that ice may have been moving parallel to the feature's present long axis. The dissection of the initial form by the meltwater channel may have occurred prior to this as the upper till blankets the whole form. The meltwater channels most probably were re-used, funnelling water.

Speculation as to the status of the two units (ie. different glacier advances separated by an interglacial or minor interstadial) leads one to consider the feature described as an ice-wedge cast (Figure 4.11). Had this structure penetrated from the hiatus between the tills and could it have been securely identified as an ice-wedge cast, inferences about the temperatures during the time of formation (i.e. the period between the deposition of the tills) may have been made based on the work of Péwé (1966). However, the feature is within the lower till unit and a positive identification was not made before the face was destroyed. Unless fresh quarrying reveals further evidence the problem seems unlikely to be solved.

In summary then: the tills are markedly different in visual appearance, clay sized content of the matrix, bedding and clast integrity, and both show different strongly preferred orientations. These characteristics together with the subglacial origin suggested for the feature formed of the lower till are incompatible with the interpretation of the total feature as an end moraine formed during either depositional phase. From the presence of two subglacial tills it is inferred that at least two glacial phases are recorded. The length of time and conditions between each phase cannot be suggested at this time.

4.4 Summary.

The picture emerging from the regional geomorphology indicates that the whole area has been glaciated in the past. An interpretation of the gross ice flow pattern could suggest that more than one glacial expansion is recorded in the landscape:

ie. 1. glacially modified valley troughs orientated southwest to northeast

2. high level cols breaching ridges bordering the troughs.

Similarly the exposure of two tills at "Birch Hill's Quarry" may also indicate two glacial advances in the area. However an equally valid interpretation of the evidence could relate these differences to the waning and waxing of one glaciation.

The distribution of glacial and related features suggests that within the area two zones can be recognized. Zone I, north of the "Bauline-Pouch Cove trough" can be characterized as follows:

1. the till covering is not only sparse on the valley slopes but also on the valley floors.

and 2. the forms of till and rock have been glacially moulded and streamlined. Glacial erosion is most noticeable near the coast.

Zone II, the "Bauline-Pouch Cove trough" and the area to the south is characterized as follows:

1. the mantle of till covering troughs and ridges is more complete.

2. morainic forms are less streamlined

and 3. the development of a distinct proglacial meltwater system south of "Birch Hill".

The landscape of Zone I can be broadly regarded as the result of eroding, moving ice. That of Zone II contains elements of Zone I, for instance the trough orientation and shaping. However, the smaller features of the area lack the sculpturing of the north and seem to be more akin to the blanketing of an area with till by a non-eroding ice sheet.

The zones may record different phases of one glaciation. The ice-moulded features of Zone II could be the product of glacier ice active at the same time as that recorded in Zone I.

The chaotic features of Zone II might then relate to a later period, perhaps when the ice in Zone I had disappeared. The ice that remained in Zone II was probably thin and/or inactive and so failed to streamline deposits.

Another interpretation is that the zones are the product of two separate ice covers. In this interpretation an early advance of ice extended from a centre in the southwest to beyond the present coastline of Cape St. Francis. During this advance many of the erosional features now visible in the whole study area were formed. The cols connecting the troughs may relate to a period during this advance when the ice was sufficiently thick to over top the intervening ridges. The lower till of "Birch Hill's Quarry" could correlate to the major ice advance of this glaciation.

A second advance of ice from the southwest failed to extend far north beyond the "Bauline-Pouch Cove trough". It may have been of limited thickness, with the greatest concentrations of ice found in the troughs and only a restricted covering of ice on the intervening ridges. Ice would have moved under the influence of gravity from the ridges and into the troughs where flow continued towards the east coast. A thin covering of highland ice must have existed over Zone I since periglacial deposits are not more pronounced here than Zone II but presumably the ice failed to gain any momentum. The surface till of Zone II (including the upper unit of "Birch Hill's Quarry") would then relate to the second advance.

The chaotic forms in the troughs of Zone II reflect the inability of the last ice to affect the terrain beneath it. The development of the meltwater system suggests an environment of high water discharge. This may perhaps relate to the stagnation of trough ice during deglaciation.

To verify either interpretation the glacial geomorphology has to be linked convincingly to a time scale; either absolute or relative.

Chapter 5

Analysis of the lake sediments from "Birch Hill's Pond".

5.1 Introduction.

Within this chapter the observations and analyses of the results from the sediments of "Birch Hill's Pond" will be outlined. Suggestions will then be made as to the interpretation of the results from this pond.

5.2 Results from "Birch Hill's Pond".

a. Stratigraphy

Two cores were taken from "Birch Hill's Pond" and both revealed a similar stratigraphy. The following stratigraphic description is based on the 4.38 m long BH I core and is represented diagrammatically on Figure 5.1.

The sequence shows a change in the type of sediment preserved; telmatic peat is sandwiched between gyttja. The sequence terminated when the corer struck rock or gravel with no transition to minerogenic sediment found. The degree of humification varies but the matrix remained a uniform black colour (10 YR 2/1: moist). The lowest gyttja (4.38 m to 4.19 m) has little fibrous or woody matter. At a depth of 4.19 m the amount of fibrous organic material

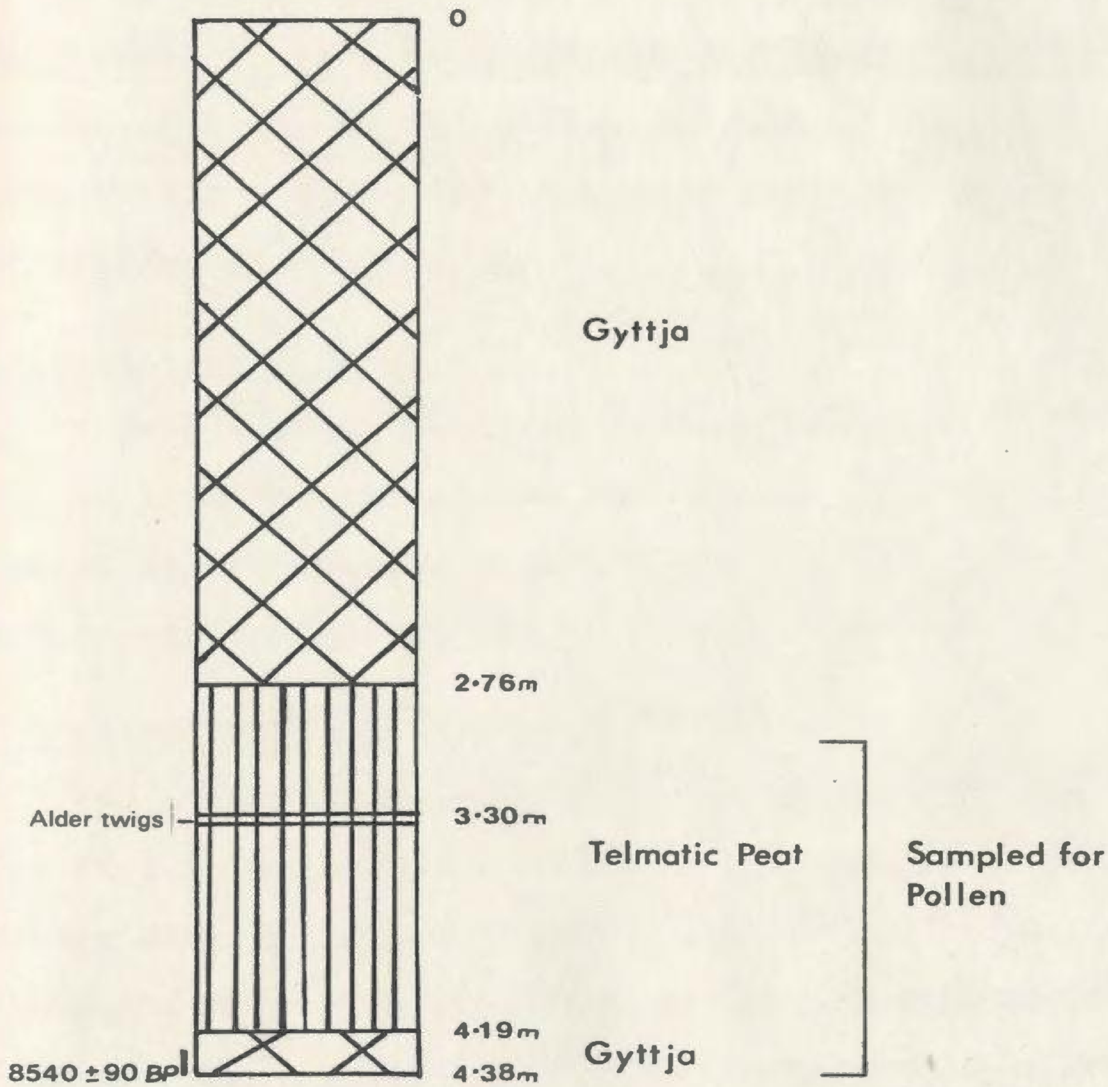


Figure 5.1 Stratigraphy of the lake core BH I.

increases with the change to telmatic peat. Lighter-toned sedge macrofossils may be recognized embedded in the dark matrix. Within the telmatic peat there is a marked concentration of alder twigs preserved at 3.30 m to 3.33 m which presented resistance to the corer. Similar resistance was encountered in each test boring, suggesting that the concentration of twigs is found beneath much of the lake basin. Above 2.76 m the deposit of gyttja continues to the present sediment/water interface.

b. Radiocarbon date.

A sample from the basal sediment (4.38 m to 4.33 m) from core BH I was submitted for radiocarbon dating. The gyttja yielded an uncorrected absolute age of 8540 ± 90 BP (GSC-2985). Such an age lay within the time span expected.

c. Pollen profile.

Two pollen diagrams are presented for the section of core BH I between 3.00 m and 4.38 m; Figure 5.2 is a percentage diagram, while Figure 5.3 shows concentrations of the pollen and spores whose percentage values exceed 5% somewhere on Figure 5.2. Calculations are presented in Appendix A p. 167 Only the basal pollen profiles were worked since the study was concerned with the early postglacial period represented by the lower portion of the core. The core was worked up to the 3.00 m level so as to allow comparison of the profile with the full diagrams of Terasmae (1963) and Macpherson

(pers. comm.). By the 3.00 m level the majority of the present pollen producing taxa had established themselves in the area and a boreal forest similar to that of today had been established. Depositional rates within the pond are unknown and therefore it is impossible to calculate the annual pollen influx.

The pollen diagrams for ease of description have been divided into three pollen assemblage zones;

BH 1 Sweet gale - sedge - birch pollen zone.

BH 2 "Tree" birch - sweet gale pollen zone.

BH 3 "Tree" birch - spruce - balsam fir pollen zone.

These zones have been delimited on the basis of variations in the two or three most important taxa. These variations have been arbitarily defined but are generally correlated to significant decreases in the percentages of one or more of these taxa. Pollen zones have been named after two or three characteristic taxa in the assemblage.

1. BH 1 Sweet gale-sedge-birch pollen zone (below 4.20 m)

This zone is characterized by high percentages of *Myrica gale*, Cyperaceae and birch with the pollen assemblage suggestive of a shrub-sedge tundra. Absolute pollen concentrations show an uneven overall decline through this zone from 1628×10^3 grains cm^{-3} at 4.35 m to 703×10^3 grâins cm^{-3}.

Successive peaks of *Myrica gale* (36%) and Cyperaceae (24%) occur in this zone. "Tree" birch increases throughout BH 1 to 32%. Smaller contributors are "shrub" birch (up to 10%), Coryloid (up to 10%), Gramineae (up to 7%) and Lycopodium (up to 5%). Variations in the curve of Myrica gale are broadly reflected in that of Coryloid pollen. Since all triporate grains which lacked a clear pore structure were counted in this category it is suggested that much of this pollen is deteriorated Myrica gale.

2. BH 2 "Tree" birch-sweet gale pollen zone (3.98 m to 4.20 m).

The main characteristic distinguishing pollen zone BH 2 from pollen zone BH 1 is the fluctuation in the Cyperaceae curve; values initially decline to 5% but then rise to a second peak by 4.025 m (40%). The non-arboreal pollen contribution continues to decline from 55% to 24% before the second increase of Cyperaceae brings the percentage of non-arboreal pollen to 61%. Pollen concentrations continue to decline unevenly from 611 x 10^3 grains cm^{-3} at 4.15 m to 300 x 10^3 grains cm^{-3} at 4.00m.

Except during the Cyperaceae peak the pollen spectra of BH 2 are dominated by "tree" birch and Myrica gale. "Tree" birch contributions rise to 58% and then decline while those of Myrica gale show an overall decline (to 5%) rising slightly with the Cyperaceae increase. "Shrub" birch shows an uneven decline to insignificant amounts throughout the zone.

Percentages of arboreal pollens, other than "tree" birch, increase compared with pollen zone BH 1; e.g. Picea up to 13% and Abies balsamea up to 9%. Concentration values fluctuate but Abies balsamea does record concentrations up to 26 X 10^3

grains cm^{-3} which is the second highest value recorded in the profile for this species. Pinus pollen is recorded throughout BH 1 and BH 2 but never in significant amounts (less than 4% of pollen sum). The contribution of Gramineae declines to insignificant values while Rosaceae values are the highest recorded but remain less than 2%. Lycopodium percentages are insignificant although a rise in the concentration occurs as Cyperaceae increases.

3. BH 3 "Tree" birch-spruce-balsam fir pollen zone (3.00 m to 3.98 m).

The pollen assemblage of BH 3 is characterised by the high percentages of "tree" birch, Picea and Abies balsamea and the increased presence of grains of other arboreal taxa. These high values probably reflect the development of a forest in the surrounding area.

"Tree" birch values fluctuate (32 to 58%) but remain high. Abies balsamea rises to a peak (26%) early in the zone to decline to values of 4%. Picea values rise unevenly to a value of 34% while Pinus remains low.

Pollen concentrations are variable ranging from 415×10^3 grains cm^{-3} at 3.40 m to a profile minimum of 36×10^3 grains cm^{-3} at 3.70 m. The concentrations of all arboreal pollen taxa, except "tree" birch decline individually to less than 2×10^3 grains cm^{-3} in this sample. The percentage diagram suggests that at this level there is an increase in non-arboreal pollen (especially *Myrica gale*, *Alnus crispa*, Gramineae and Cyperaceae). The absolute counts fail however to confirm any significant increase in these pollens, suggesting therefore that the percentage increases are mathematically induced. However the low concentration values may indicate a temporarily accelerated rate of accumulation. Ericales pollen is more abundant on both diagrams above 3.70 m, although it is not recorded in the uppermost sample.

Sphagnum is a notable feature of the upper part of pollen zone BH 3. It rises rapidly to a peak of 50% before declining equally rapidly to less than 1%. The increase in *Sphagnum* most probably reflects very local conditions. This peak correlates with the layer of twigs between 3.30 m and 3.33 m and may suggest a drier bog surface where *Sphagnum* and possibly alder grew on site. If such conditions existed they were very temporary since both the amount of *Sphagnum* pollen and the macro-fossil remains of the alder are stratigraphically very localized.

Through the profile isolated grains of the following were identified: *Fagus*, *Juglans*, *Populus*, *Quercus*, *Tsuga*, *Ulmus*, Caprifoliaceae and Umbelliferae. Those of *Fagus*, *Juglans*, *Quercus*, *Tsuga* and *Ulmus* may have been blown from the mainland of North America since they are not indigenous to Newfoundland. *Populus* pollen grains are generally underrepresented in recovered fossil spectra because the grains are comparatively easily destroyed (Mott, 1976). Therefore the isolated recognition of grains of Populus may in fact mask its importance in the regional pollen rain. It fails to occur above 4.30 m which may indicate its absence from the region. The scattered isolated grains of Caprifoliaceae and Umbelliferae identified at various levels in the profile may have been present within the local vegetation.

5.3. Interpretation of the results from "Birch Hill's Pond".

a. Deglaciation.

The radiocarbon date (GSC-2985; 8540±90BP) establishes a minimum age for deglaciation at this site. This must be regarded as a minimum age since the date comes from 5 cm of postglacial gyttja. Pollen analysis indicates that during the time the gyttja was accumulating the area's vegetation was that of a shrub-sedge tundra and not any pioneer assemblage normally associated with the very recent colonization of deglaciated terrain. Also a basal organic date of 9270±150 BP (GSC-2601) has been obtained from Sugar Loaf Pond, approximately 15 km south-southeast of "Birch Hill". This suggests that some coastal areas may have been ice free as early as 10,000 BP. The pollen assemblages of the basal sediments of SL 1 and BH 1 are not similar. The assemblage of BH 1 occurs much higher in the profile of SL (possibly SL 2 and HH 1) as can be seen by comparison with Table 5.1, a summary of Macpherson's (pers. comm.) Sugar Loaf Pond and Hawke Hills sites. Table 5.2 summarises the unzoned diagrams of the Goulds

Table 5.1 Summary of the pollen zones suggested by Macpherson (pers. comm.) for cores from Sugar Loaf Pond and the Hawke Hills.

Sugar Loaf Pond (SL)

SL 4: Birch-Spruce-balsam fir pollen zone - 0-335 cm
Concentrations ca 170 000 grains cm^3
Arboreal pollen 83-95%
Major taxa: "Tree" birch (33-61%) *Picea* (18-28%) *Abies balsamea* (6-20%)
Interpretation: Boreal forest

SL 3: Birch-spruce-balsam fir with poplar pollen zone 335-518 cm
Concentrations 270,000 grains cm^3
Arboreal 68-89%
Major taxa: "Tree" birch (63-40%) *Picea* (to 30%) *Abies balsamea* (to 10%) *Populus* (to 4%) *Alnus* (to 15%) *Taxus canadensis* (to 8%)
Interpretation: Open woodland

SL 2: Birch-shrubs-Lycopodium pollen zone 518-563
Concentration 400,000 grains cm^3
Arboreal pollen 15-57%
Major taxa: "Tree" birch (to 43%), *Myrica gale* (to 32%) "Shrub birch (to 30%), *Lycopodium* (to 21%) *Juniperus* (to 16%), *Picea* (to 12%)
Interpretation: Shrub tundra with increasing trees

SL 1: Sedge-willow pollen zone below 563 cm

SL 1(ii) Sedge-Oxyria digyna pollen sub-zone 563-572 cm
Concentrations 25,000 grains cm^{-3}
Major taxa: Cyperaceae (to 48%), *Oxyria digyna* (to 27%) Gramineae (to 15%), *Lycopodium* (to 16%)

SL 1(i) Sedge-willow-Ericalespollen sub-zone below 572 cm
Concentrations generally lower than 6500 grains cm^{-3}
Major taxa: *Salix* (to 43%) Cyperaceas (to 35%). Ericales (to 23%)

Interpretation of SL 1: Sedge tundra with low shrubs in areas deglaciated longer.

Years BP

3200

4800

7290±150

8300

Hawke Hills site (HH)

HH 4: Spruce-birch-balsam fir-shrub pollen zone 0-72 cm
(Kettle site)
Concentrations 40,400-140,000 grains cm^3
Arboreal pollen 61-80%
Major taxa: *Picea* (to 41%) "Tree" birch (36%-20% surface) *Abies balsamea* (to 16%), *Juniperus* (to 2-5%) "Shrub" birch (to 3%)

HH 3: Birch-spruce-balsam fir pollen zone 72-190 cm
(Kettle site)
Concentrations 55,300-149,200 grains cm^3
Arboreal pollen 77-93%
Major taxa "Tree" birch (to 52%) *Picea* (to 37%) *Abies balsamea* (to 18%)
Interpretation: Boreal forest

HH 2: Birch-spruce-balsam fir with poplar pollen zone below 190 cm
(Kettle site)
Concentrations 41-500-140,000 grains cm^3
Arboreal pollen 65-83%
Major taxa "Tree" birch (to 52%) *Picea* (to 30%) *Abies balsamea* (to 14%), *Populus* (to 3%) *Taxus canadensis* (to 10%)
Interpretation: Open boreal woodland

HH 1: Birch-shrub-spruce pollen zone below 360 cm
Arboreal pollen 41-61%
Major taxa "Tree" birch (21-44%) *Picea* (5-21%) "Shrub" birch (to 17%), *Juniperus* (to 17%) *Myrica gale* (to 17%), Gramineae (to 16%) *Lycopodium* (to 13%)
Interpretation: Shrub tundra.

... the pollen diagrams of Terasmae (1963) for the Goulds Bog, near St. John's and the Whitbourne Bog in the central Avalon.

Whitbourne Bog

WB 3: Ericales - tree birch pollen zone 0 - 50 cm

Arboreal pollen 70-40% (NAP 150%)[2]

"Tree" birch 53%
Picea 23%
Abies balsamea 35%
Ericales 125%
Gramineae 7%

Human influence suggested cause of expansion of heathland.[3]

WB 2: "Tree" birch-balsam fir-pollen zone 50 cm - 440 cm

Arboreal pollen 79% (NAP max 30%)

"Tree" birch declines from 80%
Picea 25%
Abies balsamea increases to 30%
Cyperaceae 25%
Ericales increase to 17%
Nymphaeaceae 6% disappears by 250 cm

Forest vegetation; both *Abies balsamea* and *Betula lutea* are first recorded in substantial amounts in this zone.

WB 1: Birch-(shrub and tree) Pine pollen zone 440 - 610 cm

Arboreal pollen (70%) (NAP 50%)

8420±300

"Tree" birch 80%
"Shrub" birch 50%
Pinus 32%
Picea 15%
Alnus 5%
Salix 8%
Quercus 3%
Ericales 10%
Gramineae 10%

Grass and sedge meadow with Ericales, willow, alder and birch shrubs. Scattered pine and spruce

Goulds Bog

GB 2: "Tree" birch-spruce-balsam fir pollen zone 50-1350 cm

Arboreal pollen 75% (NAP 40%)
"Tree" birch 33%
Picea 40%
Abies balsamea 40%

Forest vegetation of fir, spruce and tree birch.

GB 1: Birch (tree and shrub) - balsam fir-spruce 1350-1700 cm

Arboreal pollen 40% (NAP 66%)

7400±150

"Tree" birch 45%
Shrub birch 20%
Picea 35%
Abies balsamea 30%

Forest with non-forested areas in the vicinity. "Shrub" birch is only found in this zone. NAP is decreasing. *Abies balsamea* is already present in the region in the earliest retrieved sediments.

1 Terasmae did not zone his profile and this is only a suggested zonation of his diagrams for comparison with profiles from this study.

2 Terasmae's profiles were constructed using a pollen sum restricted to arboreal taxa (AP = 100) and the values for taxa shown in this summary are taken direct from his paper. However, the total arboreal pollen percentages have been converted using the total land pollen sum for comparative purposes.

3 The palynological interpretations offered are from Terasmae's 1963 paper.

and Whitbourne sites of Terasmae (1963). Following the discussion of the results from "Birch Hill's Pond" and Northeast Pond tentative correlations between the pollen profiles from these ponds and those of Sugar Loaf Pond (Macpherson pers. comm.) and the Goulds and Whitbourne bogs (Terasmae 1963) will be suggested; (Table 7.1 p. 151).

Previously some authors (e.g. Henderson 1972, Grant 1975) have suggested that both the St. John's and Carbonear peninsulas were covered by thin ice. If this was the case it would be expected that some areas of the St. John's Peninsula would be ice free soon after deglaciation began on the Avalon Peninsula.

The sequence from "Birch Hill's Pond" does not represent the complete sequence since deglaciation because there is no record of a pioneer vegetation assemblage and the stratigraphy fails to record a period of soil instability immediately following deglaciation. The cause of this truncation is open to speculation. Five possible causes are suggested and their merits examined.

1. Failure of the corer to retrieve a full sequence

There was no evidence to suggest a malfunction of the corer during field work. Other trial cores failed to register any variations in the basal stratigraphy. That is, no solifluction clay was found.

2. If the initial postglacial deposits were not preserved as a sequence

Had the initial lake floor been felsenmeer covered then inwashed sediments may have been trapped within the interstices of the rock and have been irrecoverable with the Livingstone corer. Many of the lakes in the area do have partially or wholly fractured rock bottoms (eg. Northeast Pond). The corer did consistently strike an obstruction of rock or gravel. It is therefore possible that the initial lake floor may have swallowed the inwashed early postglacial sediment.

3. <u>If early deposition of sediments had been prevented by a residual ice mass or perennial snow patch</u>.

There is no geomorphic evidence to suggest that the pond has formed in a kettle hole. However, the position of the pond on the northeast facing slope of "Birch Hill", does not preclude the continual presence of a perennial snow patch after the general regional deglaciation.

4. <u>If the lake is a product of postglacial bog growth</u>.

Although bog growth may have altered the direction of lake outflow, the recovery of the basal gyttja suggests that the initial deposition did take place within a lacustrine environment. (The reader is referred to the subsequent discussion of the drainage p. 109). Had the site initially been fen or bog deposits suggestive of this environment should have been present.

5. <u>The initial pond may have been subject to flushing of deposited sediments by through flow</u>.

Water may have drained rapidly through the shallow basin without significant settling of sediment. Runoff from the surrounding slopes would have been more effective without a vegetation cover to reduce transmissibility. Run-off may have been seasonally greater during deglaciation through ice melt. Also although a depression existed prior to bog growth, it was relatively shallow. Borings of bog and lake suggest a maximum depth of 2.70 m. With a shallow pond sedimentation would have been less and seasonal flushing of the pond more efficient. Such flushing could even have removed sediments older than the early Holocene had they been present.

It is suggested that probably a combination of flushing of the pond by through flow and the loss of sediment through rock interstices is responsible for the truncation of the lake core.

b. Water-level fluctuations at the "Birch Hill's Pond" site.

The stratigraphy of the core is interesting as it indicates the local water-level has varied in the past. The basal gyttja below 4.19 m, is as already suggested, indicative of deposition within water. By 4.18 m the lake was sufficiently shallow for sedge peat to accumulate. Dr. P. Scott, Department of Biology, M.U.N. (pers comm.) states that sedges in Newfoundland are found in water less than 0.50 m, therefore the lake/fen must have had a water depth of less than 0.50 m. Between 3.30 m and 3.33 m a layer of alder twigs occurs. This coincides with a peak in the *Sphagnum* curve. This suggests that the site became temporarily drier and allowed the growth of alder and a proliferation of *Sphagnum* perhaps on a bog.

Dr. P. Scott has identified the alder macrofossils as the species *Alnus crispa* (pers. comm.). According to Ryan (1978) this species can be found today along stream banks, pond fringes and in wet thickets and swamps. One puzzling fact is the only slight increase recorded in alder pollen at this time. Had the plant flourished across the bog surface for any length of time the alder pollen should have greatly increased. It is possible the alder failed to reach maturity before it was destroyed by a return to wetter conditions. If so it would indicate the bog was only dry for a very short period. As the bog returned to fen conditions *Sphagnum* declined. Telmatic peat is recorded up to a depth of 2.76 m when a return to gyttja shows deposition was within a lacustrine environment.

The oscillation to and from lacustrine conditions could be construed as directly reflecting climatic change, however it is suggested that it is more likely attributable to changes in local drainage. These changes may however reflect more subtly variations in the climate.

Probings to ascertain the depth of peat around the perimeter of the bog established that a greater depth of material existed towards the east. Figure 5.4 shows the transects constructed from bog probings. The bog surface has not been levelled but the slope is negligible and peat was 1.49 m thicker to the east (A) than at the position of the present

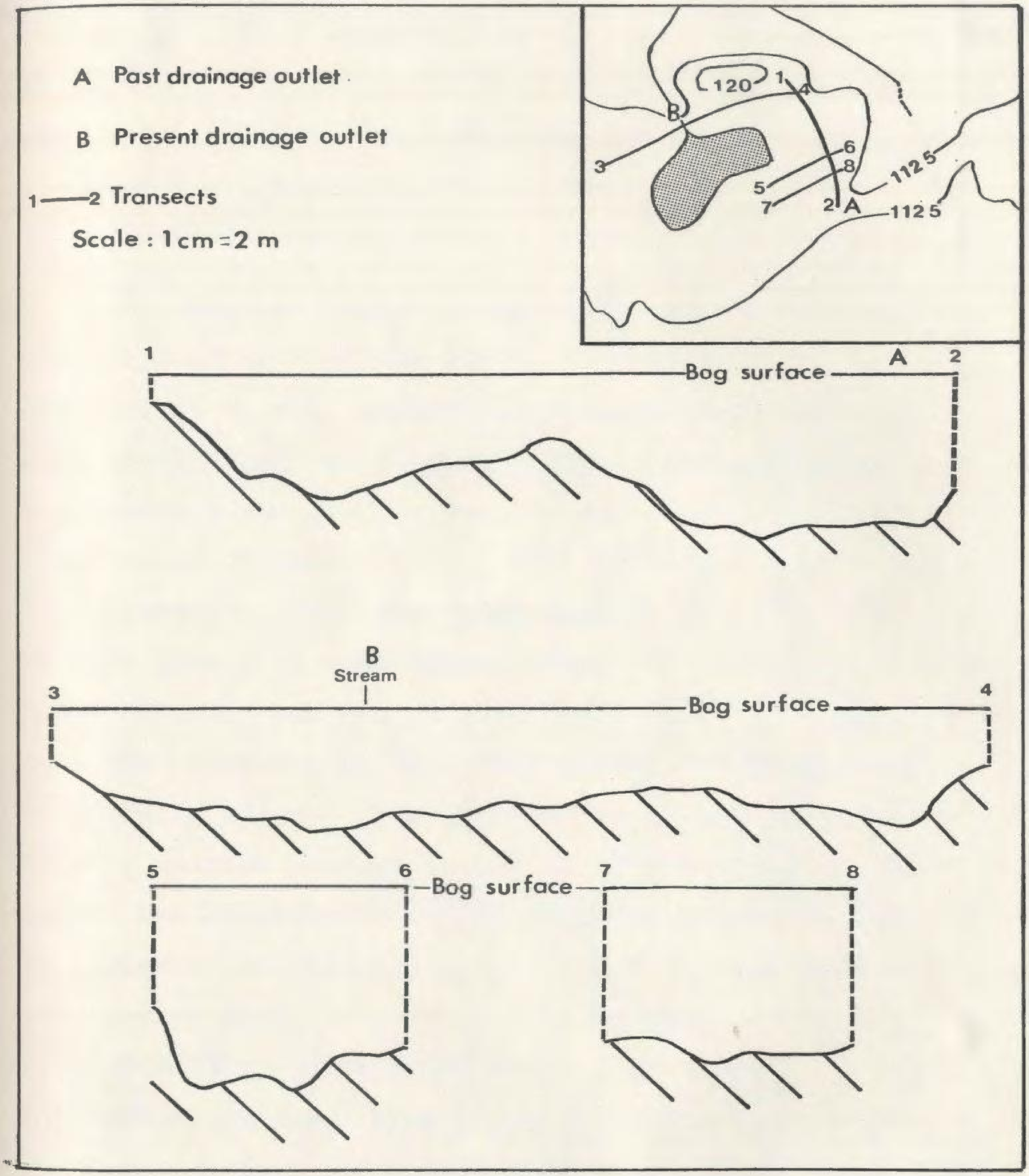
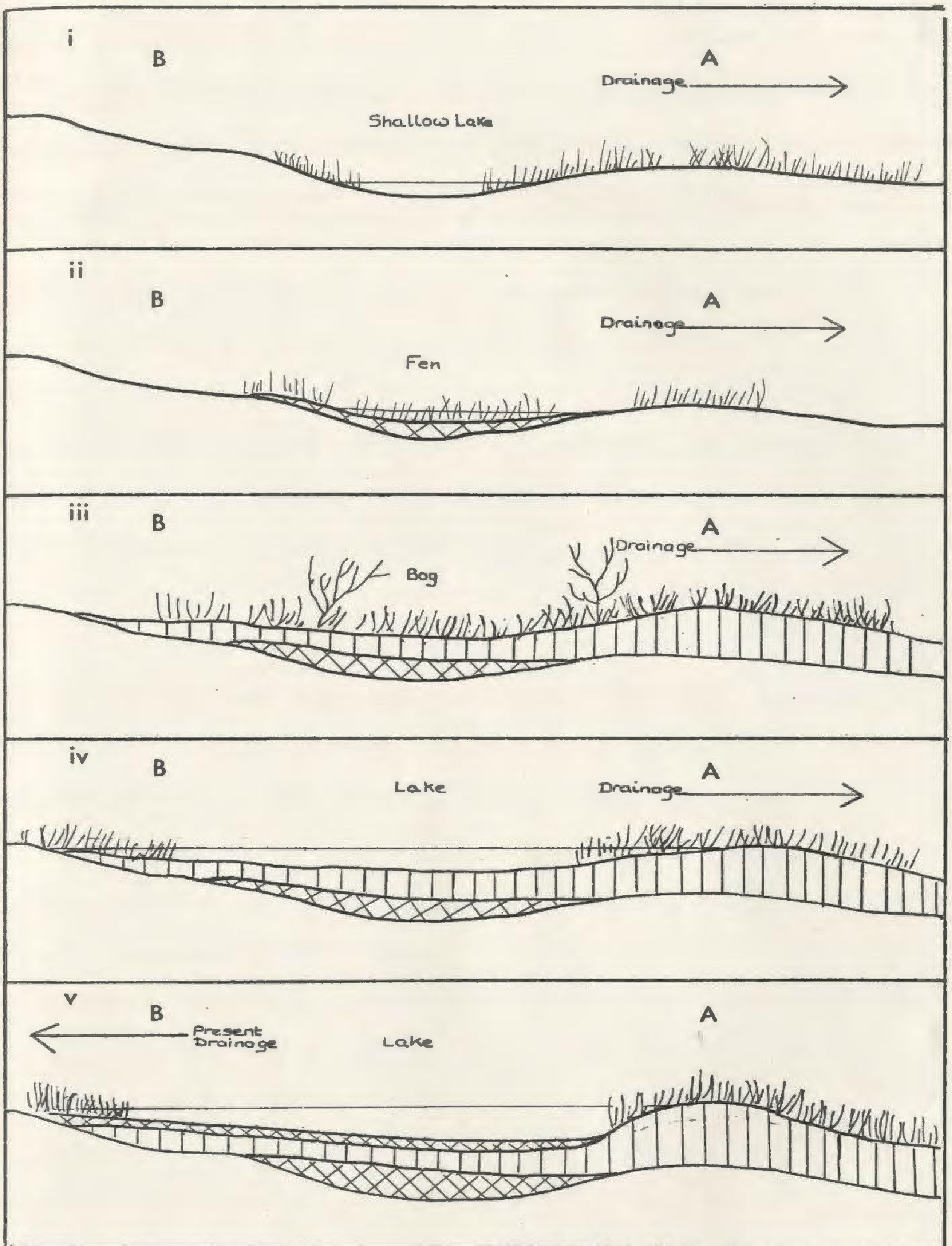


Figure 5.4 Transects of the topography underlying the marginal bog at "Birch Hill's Pond".

outlet (A). This suggests that A was originally lower than B and would have initially been the favoured direction for drainage. Eastward drainage would have ceased with increased bog growth as this exit was blocked. Bog growth may have been stimulated by the warming trends of the hypsithermal.

The greatest depth to bedrock or gravel found in the lake (including both the water and sediment) was 6.05 m. The borings in the marginal bog suggest that the greatest peat depth is around 3.40 m. This suggests that prior to bog growth a shallow depression existed at this point; as suggested in Figure 5.5 (i). The basal sediments support the hypothesis of initial accumulation within a water body of more than 0.50 m in depth. From the change to telmatic peat the inference can be drawn that water depths within the lake had decreased to less than 0.5 m. This reduction in water depth may have been the result of the gradual silting up of a shallow lake basin (20 cm of gyttja had accumulated) and/or the establishment of a drainage channel to the east, as suggested in Figure 5.5 (ii). Another possibility is that the flow of water into the area decreased, possibly after the final melting of a residual snow patch or as the result of artificial damming. However no distinct channel supplies water to the lake today so the question arises as to whether water were ever channelled to the area and therefore if it would be possible to dam the water supply. It is suggested that during this period drainage was through the eastward gap (A). The



-gure 5.5 Fluctuations of the water-level at "Birch Hill's Pond". (symbols as in Fig. 5.1)

i Initial condition; drainage through A

ii Growth of telmatic peat

iii Invasion of alder contemporary with drier site conditions

iv Return to a lacustrine environment

partial drying of the site allowed the growth of sedge and the continued drying resulted in the invasion of alder with Sphagnum carpeting a bog surface; Figure 5.4 (iii). The bog surface was only temporarily dry enough to allow this as the alder did not reach sufficient maturity to flower. The bog surface may have dried out in response to a series of particularly dry years or in response to changes in the efficiency of the drainage. However there is no indication from the other pollen spectra of a dramatic climatic change. The cause of the return to wetter conditions by 3.30 m and the continued accumulation of telmatic peat is similarly open to speculation. The inundation of the site by water resulted in the destruction of the alder. Fen conditions are recorded until 2.76 m. At this depth the stratigraphy suggests a reversion to a lacustrine environment (Figure 5.5 (iv)) which has persisted to the present day. This lake may be the product of bog growth at A exceeding deposition in the initial depression and thus impeding the drainage. The postulated slower drainage resulted in a rise of the water-level as water was ponded up. Once the water level had risen sufficiently (above 0.5 m) the sedges would, in effect, have been drowned. As bog growth continued at A drainage would have been further impeded and the lake level would have risen further. At a point, unrecorded in the stratigraphy, the lake level was sufficiently high to initiate drainage through the westward passage; Figure 5.5 (v). Drainage continues westward but the outlet is sufficiently high to prevent complete drainage of the lake. The eastward drainage has been abandoned as bog growth in this vicinity has now raised this area above the level of the lake.

The change in the onsite vegetation caused by variations in the water-level has important implications for the interpretation of the pollen profiles. It has been noted that different environments preserve different vestiges and quantities of the pollen rain (Moore and Webb 1978). Within the peat habitat local vegetation generally provides a disproportionately high percentage of the pollen rain, compared to the extent of the vegetational assemblage. In the case of reed swamp large amounts of grass and sedge pollen are produced which cannot always be distinguished from the regional pollen rain (Moore and Webb 1978).

c. Palynological interpretation.

Pollen zone BH 1 falls wholly within the basal gyttja. The lake may have been surrounded by a marginal bog at this time, but the pollen spectra are not believed to be unduly influenced by over-representation from this source.

The fossil pollen assemblage of this zone is not analogous to existing published pollen assemblages, although it has similarities with the sedge-moss tundra pollen spectrum published for Cambridge Bay, Victoria Island (Ritchie and Lichti-Federovich, 1967). There comparable values for

Picea (2.3%-3.78%) Gramineae (6.72%-6.9%) and Cyperaceae (24.36%-37 %) are found, the former percentages being maximum values for zone BH1. However, the values recorded for *Betula* (39.1%), *Ericales* (2.52%), and *Pinus* (2.76%) are more akin to those of modern forest-tundra spectra from Great Whale River, Fort Chimo and Knob Lake in Quebec (Ritchie and Lichti-Federovich 1967). The large percentages of *Myrica gale* and Coryloid pollens (up to 54%) recorded in BH1 are without present day equivalents.

Fossil pollen spectra from the Northern Peninsula, Newfoundland (Henningsmoen 1977), southeastern Labrador (Lamb 1980) and Prince Edward Island (Anderson 1980) similarly do not contain these high percentages of *Myrica gale*. This suggests that conditions which allowed this shrub to flourish on the St. John;s Peninsula were peculiar to it and the early postglacial. In some aspects pollen zone BH1 is similar to Anderson's (1980) regional pollen zones 7 and 6 for Prince Edward Island and Lamb's (1980) regional pollen zone I for southeastern Labrador, although not necessarily contemporaneous. The early peaks of Gramineae and Cyperaceae are repeated in these zones. However the assemblages from Prince Edward Island contain more *Pinus*, *Picea* and *Abies balsamea* while those of Labrador contain higher percentages of *Salix* and herbs.

The BH1 pollen assemblage suggests a shrub-sedge tundra where perhaps tundra prevailed on the more exposed ridges and summits with shrubs restricted to more sheltered localities.

Arboreal pollen percentages and concentrations are relatively low during this period (less than 33% and 177×10^3 grains cm^{-3}). Early within pollen zone BH1 *Picea*, *Abies balsamea* and *Pinus* do not appear to be present within the vegetation and the grains counted are those which have been blown from outside the region. The increases in the percentages and concentrations of these taxa during pollen zone BH1 suggest they are migrating towards the study area. *Picea* values are higher above 4.275 m which suggests this species has entered the local region. Concentrations of *Pinus* are highest at 4.275 m (12×10^3 grains cm^{-3}) but remain low throughout the profile. This may indicate that *Pinus* never successfully colonized the study area during the period represented by the pollen profile. *Abies balsamea* is constantly present within the profile from 4.25 m. As *Abies balsamea* is a low pollen producer (Mott 1974) this may indicate its presence in the surrounding area.

As the trees initially entered the region they were probably restricted to more environmentally favoured sites; for instance where a deeper soil had developed. Their rate of recolonization may have been determined by climatic amelioration but was more probably limited by the development of suitable sites and the actual speed at which recolonization from their glacial refugia could proceed.

Pollen zones BH 2 (above 4.19 m) and BH 3 are within the telmatic peat. The second Cyperaceae peak in pollen zone BH 2 most likely reflects the taxon's prominence in the site's vegetation. Its subsequent decline may reflect the gradual drying of the site. It is unlikely that its peak records a deterioration of climate and a second expansion of sedge tundra.

The peak of Sphagnum in BH 3 attributed to a relative drying of the site and is accompanied by increases on both diagrams of the taxa Myrica gale, Coryloid, Ericales and Gramineae. All probably reflect the local conditions. A concentrated layer of alder twigs between 3.30 m and 3.33 m was identified although only pollen values of less than 2% were recorded for Alnus. This as already discussed may indicate the short duration of the "dry" period. It should be noted that both A. crispa and A. rugosa pollens have been identified in the profile although only A. crispa is found in surrounding vegetation today. Ryan (1978: p. 61) suggests A. rugosa is not found on the Avalon Peninsula. It is presumed that A. rugosa grains have been blown from the main part of Newfoundland.

The arboreal spectra of pollen zones BH 2 and BH 3 show the rising importance of these species in the regional pollen rain. Picea increased markedly by 3.60 m attaining 34% by 3.00 m. This probably reflects the expansion of Picea within the drainage basin or possibly its growth around the perimeter of the fen or bog. Abies balsamea is present in relatively high proportions through-out pollen zones BH2 and BH3 and this most probably records its presence within the surrounding vegetation. The percentage pollen profile from West Saddle Pond, Northern Peninsula, Newfoundland (Henningsmoen, 1977) has arboreal pollen values similar to these zones: Picea (30%), Abies balsamea (15%), Betula (undifferentiated, 70%) and Pinus (3%). However local site influences complicate a more detailed comparison of these profiles.

There are broad similarities between the representation of arboreal pollen in zones BH2 and BH3 and in southeastern Labrador in Lamb's (1980) pollen assemblage zone II. However, the strong Cyperaceae and Sphagnum values of BH2 and BH3 are absent from the Labrador diagrams at this level.

Pollen concentrations decline from 90 x 10^3 grains cm^{-3} at 3.80 m to 36 x 10^3 grains cm^{-3} at 3.70 m before recovering to 129 x 10^3 grains cm^{-3}. It is suggested that this records the effect of a natural disaster within the area. At 3.70 m level there was much indeterminable pollen and charcoal which suggests the area may have been swept by fire which destroyed many of the arboreal pollen producers. Picea and Abies balsamea contributions decline to less than 5%. After 3.70 m percentage values of "tree" birch and Abies balsamea increase. Had a fire removed the shading provided by other trees seedlings of Abies balsamea may have prospered although this species is not normally noted as part of the primary succession following fire (Damman 1964). This initial increase would have declined as the seedlings overcrowded one another or as other species recolonized the area. Damman (1964) suggests that white birch can colonize a burnt over area before the previously dominant tree species recovers; hence perhaps the increase recorded in "tree" birch.

Overall BH2 and BH3 pollen assemblage zones reflect the development of a forest cover consisting primarily of "tree" birch, *Picea* and *Abies balsamea*. Apart from the natural disaster at 3.70 m the profile of the regional pollen rain does not vary significantly.

5.4 Summary.

Deglaciation of "Birch Hill's Pond" occurred before 8540 BP. The stratigraphy and palynological evidence suggest deglaciation of the site happened some time before the radiocarbon date for the basal sediments indicates; before 9000 BP.

Fluctuations in the water-level of the pond have resulted at different times in the deposition of gyttja and telmatic peat. These changes in water-level were probably associated with alterations in the drainage of the area. It has been suggested these alterations are attributable to differential bog growth around the perimeter of the present bog. Bog growth may have been stimulated during the hypsithermal warming.

The pollen profiles (Figures 5.2 and 5.3) show the recolonization of the area during the postglacial. Originally an early shrub-sedge tundra dominates (pollen zone BH1) but gradually "tree" birch, *Picea* and *Abies balsamea* enter and colonize the region. There does not appear to be any present day analogue from published surface spectra from areas of southerly tundra (Short 1978) with the early spectra of this site. This may suggest that the vegetation assemblage which produced the pollen spectra existed because of unique conditions which prevailed during the postglacial and which are unlike those of Labrador today. These unique conditions were the product of a combination of factors including climate, site and environmental conditions as well as the characteristics of the vegetation.

The rapidity with which the taxa established themselves once they reached the area suggests that the colonization was not inhibited by the climate. Work from the west coast of Newfoundland (eg. Grant 1969a, 1969b; Brookes 1969, 1975) and elsewhere in the Maritimes suggests initial deglaciation of coastal sites began around 13000 BP. Although there is evidence to suggest severe conditions persisted it is likely that the warming trends began before the minimum ice-free date for the "Birch Hill's" site. Lamb (1971) suggests the European hypsithermal can be bracketed by the dates 8500 and 6000 BP. Although the climatic optimum may have been delayed in North America because of the presence of sizeable ice masses until much later, the warming trend was probably initiated by 9000 BP and the recolonization of the Avalon Peninsula was not primarily controlled by climatic improvement.

Chapter 6

Analysis of the lake sediments from Northeast Pond.

6.1 Introduction.

As outlined in section 4.1 this chapter forms the third group of results from the studied area, dealing specifically with the results obtained from the study of the sediment from Northeast Pond. The results from stratigraphic analysis, radiocarbon dating and pollen analysis will be described during the first section. Those from core NEP I will be dealt with after the results from core NEP II as they are more complicated. The second section will suggest and discuss the implications of certain interpretations of the evidence.

6.2 Results from Northeast Pond.

a. Stratigraphy.

Boulders line much of the floor of Northeast Pond, and are covered with fine sediment only in the southern third of the basin. Trial bores (some taken after analysed cores were obtained) indicate both an uneven upper surface to the fine sediments and stratigraphical inconsistencies within them.

The most frequently observed stratigraphy showed basal sediments of grey clay (up to 0.50 m) changing abruptly to gyttja. Towards the northern limit of deposition the thickness of accumulated gyttja decreased and basal grey clay was

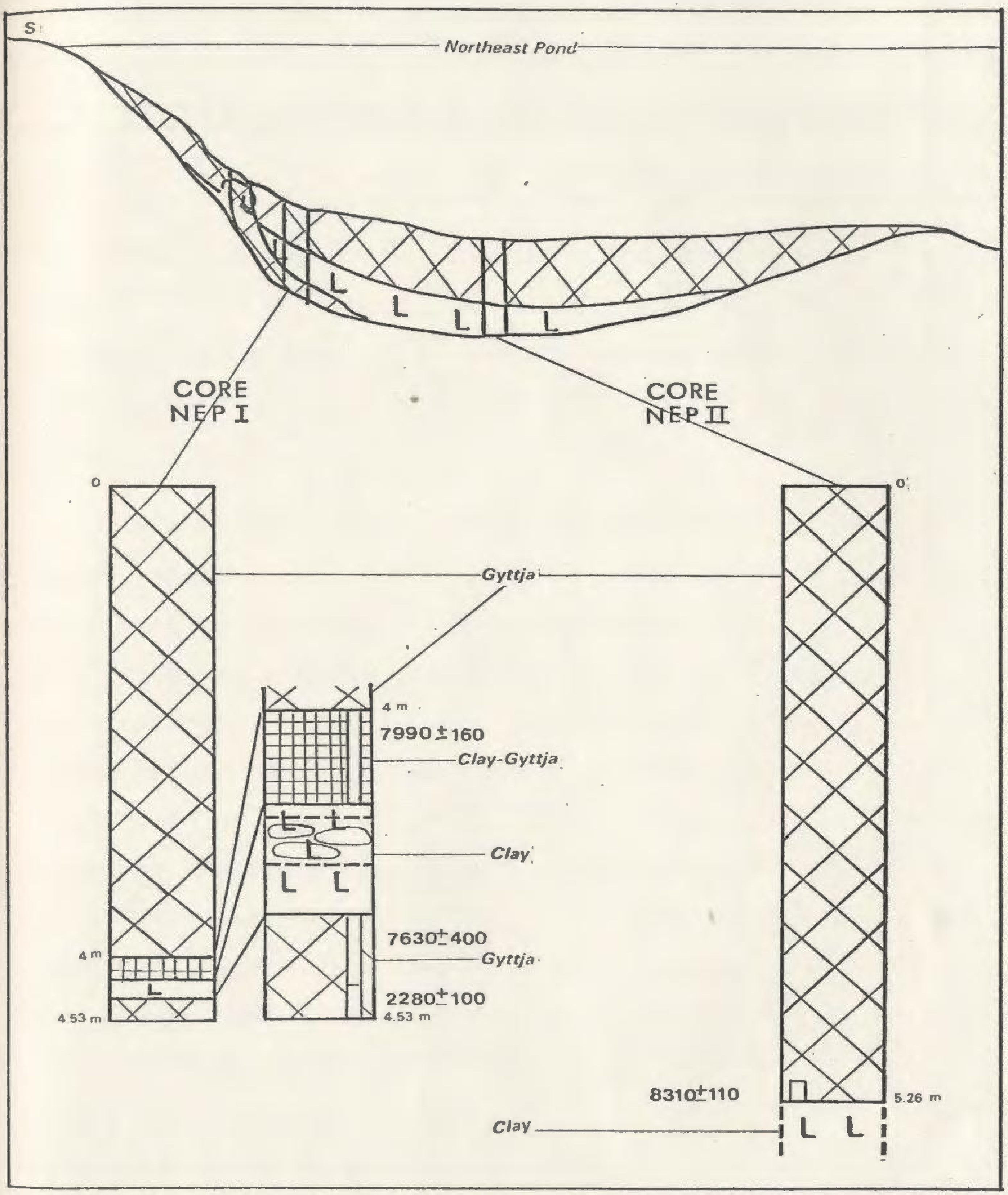


Figure 6.1 Idealized stratigraphy of Northeast Pond and the stratigraphy of cores NEP I and NEP II.

not found. Figure 6.1 is an idealized diagrammatic representation of Northeast Pond and the details of two basal cores, NEP I and NEP II.

The transition from grey clay to gyttja is recorded as an abrupt change. The core referred to as NEP II revealed the lower black gyttja (5 YR 2.5/1: moist). NEP II (as did other trial cores) contained a fluctuation to a lighter colour (2.5 Y 3/2: moist) within the overlying black gyttja between 4.42 m to 4.45 m. Unlike the sediments of "Birch Hill's Pond" the gyttja was not fibrous and was more uniformly finer textured.

In core NEP I the basal sediments varied from this gross pattern. In the field these variations were expressed by marked differences in the resistance to the sampler during coring. As with other cores from Northeast Pond the initial sampling through gyttja was relatively easy. However once the clay was reached greater pressure had to be exerted to continue sampling. On this occasion the grey clay was encountered at 4.10 m below the water/sediment interface. Increased pressure was applied and sampling continued. At 4.35 m from the water/sediment interface the resistance was drastically reduced and sampling continued for a further 18 cm. The sampler was retrieved without mishap and the chamber extruded in the laboratory to reveal an accumulation of gyttja beneath the clay.

b. Radiometric dates.

Four samples were submitted for radiocarbon dating. Three of these were from black gyttja; the other a segment from the transition from grey clay to black gyttja (NEP I: 4.00 m to 4.15 m).

Table 6.1 Radiocarbon dates from Northeast Pond

Depth (m)	Core Designation	Laboratory Reference	Radiocarbon years BP.	±
4.00-4.15	NEP I	GSC-3102	7990 (corrected)	160
4.35-4.48	NEP I	WAT- 634	7630 (corrected)	400
4.48-4.53	NEP I	GSC-2920	2280 (uncorrected)	100
5.21-5.26	NEP II	GSC-2961	8370 (corrected)	110

The dates obtained from the top of the analysed NEP I core (GSC-3102) and the base of NEP II core (GSC-2961) are within the expected age ranges. The stratigraphically lower samples dated from NEP I (i.e. GSC-2920 and WAT-2920) are much younger than originally anticipated. In section 6.3 the implications of these dates will be discussed.

c. Pollen profiles.

i. NEP II

The pollen counts from core NEP II (3.00 m to 5.26 m) are tabulated in Appendix A (page 167). These form the basis of two pollen diagrams. Figure 6.2 records the pollen as percentages, while Figure 6.3 is a concentration diagram of selected taxa. Inclusion in 6.3 is limited to taxa which exceed 5% in the observations from either NEP II or NEP I. The diagrams are divided into two zones on the basis of the relative importance of arboreal pollen in the land pollen sum. Above 4.95 m arboreal pollen contributes more than 70% (except in sample 3.60 m: 58%). Below 4.95 m the non-arboreal component is more important (up to 62% of the sum). The zones are:

NE 3 (ii) Coryloid - "tree" birch pollen sub-zone

NE 4 "Tree" birch-spruce pollen zone.

In the pollen counts from Northeast Pond all triporate pollen grains without a clear pore structure are included in the Coryloid category. In core NEP II <u>Myrica gale</u> is not differentiated and is included with the Coryloid pollen.

<u>1. NE 3 (ii) Coryloid-"tree" birch pollen sub-zone (below 4.95 m)</u>.

The resemblance this zone bears to pollen sub-zone NE 3 (i) from core NEP II will be discussed later in this chapter. However the similarites are consistent enough to allow this sub zone to be termed NE 3 (ii).

The major components of the pollen spectra of NE 3 (ii) are Coryloid (up to 34%) and "tree" birch (up to 46%). Coryloid pollen is inconsistent but declines overall from 34% to 17% and the concentration values rise to 152 X 10^3 grains cm^{-3} at 5.10 m but decline to less than 62 X 10^3 grains cm^{-3} by the top of the zone. The "tree" birch curve is uneven, fluctuating between 21% and 46% with concentration values varying between 96 X 10^3 grains cm^{-3} and 182 X 10^3 grains cm^{-3}. Total concentrations increase to 940 X 10^3 grains cm^{-3} at 5.10 m but drop dramatically in the next sample (5.05 m) to 480 X 10^3 grains cm^{-3}. Following this sample concentrations increase but remain below 493 X 10^3 grains cm^{-3}.

Picea and Abies balsamea increase during NE 3 (ii) from 5% to 20% and from 1% to 4%, respectively. "Shrub" birch peaks at 5.10 m with percentages of up to 15% and concentrations of 71 X 10^3 grains cm^{-3}. Pinus values also rise at this point and peak at a maximum of 22 X 10^3 grains cm^{-3} for this zone.

Other taxa consistently present in low amounts are: Juglans (less than 1%), Alnus (up to 4%), Ericales (up to 4%) Salix (less than 1%), Gramineae (up to 6%), Cyperaceae and Compositae (up to 1%), Rosaceae, Thalictrum and Urtica (up to 2%), and Leguminosae and Sphagnum (up to 1%).

Isoëtes concentrations range between 63 X 10^3 grains cm^{-3} and 218 X 10^3 grains cm^{-3} but are very variable. The percentage of Lycopodium declines generally from 12% at 5.26 m to 4% at 5.00 m with a profile concentration maximum of 57 X 10^3 grains cm^{-3} at 5.26 m.

2. NE 4 "Tree" birch-spruce pollen zone (3.00 m to 4.95 m).

Pollen zone NE 4 is distinguished from NE 3 (ii) on the basis of a rise in importance of arboreal pollen, which is believed to indicate the development of forest near the lake. The arboreal pollen contribution (with one exception at 3.60 m) remains above 70% with concentrations of up to 903 x 10^3 grains cm^{-3} (4.70 m). Total pollen concentrations vary between 903 x 10^3 grains cm^{-3} at 4.70 m to 304 x 10^3 grains cm^{-3} at 3.00 m.

The dominant taxa are "tree" birch and Picea. The "tree" birch curve is uneven with percentages ranging from 56% at 5.90 m to 22% at 3.60 m. Concentrations vary as well from 280 x 10^3 grains cm^{-3} to 34 x 10^3 grains cm^{-3} at 3.60 m. Picea values exceed 17% above 4.90 m, reaching a maximum of 38% at 4.40 m. The highest concentration of Picea (142 x 10^3 grains cm^{-3}) also occurs at 4.40 m.

Within NE 4 there are major peaks of other taxa: i.e. Alnus at 3.60 m (28%, 42 x 10^3 grains cm^{-3}) Abies balsamea at 3.10 m (15%, 34 x 10^3 grains cm^{-3}) and Pinus at 3.40 m (10%, 21 x 10^3 grains cm^{-3}). The Alnus profiles of A. crispa and A. rugosa remain below 3% until 4.30 m when they rise unevenly, increasing sharply to 28% at 3.60 m. Actual concentrations of Alnus reach a maximum (42 x 10^3 grains cm^{-3}) in this sample while there is a total decline in the concentrations of other pollen.

Coryloid pollen is important during NE 3 (ii) but declines with only minor reversals during NE 4 rising to 6% at 3.00 m.

"Shrub" birch values are below 9% throughout NE 4. *Sphagnum* and *Osmunda* are recorded higher in the zone but remain at less than 7% and 4% of the pollen sum, respectively.

Isolated grains of the following were recognized inconsistently through the Northeast Pond cores: *Acer*, *Fagus*, Aquifoliaceae, *Juglans*, *Tilia*, *Tsuga*, and *Ulmus*, Chenopodiaceae and Umbelliferae. *Fagus*, *Juglans*, *Tilia*, *Tsuga* and *Ulmus* are not indigenous to Newfoundland and their pollen has probably been wind blown from the mainland of North America. *Acer*, Aquifoliaceae, Chenopodiaceae and Umbelliferae are found in Newfoundland so their grains may indicate the isolated presence of such taxa in the region.

ii. NEP I.

Appendix A (page 167) contains the figures of percentage and concentration values of the pollen spectra from core NEP I (4.00 m to 4.53 m) upon which the relevant portions of Figures 6.2 and 6.3 are based. The profile has been divided into three pollen assemblage zones on the basis of the distinct changes in pollen concentrations and variations in the pollen spectra. The zones are:

NE 1 "Tree" birch-spruce-balsam fir pollen zone.

NE 2 Sweet gale-Ericales-willow pollen zone.

NE 3 (i) Sweet gale-birch pollen sub-zone.

1. NE 1 "Tree" birch-spruce-balsam fir pollen zone (below 4.36 m).

This zone coincides with the lowest gyttja and is characterized by "tree" birch, *Picea* and *Abies balsamea*. The pollen spectra would not be at variance with that produced by a boreal forest although concentration values vary (range of between 489 X 10^3 grains cm^{-3} at 4.40 m and 124 X 10^3 grains cm^{-3} at 4.475 m).

The percentage diagram shows "tree" birch generally increasing through NE 1 from 29% up to 60%. *Picea* contributions remain relatively stable varying from 23% to 35% until 4.36 m when values drop to less than 11%. *Abies balsamea* declines unevenly to 2% from 17% through NE 1.

Smaller contributions are made by *Pinus* (up to 6%) *Myrica gale* (up to 8%) and *Alnus* (up to 8%). *Alnus* percentages decline towards the boundary of NE 1 and NE 2 above 4.40 m. "Shrub" birch increases significantly (6%) in the uppermost sample of zone NE 1 at 4.36 m, which may indicate a slightly more open environment.

2. NE 2 Sweet gale-Ericales-willow pollen zone (4.10 m to 4.36 m).

This zone is differentiated from NE 1 by the drastic drop in concentration values from 374 X 10^3 grains cm^{-3} at 4.36 m to 26 X 10^3 grains cm^{-3} at 4.34 m. This decrease in concentration coincides with the transition to grey clay.

The pollen assemblage of NE 2 is difficult to interpret as the sediment is so poor in pollen that pollen sums are less than 100 grains below 4.125 m; nevertheless the closely spaced samples (2.5 cm apart) do suggest species which are consistently present. The low concentrations suggest a very variable vegetation but this is most probably a reflection of the low pollen sum. The quality of data available allows only very general statements to be made. Shrub taxa are the greatest contributors of pollen; generally exceeding 50% throughout NE 2 (maximum 73%). Arboreal pollen provides up to 43% but is very inconsistent. Herb pollen varies (up to 59%) with concentrations falling from 11 X 10^3 grains cm^{-3} at 4.34 m to remain below 4 X 10^3 grains cm^{-3} until 4.125 m (23 X 10^3 grains cm^{-3}). Those pollens most consistently present are "tree" birch (up to 32%) "shrub" birch (up to 22%), Coryloid (including *Myrica gale* up to 56%),Ericales (up to 24%), *Salix* (up to 18%) and Gramineae (up to 41%).

3. NE 3 (i) Sweet gale-birch pollen sub-zone (4.00 m to 4.10 m).

Between 4.175 m and 4.15 m land pollen concentrations rise from 35 X 10^3 grains cm^{-3} to 102 X 10^3 grains cm^3. From this zone values increase rapidly to a maximum of 909 X 10^3 grains cm^{-3} at 4.10 m. Arboreal pollen contributes over 50% of the land pollen sum above 4.10 m *Myrica gale* and "shrub" birch decline through the zone while "tree" birch values rise from 14% at 4.15 m to remain above 32%. Other taxa which rise at 4.10 m are *Picea* (11%), *Alnus* (4%), Gramineae (4%) and

Cyperaceae (3%), with Ericales, Compositae, Rosaceae, *Thalictrum*, *Urtica* and *Sphagnum* consistently present but remaining below 2%. *Isoëtes* and *Lycopodium* observations indicate maximum concentrations (442×10^3 grains cm^{-3} and 50×10^3 grains cm^{-3}) during this zone.

6.3 Interpretation of the results from Northeast Pond.

a. Deglaciation.

1. Hypotheses for deglaciation.

The oldest radiocarbon date (GSC-2961: 8370±110 BP) was obtained from the lowest organics (5.21 m to 5.26 m) of core NEP II above a clay layer. However, the stratigraphy of core NEP I suggests that gyttja underlying the clay may be older although the radiocarbon ages (WAT-634: 7630±400 BP, GSC-2920: 2280±100 BP) from the lower organic deposit do not support this interpretation.

Hypothesis A.

The lower gyttja of NEP I represents an interglacial or interstadial deposit of unknown age, when a boreal forest whose primary components were "tree" birch, spruce and balsam fir, flourished. This period is represented by the lowest gyttja found only in core NEP I. Subsequently, environmental conditions deteriorated and soil stability decreased. This period is correlated tentatively with the last expansion of ice on the central Avalon and is recorded at Northeast Pond by the deposition of the solifluted grey clay. Following an amelioration in the climate (coincidental with the deglaciation of the rest of the Avalon Peninsula), the stability of the soil increased due in part to the change in the climate and the growth of a more dense vegetation mat with recolonisation. A minimum date of 8370±100 BP (Table 6.1: GSC-2961) could be assigned to the amelioration of climate. However for such a hypothesis to be accepted the two stratigraphically lower dates from core NEP I must be rejected.

Hypothesis B.

The lowest organic material of core NEP I is sediment which has been transposed from its original position in the stratigraphic column, to a position beneath the grey clay. The lowest sediment is dislocated and inverted gyttja from higher in the profile. Hence the lowest dated material from core NEP I (4.48 m to 4.53 m) yielded a date of 2280±100 BP (GSC-2920) and the immediately overlying material (4.35 m to 4.48 m) a date of 7630±400 BP (WAT-634). The depth of gyttja (18 cm) and the juxtaposition of the samples submitted for absolute dating suggests that the total stratigraphic column is not present beneath the grey clay. The minimum age for deglaciation of Northeast Pond would then be 8370±100 BP (GSC-2961).

ii. Discussion of the hypotheses.

1. Stratigraphy versus the determined radiocarbon ages.

The acceptance of hypothesis A demands the rejection of the lower two radiocarbon dates from core NEP I. Care was taken to avoid contamination during the extrusion of NEP I but the outer surface of the core was smeared with grey clay. This partly resulted from the sticky nature of the grey clay and also from the disturbance caused during extrusion by the pebble concentration in the clay layer. The outer contaminated layer was removed in the laboratory prior to submission for radiocarbon dating. Precautions taken before radiocarbon counting normally include the removal of the outer surface of the submitted sample. Thus all traces of "foreign" sediment were most likely removed. It is not therefore considered justifiable to refute these dates on the basis of field contamination without other evidence.

Occasionally errors in radiocarbon dating can occur at the laboratory (Ogden III, 1977). As a precaution against such error, two lower samples from core NEP I were submitted to different laboratories; 4.48 m to 4.53 m to the Geological Survey of Canada and 4.35 m to 4.48 m to the University of Waterloo, Department of Earth Science. Both laboratories reported dates less than 8000 BP which is much younger than would be anticipated for interglacial or interstadial sediments. However, the dates are 5000 years apart, which with limited sediment length (18 cm), and the erratic pollen curves, supports the conclusion that the sequence has either been compressed or that a part is missing. If this is so there is nothing incompatible with the 5000 years difference between the dates, even though the dates were obtained from juxtaposed sediments.

2. Palynological evidence.

The palynological evidence is equivocal. It is possible to interpret the pollen diagram to support either hypothesis to some extent. The pollen curves from the lower gyttja are indicative of a "tree" birch-spruce-fir woodland, changing in the upper samples of the zone to one dominated by "tree" birch and spruce. Such a partial vegetation sequence might be found accompanying a climatic detoriation where only part of the sequence has been preserved. However, the pollen assemblages and concentrations are similar to those deposited at approximately the time suggested by the radiocarbon dates. The "tree" birch-spruce complex of NEP I 4.36 has concentration and percentage similarities with pollen observations from between 4.90 m to 4.95 m (Table 6.2). Also, the spectra in part are similar to Macpherson's Sugar Loaf pollen zones SL 2 to SL 3 (Table 5.1 page 105).

The concentrations of Isoëtes and Picea from NEP I: 4.36 m are significantly lower than those recorded from NEP II: 4.90 m and 4.95 m. Comparable concentrations are found by NEP II: 4.30 m.

Although an absolute age has not been obtained for the segment from core NEP II between 4.90 m and 4.95 m, it is stratigraphically younger than the sediment dated from 5.21 m to 5.26 m (GSC-2961: 8370±100 BP). It is therefore suggested that core NEP II between 4.90 m to 4.95 m was deposited probably between 7000 to 8000 BP. The similarity of these

Table 6.2: Comparison of the observations from core NEP I 4.36 m: zone NE 1 with those from core NEP II 4.90 m and 4.95 m: zone NE 4

Conc. 10^3 / %	Total Conc.	Tree	Shrub	Herb	Picea	Abies	Pinus	Betula 20	Coryloid (incl. Myrica gale)	Alnus	Gramineae	Sphagnum	Lycopodium	Isoëtes
		Pollens, Spores and Aquatic												
NEP I	375	215	58	10	30	7	10	170	31	10	3	1	4	21
4.36 m		76	20	3	11	2	3	60	11	3	1	1	1	7
		270	56	9	59	9	11	189	38	0	0	0	4	35
NEP I	454	194	106	24	21	2	12	160	63	9	10	3	14	57
4.90 m–4.95 m range	521	80	17	3	17	3	3	56	11	0	0	0	1	10
		60	33	7	6	1	4	50	20	3	3	1	4	15

observations with those from core NEP I 4.36 m suggests that deposition occurred during the same period. The radiocarbon date obtained from the sediment of core NEP I 4.36 m to 4.48 m (WAT-634: 7630±400 BP) is within the suggested age range.

The "tree" birch-spruce-fir pollen assemblage of the lower zone NE 1 does not have an equivalent in the pollen profile of core NEP II. Nevertheless, it appears that a similar sample may be present above 3 m. The general trends at the upper worked limit of core NEP II if extrapolated yield concentration and percentage values not dissimilar from those of core NEP I: 4.50 m (Table 6.3). An indication of the broad vegetational history of the Avalon Peninsula can be gained from the work of Macpherson (1980) and Terasmae (1963), summarized in tables 5.1 and 5.2 pages 105 - 106. Review of the Sugar Loaf profile (Macpherson, 1980) reveals pollen assemblages similar to those under discussion in pollen zones SL 3 and SL 4. It would appear the extrapolations suggested are supported by the visible trends of this profile. Values from core NEP II 3.00 m are presented in Table 6.3 to enable a comparison to be made with NEP I: 4.5 m.

Concentrations are generally higher from core NEP II at 3.00 m than core NEP I at 4.50 m where shrub vegetation is more important. The variations in pollen concentrations from core NEP II show a general long term decline which may reflect a changing sedimentation rate or the less effective dispersal

Table 6.3: Comparison of observations from core NEP I: 4.50 m: zone NE 1 with those from core NEP II: 3.00 m: zone NE 4.

Pollens, Spores and Aquatic

Conc. (10^3) %	Total Conc.	Tree	Shrub	Herb	*Picea*	*Abies*	*Pinus*	*Betula* 20	Coryloid (incl. *Myrica gale*)	*Alnus*	Gramineae	*Sphagnum*	*Lycopodium*	*Isoëtes*
NEP I	145	86	12	5	33	16	3	33	3	8	1	1	1	3
4.50 m		84	12	5	32	16	3	32	3	8	1	1	1	3
NEP II	304	142	35	5	52	18	9	61	11	13	-	4	2	16
3.00 m		78	19	3	29	10	5	36	6	7	-	2	1	8

of pollen. There is a long term decline in the importance of the shrub component of the pollen rain. The pollen assemblage of NE 4 compared to lower NE 1 suggests a more mature forest at the latter. The former has large contributions from Coryloid/Myrica gale and Alnus which together with the great quantities of "tree" and "shrub" birch, suggest a more varied woodland. The Myrica gale and Coryloid profiles from NEP I suggest that much of the Coryloid pollen of core NEP II may be Myrica gale. Lower pollen zone NE 1 does contain elements of the birch-alder association. Concentrations of spruce and fir decline (as does the total pollen rain) but their relative importance is greater. This suggests that the woodland was dominated by spruce and balsam fir while conditions were less favourable for birch and alder.

iii. Conclusion.

It is felt that the most reasonable explanation of the Northeast Pond problem (stratigraphy versus radiocarbon dates) is that the underlying gyttja of core NEP I does represent a stratigraphic anomaly and that it is younger than the overlying sediment. For hypothesis A to be accepted the separately dated radiocarbon ages would have to be rejected and the similarites between the pollen spectra of NE 1 and spectra thought to be of an age similar to that suggested by the radiocarbon dates dismissed as coincidence. There is no basis for such a rejection at this point in time especially since repeated unsuccessful attempts were made to obtain another core similar in stratigraphy to core NEP I. The suggested chronological sequence of the pollen zones is shown in Figure 7.1 page 151.

The mechanism by which the sequence was displaced is open to speculation. It seems likely that some rotational slippage or other folding or faulting may account for the sequence beneath the grey clay. The date from the gyttja above the clay (core NEP I, 4.00 m to 4.15 m, GSC-3102: 7990±160 BP) suggests that the material above the clay has not been inverted. As no repetition of the stratigraphy was found elsewhere in the basin this particular sequence is believed to be of very isolated occurrence. There is no evidence from either the stratigraphy or pollen curves to suggest a disturbance of sediment in core NEP II although the topography of the basin floor is uneven and the instability of underlying sediments in places is possible.

The results from Northeast Pond thus suggest a minimum date for deglaciation of 8370±100 BP (GSC-2961) from core NEP II. As this date was obtained from gyttja and the general sequence begins with grey clay of up to 0.50 m depth, deglaciation of the site must have occurred some time prior to this; possibly before 9000 BP.

b. Interpretation of the palynological evidence.

i. Comment on interpretation of spectra.

The pollen counts are not thought to have been unduly biased by any local pollen producers. There is no evidence from the stratigraphy or environs that the lake has at any time suffered oscillations of the water level similar to those at "Birch Hill's Pond". There is no marginal bog surrounding the lake. The pollen curves of NEP II are taken generally as representing the regional vegetation. However the criticisms raised by Davis (1963) about the reliability of a direct interpretation of vegetation from fossil pollen counts are acknowledged. Statements concerning the actual composition of the vegetation can only be very tentative and concern only the most dominant aspects of the pollen rain.

ii. Summary of trends in the pollen spectra.

Pollen concentrations are low in pollen zone NE 2 (up to 554 X 10^3 grains cm^{-3}, but all except 4.15 m and 4.125 below 36 X 10^3 grains cm^{-3}) rise unevenly in NE 3 to 940 X 10^3 grains cm^{-3} and reach a maximum in lower pollen zone NE 4 at 4.70 m of up to 903 X 10^3 grains cm^{-3}. During NE 2 and occasionally between 5.26 m and 5.10 m of core NEP II shrub taxa contribute the largest percentage of grains to the land pollen sum. Arboreal pollens are the major component of the sum during the remainder of pollen zones NE 3 and NE 4. The concentration of arboreal pollen is greatest at 4.70 m: core NEP II, with values of 425 X 10^3 grains cm^{-3}. The greatest herb percentages are recorded in NE 2 from core NEP I and a more reliable maximum (because of the higher number of grains used in the pollen sum) for NE 3 (ii) of 11% from core NEP II, sample 5.20 m. The highest concentration of herb pollen occurs in this latter sample (47 X 10^3 grains cm^{-3}).

iii. Interpretation

The low pollen concentrations and the deposition of the grey clay are indicative of an unstable soil with an environment with sparse vegetation cover. The most rapid sedimentation rate accompanied the deposition of the inorganic material (contemporary with pollen zone NE 2). The low pollen concentration in pollen zone NE2 could be attributed to three causes.

1. Recolonization delayed by the availability of plants restricted by the speed of migration.
2. Climate still not conducive to recolonization.
3. Environmental conditions (notably the state of soil development and its actual stability) unsuitable for recolonization.

With a sparse cover of vegetation the anchoring effect on the soil would be much reduced. This in itself would promote an increase in drainage basin erosion.

Concentrations similar to pollen zone NE 2 are reported by Macpherson (in prep.) from Sugar Loaf Pond in subzone SL 1 (ii), in clay to clay-gyttja, with a radiocarbon age of 9270$\pm$150 BP (GSC-2601: GSC Radiocarbon List XVIII p. 3). In some aspects the pollen assemblages are similar; i.e. peaks of Gramineae and a rise in Lycopodium. However there are some disparities among the spectra identified; e.g. the quantity of Cyperaceae recorded at Sugar Loaf is not found in zone NE 2. Henningsmoen (1977) does not record any similar pollen assemblage or low concentration of pollen for West

Saddle Pond, Northern Peninsula, Newfoundland. Deposition at this site post dates its emergence from the sea before 7500±150 BP (T-501). If a similar plant assemblage existed on the Northern Peninsula prior to the relative fall in sea level it has not been recorded in the profile.

The early pollen assemblage may relate to a shrub-tundra vegetation but the components of this assemblage are dissimilar from those of the southerly tundra of present day Labrador. Short's (1978) published surface spectra from that area differ significantly having greater amounts of Picea and Alnus with Abies balsamea, Pinus, Betula (undifferentiated) and Myrica gale much less abundant than in the fossil pollen assemblage. The regional pollen assemblage zones of Lamb (1980) for southeastern Labrador are not analogous with NE 2. In the absence of modern and past analogous for the fossil spectra of NE 2 it must be concluded that the early shrub-tundra of the Avalon Peninsula developed under conditions unlike those in Labrador today or in the past.

A series of peaks occurs during pollen zones NE 3 and NE 4 as different taxa become prominent in the regional pollen rain. The early peaks probably reflect the colonization of the drainage basin by Myrica gale succeeded by "shrub" birch and followed by "tree" birch. A broadly similar pattern can be seen in the regional pollen zones of southeastern Labrador (Lamb 1980) although they lack the distinctive Myrica gale and Cyperaceae peaks recorded at Northeast Pond. Pollen and below 5.505 in pollen sub-zone NE 3 (ii) "shrub" birch and other shrubs and herbs, (i.e. Ericales, Gramineae, Cyperaceae, Compositae, Lycopodium and Myrica gale/Coryloid) contribute high percentages of grains to the land pollen sum.

Contemporary with the drop in "shrub" birch is the rise in "tree" birch. Birch is able to colonize relatively immature soils even if affected by fire (Damman 1964), but is also a prolific pollen producer, (Davis 1963). The abundance suggested by the pollen values may therefore be illusory even though birch would be a ready colonizer. As other trees colonized the area conditions would have been less favourable to birch seedlings.

During pollen zone NE 4 further taxa continued to enter the region and Picea, Alnus and Abies balsamea were present although the pollen curves are uneven suggesting that coloniation was not a smooth process. Charcoal was found in most of the samples so it is possible that fire was one cause of the retardation of succession. The continued presence of Alnus, "shrub" birch and Lycopodium suggests that the forest surrounding Northeast Pond was more open than that around "Birch Hill's Pond". Lamb (1980) draws a similar conclusion from the presence of Alnus and Lycopodium at his Whitney's Gulch site in comparison to his sites inland and further north.

Picea is present throughout the samples of zones NE 4, NE 3 and in all save three of NE 2. The concentration values are less than 36 x 10^3 grains cm^{-3} in samples from pollen zones NE 2, NE 3 (i) and 5.26 m in NE 3 (ii). These grains have probably been blown from outside the local area. As Picea migrated towards the study area increasing amounts of pollen were blown into the pond. Once Picea arrived in the area its colonization of the basin was rapid; by 4.80 m concentrations of 106 x 10^3 grains cm^{-3} suggest that the species was ensconced in the area. Lamb's (1980) regional pollen zones suggest that Picea had arrived in southeastern Labrador by 4500BP. On the Avalon Peninsula it is suggested that colonization by Picea was limited by the process of migration rather than by climatic controls. As there are no radiocarbon dates available for this level in NE 4 the timing of the arrival of Picea on the Avalon Peninsula in relation to southeastern Labrador is open to speculation.

The late series of Alnus peaks above 4.35 m in pollen zone NE 4 includes peaks of both A. crispa and A. rugosa. The species were identified (in all profiles) using grain size and the number of pores but the success of this method is not certain. The A. rugosa curve has lower pollen concentrations and relative values than A. crispa. The oscillations in the A. rugosa curve appear to be in sympathy with the larger fluctuations of A. crispa although the A. rugosa curve does peak before the latter. This suggests that even if A. rugosa has been over estimated the two species are present within the pollen rain. A. rugosa is absent from the Avalon Peninsula (Ryan, 1978) which suggests that this fossil pollen has been blown from the main body of the island.

A. crispa is found today around the sites of Northeast Pond and "Birch Hill's Pond". A good example of the problem of correlating pollen diagrams over any distance is the relative paucity of Alnus pollen at "Birch Hill's Pond" compared with Northeast Pond. The abundance of Alnus crispa pollen suggests this species grew successfully in the study area and that the Alnus recorded by the macrofossils of "Birch Hill's Pond" (3.30 m to 3.33 m) must have been prevented from flowering for reasons other than climate. Similar percentage values (up to 25%) of Alnus (undifferentiated) are recorded at Whitney's Gulch in Zone III (Lamb 1980).

Pinus is the third taxon to peak in pollen zone NE 4 and rises unevenly from 4.10 m. The highest values of Pinus are recorded at 3.4 m (up to 10% with concentrations of 21×10^3 grains cm^{-3}). During counting no consistent attempt was made to separate Pinus into species, however during counting it was noted that a large majority of the grains were P. strobus with rare grains of P. resinosa or P. banksiana. The present distribution of Pinus affirms this observation. Pinus strobus is found on the Avalon Peninsula but is more common in the western and central parts of Newfoundland. Pinus resinosa is found in central Newfoundland but not on the Avalon Peninsula. Pinus banksiana is indigenous to other parts of Canada but is present in Newfoundland only as the result of introduction (Ryan 1978).

The values of Pinus are never very high (up to 10%) which suggests that the taxon was never very important in the vegetation and possibly never actually reached the study area. Those grains of P. resinosa and P. banksiana found in the samples have been blown into the region from the main part of Newfoundland and the mainland. The suggestion of Terasmae in 1963 that P. banksiana had once been indigenous to Newfoundland cannot be confirmed since there is insufficient evidence from any profile.

Abies balsamae increases unevenly and the possibility arises that the taxon's true peak does not occur on the diagram, although Lamb (1980) records similar percentage values (up to 10%) in southeastern Labrador in zone III where the species is present.

The uneven migration of Abies balsamea may be due to a series of fires retarding colonization. Damman in 1964 suggested that Abies balsamea is not normally an aggressive recolonizer after fire even if it had been previously a dominant species. Terasmae (1963) and Lamb (1980) also note that Abies balsamea is not normally a part of the primary vegetation after fire. Macpherson (pers. comm.) however has noted its successful growth on cut-over areas. Damman's (1964) observations indicate that seedlings of Abies balsamea will not thrive beneath an alder cover. The substantial concentrations of Alnus pollen observed in pollen zone NE 4 suggest A. crispa at least grew locally. If fire did affect the region then the growth of A. crispa may have been encouraged by an initial increase in available moisture following the fire. If Alnus increased the seedlings of Abies balsamea may not have been able to take advantage of the reduction in shade which would have promoted their growth had Alnus not regenerated rapidly. The recovery of other species would reduce the relative concentration of Alnus and thereby possibly allow the regeneration of Abies balsamea. This might produce the saw toothed pollen profile noted.

6.4 Summary.

Northeast Pond was deglaciated before 8370 BP. This (GSC-2961: 8370±110 BP) was the oldest radiocarbon age obtained but deposition began some time before this as at least 0.50 m of grey clay was found beneath the gyttja.

Pollen analysis has helped in the interpretation of the stratigraphic evidence. It seems that deposition within the rock basin has been irregular and that once laid down sediments may be unstable. The gyttja recovered from beneath the clay layer in core NEP I is apparently material which has been transposed from the stratigraphically higher organic layer.

The pollen zones NE 2, NE 3 (i) and (ii) and NE 4 record the recolonization of the area during and since the deposition of the clay layer in the Holocene. Pollen concentrations are initially low suggesting a sparse vegetation during pollen zone NE 2. This agrees with the stratigraphic evidence of a mineral soil (grey clay layer) in the profile. As colonization continued pollen concentrations increase and there is a transition to the deposition of gyttja in the lake basin. The pollen assemblages suggest the early vegetation was shrub tundra unlike any found today.

The base of the pollen profile of West Saddle Pond, Northern Peninsula, Newfoundland (Henningsmoen, 1977) post-dates the early NE 2 and NE 3 (i) pollen assemblage zones. The migration of arboreal pollen producers towards the sample site records a similar pattern to that of Northeast Pond although the dominance of local pollen producers confuses analysis of the regional pollen assemblage. The differing migration rates of certain taxa (birch, Picea, Alnus and Abies balsamea) produced a series of peaks on the pollen diagrams as they approached and colonized the study area. Their colonization probably occurred during the hypsithermal period which suggests their re-establishment was determined by environmental conditions (other than climatic amelioration) and species mobility.

Pollen zones NE 3 and NE 4 appear to correlate broadly with the pollen assemblage zones I, II and III suggested by Lamb (1980) for southeastern Labrador. However significant differences exist. None of the NE zones record the high percentages of Cyperaceae of Lamb's zone I. Conversely, the substantial quantities of Myrica gale found in the Northeast Pond profile are not found at any of the Labrador sites. The pollen assemblages of Northeast Pond do not reveal the vegetation development shown by Anderson (1980) for Prince Edward Island in that Tsuga, Pinus and Salix never become prominent in the vegetation.

The profile from the core NEP II was not worked above 3.00 m therefore the more recent vegetational trends noted by Macpherson (in prep.) from the Avalon Peninsula; Morrison (1970), Short (1978), and Lamb (1980) from Labrador; Mott (1976) from the Sept Iles area of Quebec and Livingstone's (1968) work from Nova Scotia are not recorded. The general trends of the pollen profiles do not conflict with the lower profiles of either Macpherson or Terasmae (1963).

Chapter 7

Synthesis and conclusions.

The information gained from the sediments of Northeast Pond and "Birch Hill's Pond" cannot be used to substantiate either interpretation of the glacial geomorphology offered in Chapter Four, as no significant regional difference in the absolute or relative chronologies was established in the cores. Analysis of the basal lake sediments has provided minimum absolute ages for the retreat of the last ice on the St. John's Peninsula.

Northeast Pond was ice free by 8310±100 BP (GSC-2961) and "Birch Hill's Pond" by 8540±90 BP (GSC-2985). The pollen assemblages of the dated segments of the cores do not indicate a vegetation assemblage similar to those now observed from ice marginal areas (eg. Pennington 1980, 1977) nor are they characteristic of pioneer species entering a region soon after deglaciation. At Northeast Pond 50 cm of grey clay underlie the dated organic sample which suggests that initial ice retreat probably took place before 9000 BP.

There is no evidence to suggest either core predates 10,000 BP. Earlier suggestions were advanced to account for the probable truncation of the pollen profile from "Birch Hill's Pond" (page 107). It is believed that the initial depression in which a water body existed was not very substantial and that during the early postglacial sediments were flushed from the basin by draining water. Possibly with the melting of a former perennial snowpatch which had drained periodically through "Birch Hill's" gully, the flushing of the pond ceased but sediments deposited initially may be irretrievable if the rock floor of the basin is as fractured as many of the pond floors in the vicinity seem to be. The problem is that not only would such flushing have removed early postglacial sediments but also any older accumulation. Therefore the site may indeed have lain outside the last ice limit with the flushing invoked to explain the absence of early postglacial sediment removing evidence of earlier conditions.

If the ice limit was south of "Birch Hill" then Northeast Pond should contain preglacial sediments, however none have been recovered. Postglacial sediments in this basin appear to have been locally deformed. Although core NEP II did not seem to have any of the anomalies of core NEP I the fact remains that the stratigraphy within this pond can be very deceptive. The possibility cannot be ruled out that older sediments are preserved elsewhere in its basin and that these are not necessarily in their correct stratigraphic position, hence the area may have been outside the late glacial ice limit.

Only changes in the early Holocene vegetation are recorded because of the truncation of the cores. On the basis of the basal radiocarbon dates and pollen assemblages Figure 7.1

Table 7.1 Summary of the suggested correlation of the pollen zones of Northeast Pond and "Birch Hill's Pond" with the profiles of Terasmae (1963) and Macpherson (pers. comm.)

Years BP	Goulds Bog	Whitbourne Bog	Hawke Hills sites	Sugar Loaf Pond	Northeast Pond	"Birch Hill's Pond"
1000		Ericales-"tree" birch	Spruce-birch balsam fir - shrub	Birch-Spruce - balsam fir pollen zone		
2000		(Pollen zone W B 3)	(Pollen zone HH 4)	(Pollen zone S L 4)		
3000					"Tree" birch-spruce (Pollen zone N E 4)	"Tree" birch-spruce-balsam fir (Pollen zone B H 3)
4000	"Tree" birch-spruce-balsam fir (Pollen zone G B 2)	"Tree" birch-balsam fir (Pollen zone W B 2)	Birch-spruce-balsam fir (Pollen zone HH 3)			
5000						
6000			Birch-spruce-balsam fir with poplar (Pollen zone HH 2)	Birch-spruce-balsam fir with poplar (Pollen zone S L 3)		
7000					Coryloid-"tree" birch	
8000	Birch-balsam fir - spruce (Pollen zone G B 1)		Birch-shrub-spruce 1 (Pollen zone HH 1)	Birch-shrubs-lycopodium (Pollen zone SL 2)	Sweet gale-birch (Pollen sub-zone N E 3 i)	"Tree" birch-Sweet gale (Pollen zone B H 2)
9000		Birch-pine (Pollen zone W B 1)		ii) Sedge-Oxyria digyna (Pollen sub zone SL (ii))	sub-pollen zone N E 3 ii)	Sweet gale-sedge-birch (Pollen zone B H 1)
				i) Sedge-willow -Ericales (Pollen sub-zone SL 1 (i))	Sweet gale-Ericales-willow (Pollen zone NE 2)	

suggests a tentative correlation of the pollen profiles of "Birch Hill's Pond" and Northeast Pond with those of Macpherson (pers. comm.) and Terasmae (1963). The early parts of the profiles record the colonization of the surrounding area with the arrival of the postglacial vegetation.

Taxa appear to have entered the region independently as a series of peaks suggests that their expansions occurred at different times. Recolonization may have been delayed by the speed at which taxa could migrate from their glacial refugia. As the taxa entered the region over a period of time and tended to spread rapidly once they colonized the drainage basin, it is felt that the species were not excluded from the earlier period, recorded by the cores of "Birch Hill's" and Northeast ponds, necessarily because of unsuitable climatic conditions.

If the vegetation assemblage was not a product of the then existing climate, it may explain why the fossil pollen spectra preserved in the basal cores of "Birch Hill's Ponds" and Northeast Pond are anomalous compared with present published pollen spectra. For instance, the tundra component of the vegetation from pollen zones BH 1 and NE 2 is considered to be a reflection of the slow migration rates of arboreal species (i.e. Pinus, Abies balsamea and "tree" birch) rather than the product of climatic conditions which are today associated with tundra. An examination of the published surface spectra from Labrador (Short, 1978) fails to show any pollen spectra similar to the early postglacial period of "Birch Hill's" and Northeast Pond. The high values of Myrica gale (up to 38% in pollen zone BH I: 4.275 m) are not recorded from Labrador in published surface pollen spectra or at any time during the Holocene (Morrison 1970, Short 1978, Lamb 1980). The ecological conditions which allowed Myrica gale to flourish on the Avalon Peninsula no longer exist nor have existed during the Holocene in Labrador. The succession of vegetation within the early post glacial period may have been primarily controlled by migration rates while the vegetation assemblage of many areas today is a product of other ecological restrictions.

The initial interpretation of the stratigraphy of the core NEP I was that Northeast Pond did contain sediments older than 10,000 years and that the site had remained ice free during the last expansion of ice on the Avalon Peninsula. Subsequent radiocarbon dating of the basal organic sediments indicate this interpretation is wrong. The former interpretation was rejected as the pollen counts of pollen zone NE 1 supported the determined radiocarbon ages. Therefore although both Northeast Pond and "Birch Hill's Pond" potentially may have contained sediments older than 10,000 years (if Grant's 1977a late ice limit is correct) such sediments were not retrieved. However, this does not preclude the existence of such sediments within these ponds (especially in the light of the disturbed stratigraphy of Northeast Pond) or that they may have been removed (by the flushing suggested for "Birch Hill's Pond"). Older sediments may exist elsewhere on the St. John's Peninsula but the evidence to date does not support Grant's hypothesis. A similar palynological study of bogs from Prince Edward Island (Anderson 1980) failed to substantiate the late glacial limit suggested by Grant (1977a).

The geomorphic evidence has not helped to clarify the glacial history of the study area. It is obvious that the whole area has been glaciated in the past and it is suggested that within the studied area two different glacial landscapes may be recognized. These have been designated Zones I and II, and refer respectively to a landscape primarily exhibiting features of glacial erosion and a landscape dominated by deposition in the vicinity of stagnant or passive ice. The status of these zones is unclear: that is, whether they are the product of one glaciation or two, and if the latter, whether or not the northern boundary of Zone II correlates with the limit of a late-glacial ice sheet.

The identification of the landscapes agrees broadly with the division of the area suggested by Vanderveer's map (1975, see Figure 2.3). The zones can be integrated into either Henderson's (1972) hypothesis of extensive late ice cover or Grant's (1977a) more restricted ice advance theory, since neither landscape can be linked to a chronology. It was hoped that the lake cores could provide such a chronology for the deglaciation of the area. Both have provided minimum ages which indicate that some sites were probably ice-free by 9000 BP. However, there is no evidence from either core that suggests either site was ice-free long before the other or during the final ice advance. Therefore there is no way of assigning relative or absolute ages to the glacial landscapes on the basis of the results of the analysis of the lake sediments.

The radiocarbon dates at present available relating to the early postglacial period of the St. John's Peninsula suggest that the areas along the Atlantic coast were not ice-free as early as on the west coast of Newfoundland, in southeast Labrador, Quebec and the Maritimes. Early Holocene dates from the Avalon Peninsula are presented in Figure 7.2 while Figure 7.3 lists selected early dates which have been used to suggest minimum dates for initial late-ice retreat in area Newfoundland and Labrador, Nova Scotia, Quebec and New Brunswick.

From the present information it would seem that the initial deglaciation of the St. John's Peninsula did not occur before 10,000 BP while elsewhere evidence has been found which suggests that the late ice began to retreat probably as early as 14,000BP from coastal sites. Future work may provide older dates for the St. John's Peninsula.

Table 7.2 Selected early Holocene radiocarbon dates from the Avalon Peninsula

Age BP	Laboratory designation	Site
9270±150	GSC - 2601	Sugar Loaf Pond, nr. St. John's
8540± 90	GSC - 2985	"Birch Hill's Pond", nr. Pouch Cove
8310±100	GSC - 2961	Northeast Pond, nr. Cape St. Francis
8120±300	GSC - 4	Whitbourne Bog, central Avalon Peninsula
7400±100	L - 3911	Goulds Bog, nr. St. John's

Table 7.3 Selected radiocarbon dates for the initial retreat of the late-Wisconsinan ice along the Atlantic Seaboard of Canada

Age BP	Laboratory designation	Site
13,800±260	GSC - 2113	Wreckhouse Cabot Strait, southwestern Nfld. (Lowdon and Blake 1975)
13,600±110	GSC - 2015	St. George's Bay, southwestern Nfld. (Lowdon and Blake 1975)
12,600±170	GSC - 868	Cox's Cove, western Nfld. (Lowdon and Blake, 1970)
12,000±320	GSC - 1462	Little Port, western Nfld. (Lowdon and Blake 1973)
11,950±170	GSC - 75	Middle Arm, Green Bay, Nfld. (Dyck and Fyles, 1963).
10,500±150	GSC - 1343	Quirpon, Northern Peninsula, Nfld. (Lowdon and Blake 1973)
10,550±290	SI - 3345	Southeast Labrador, Nfld. (Lamb, 1980)
14,400±530	GSC - 2573	Mispec Bay (1), N.S. (Lowdon and Blake, 1979)
13,800±160	GSC - 1908	Ruisseau Castor, Gaspe, Que. (Lowdon and Blake, 1979)
11,500±270	GSC - 2185	Central Chaleur Bay, N.B. (Lowdon et al. 1977)
11,300±160	GSC - 541	Port Hood Island, N.S. (Lowdon and Blake, 1976)

If one were to speculate on the premise of the presently available evidence then the delayed ice retreat of the late-ice on the Avalon Peninsula has important implications as to the global circulation patterns over the North Atlantic 10,000 BP. Ruddiman and Glover (1975) suggest that the sub-polar circulation over the North Atlantic 9300 BP would indeed have drawn depression tracks over the Avalon Peninsula bringing increased precipitation. If this precipitation fell as snow, it might have been sufficient to maintain an ice cover over the Avalon Peninsula even though ice was in retreat from other coastal areas in Eastern Canada.

Further radiocarbon dates from other coastal sites on the Avalon Peninsula are needed to clarify the problem of the date of the last ice retreat. This study found no conclusive evidence to refute Grant's restricted ice hypothesis for the St. John's Peninsula but the evidence presented does not support it. The coastal area of the northern St. John's Peninsula was probably ice-free by 9,000 BP but a maximum age for the initial deglaciation of the study area is not available. Therefore the limit of late-glacial ice on the St. John's Peninsula remains open to speculation.

The lake cores do not record the severe climatic conditions during the post glacial as suggested by work from elsewhere on the island (Brookes 1970, Eyles 1977, Tucker 1979) although the grey clay retrieved from Northeast Pond does suggest harsh environmental conditions with an unstable soil cover. It is probable that the severe conditions reported from elsewhere on the island are older than the basal sediments recovered from the St. John's Peninsula. If the ice had retreated earlier than present evidence suggests then such severe conditions may have affected the peninsula but no evidence has been found which suggests this. The morainic mound now quarried at "Birch Hill's Pond" is not believed to be an end moraine attributable either to the limit of the last glacial ice or to a readvance associated with the severe conditions recorded elsewhere on the island. If climatically severe conditions extended to the Avalon Peninsula periglacial features would not have formed if the area was covered by glacial ice. If deglaciation was delayed and ice retreat occurred as the result of climatic amelioration and did not suffer any marked reversal, then the ice marginal and periglacial features reported from elsewhere may not be present on the St. John's Peninsula.

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Appendix A

All percentage and concentration calculations based on the pollen counts of the core BH I from "Birch Hill's Pond" and the cores NEP I and NEP II from Northeast Pond are tabulated within this appendix.

Percentage computations (i.e. Tables A:1, A:3, and A:5) are based on the mathematical formula outlined in Chapter Three (p. 60).

In brief:

$$\frac{100}{Ps} \cdot n = N$$

where

(1) Ps is the pollen sum = all Σ trees, Σ shrubs, + Σ herbs.

n is the number of observations per taxon.

and N is the percentage contribution of n observations to the pollen sum.

The percentage of spores is obtained by including the number of spores in the sum for this group of plants (2).
Similarly the percentage of aquatics was obtained by adding the number of observations to the original land pollen sum (3).
The indeterminable percentage was detained by a similar modification to the original land pollen sum (4).

Concentration values of grains cm^{-3} of sample (tabulated in A:2; A:4 and A:6) are to 4 d.p but are presented as 10^3. The mathematical technique for obtaining these values is outlined in Chapter Three (p. 56).

The formula used was

$$\frac{Ex}{Ex^1} \cdot n = N^1$$

where Ex is the average number of exotic grains added

Ex^1 is the number of exotic grains observed per sample slide

n is the number of observations per taxon

and N^1 is the concentration of taxon per 1 cm^3 of sample.

Table A.1: Percentage calculations based on observations from core BH I

Sample depth (cm)		438	435	432.5	430	427.5	425	422.5	420	417.5	415	412.5	410	407.5	405
Land pollen sum	(1)	728	604	667	361	377	231	216	231	290	179	250	305	211	169
Tree %	(1)	20.44	19.2	23.7	24.64	24.84	32.25	37.26	44.72	44.54	46.48	63.2	67.32	74.73	40.71
Shrub %	(1)	49.84	53.55	43.95	42.84	54.27	44.72	37.72	41.28	37.06	38.08	26.0	21.78	15.04	18.88
Herb%	(1)	31.64	29.41	32.4	33.6	22.68	22.36	24.38	13.33	17.0	15.68	10.8	11.55	9.4	40.12
Spore %	(2)	4.55	4.0	3.36	4.05	2.34	5.74	1.8	2.94	5.61	1.65	2.73	0.66	1.88	3.42
Aquatic %	(3)	31.68	51.68	56.	40.46	35.36	26.97	32.86	27.59	23.66	20.68	3.51	8.7	4.05	7.7
Indeterminable %	(4)	16.83	14.84	21.12	36.72	24.2	45.84	50.6	68.32	55.95	58.74	52.0	41.04	29.24	45.21
Picea		1.96	1.36	1.2	1.4	3.78	1.72	4.6	6.88	5.44	7.84	8.4	9.24	5.64	12.98
Abies balsamea			0.51		0.28		1.29	0.92	2.15	1.02	2.24	9.2	2.97	8.46	3.54
Pinus		1.4	0.17	0.9	2.52	2.16	2.15	2.76	3.87	1.7	1.68	2.4	1.65	2.35	2.36
Betula (arboreal)		16.8	17.34	21.15	20.16	18.63	27.09	28.98	31.82	36.38	34.72	42.8	52.8	57.81	21.83
Acer															
Fagus				0.15											
Juglans		0.28	0.17	0.15								0.4	0.66		
Populus			0.17	0.15											
Quercus															
Tilia					0.28										
Tsuga														0.47	
Ulmus						0.27									
Betula (shrubs)		8.4	4.42	7.2	7.28	8.91	6.88	10.12	9.89	7.48	7.28	3.2	3.96	4.7	1.18
Myrica gale		28.7	36.38	25.8	26.32	37.53	26.66	19.32	24.08	20.4	21.84	18.4	12.87	5.17	13.57
Coryloid		8.82	9.52	8.15	5.04	4.05	9.89	6.44	4.73	4.76	6.16	3.2	3.3	3.76	2.95
Alnus crispa		1.12	0.85	1.05	0.84	0.54	0.86	0.46	1.29	3.06	1.12	0.4	0.33	0.47	
Alnus rugosa		0.28		0.15	0.56	0.54			0.43			0.4	0.33		0.59
Ericales		2.52	2.04	1.2	2.24	2.43	0.43	1.38	0.86	0.68	1.68	0.4	0.33		0.59
Salix			0.34		0.56	0.27				0.68			0.66	0.94	
Caprifoliaceae															

Table A.1 (continued)

Sample depth (cm)	438	435	432.5	430	427.5	425	422.5	420	417.5	415	412.5	410	407.5	405
Gramineae	6.44	5.27	6.6	6.72	4.32	4.3	3.22	0.86	4.08	2.24	2.0	1.65	0.94	1.77
Cyperaceae	19.46	19.21	21.6	24.36	16.47	15.91	18.86	9.03	11.56	12.32	6.8	7.59	5.17	34.22
Compositae	3.08	4.42	1.95	1.12	0.54	0.43	0.46	1.72	0.34	0.56	0.8	0.33		1.77
Rosaceae	0.28	0.17	0.45	0.56	0.27			0.43				1.98	0.47	1.18
Thalictrum	1.4	0.17	0.9	0.56	1.08	1.29	1.38	1.29	1.02	0.56	0.8			0.59
Urtica	0.7	0.17	0.75	0.28			0.46						0.94	
Gentianaceae													1.88	
Leguminosae	0.14		0.15			0.43					0.4			0.59
Saxifragaceae	0.14													
Umbelliferae														
Sphagnum	0.39		0.28	0.54		0.82					0.39			
Lycopodium	4.16	4.	3.08	3.51	2.34	4.92	1.8	2.94	5.61	1.65	1.95	0.66	1.41	3.42
Selaginella														
Osmunda											0.39		0.47	
Isoëtes	30.87	51.2	55.16	39.78	33.76	25.11	30.69	22.63	22.1	18.8	1.95	7.8	1.35	6.6
Typha	0.63	0.24	0.14	0.17	1.28	0.93	1.86	2.48		1.76	0.39	0.3	2.25	1.1
Potamogeton						0.31								
Nymphaeaceae	0.18	0.24	0.7	0.51	0.32	0.62		0.93	1.56	0.44	1.17	0.6	0.45	
Eriocaulon							0.31	1.55						

Table A.1 (continued)

Sample depth (cm)	402.5	400	395	390	380	370	360	350	340	330	320	310	300
Land pollen sum (1)	155	176	187	156	152	101	150	151	205	151	150	226	241
Tree % (1)	46.8	29.07	78.97	87.68	77.88	49.5	89.1	77.22	70.07	78.54	71.94	69.96	75.44
Shrub % (1)	11.05	26.79	8.48	6.4	11.88	33.66	9.38	19.14	22.54	15.84	23.1	19.8	9.84
Herb % (1)	42.9	44.46	11.66	5.76	10.56	16.83	2.01	3.3	7.84	5.28	3.96	9.68	13.53
Spore % (2)	0.64	1.12	1.59	2.52	3.78	1.94	9.6	9.6	35.96	49.83	34.4	0.44	1.23
Aquatic % (3)	4.34	3.78	4.08	3.72	3.15	5.58	0.66	4.41	3.76	2.6	1.95	5.04	7.38
Indeterminable % (4)	38.	46.19	42.47	29.7	24.5	35.2	36.12	15.68	26.28	26.95	22.88	34.8	30.45
Picea	3.25	3.42	15.37	5.76	10.56	3.96	7.37	24.42	23.03	28.38	26.4	23.76	34.04
Abies balsamea	1.95	1.14	12.72	26.24	23.76	4.95	24.12	17.82	9.8	12.54	3.96	9.24	4.1
Pinus	0.65	3.42	5.83	5.76	4.62	1.98		0.66	0.49	3.3	3.3	3.08	
Betula (arboreal)	40.95	21.09	45.05	49.92	38.94	36.63	57.62	34.32	36.75	34.32	38.28	32.12	36.9
Acer												0.44	
Fagus													
Juglans						0.99						0.44	
Populus													
Quercus													0.41
Tilia													
Tsuga													
Ulmus						0.99						0.88	
Betula (shrubs)		1.71			1.32	0.99	1.34		2.94	0.66	0.66	0.88	0.82
Myrica gale	7.8	19.95	4.77	3.2	8.58	23.76	4.69	11.22	12.25	9.24	14.52	11.88	7.79
Coryloid	2.6	3.99	1.06	1.28		1.98	0.67	2.64	2.94	1.98	1.98	3.52	
Alnus crispa		0.57	0.53	0.64	1.32	2.97		2.64		0.66	1.32	2.2	0.41
Alnus rugosa			0.53	1.28		0.99		0.66		0.66	1.32	0.44	
Ericales	0.65	0.59	1.57		0.66	1.98	2.68	1.32	3.92	2.64	3.3	0.88	
Salix								0.66	0.49				0.82
Caprifoliaceae						0.99							

Table A.1 (continued)

Sample depth (cm)	402.5	400	395	390	380	370	360	350	340	330	320	310	300
Gramineae	0.65	2.85				5.94	0.67		0.98		1.32	1.32	3.69
Cyperaceae	40.3	40.47	9.01	4.48	6.6	7.92	1.34	2.64	5.39	3.3	2.64	7.48	4.51
Compositae			0.53	1.28	1.32	0.99		0.66	0.49	0.66			4.92
Rosaceae	1.3		0.53		0.66					0.66		0.44	
Thalictrum	0.65				0.66	1.98				0.66			
Urtica		1.14	0.53						0.98				
Gentianacaeae					0.66								0.41
Leguminosae					0.66							0.44	
Plantago													
Saxifragaceae			0.53										
Umbelliferae			0.53										
Sphagnum		0.56	0.53	0.63	3.78		7.2	9.0	35.34	49.83	33.54	0.44	0.82
Lycopodium	0.64	0.56	1.06	1.89		1.94	2.4	0.6	0.62		0.43		0.41
Selaginella											0.43		
Osmunda													
Isoëtes	4.34	3.24	3.06	3.72	3.15	5.58	1.95	3.78	3.76	1.95	1.95	4.2	6.15
Typha		0.54	1.02				0.65	0.63		0.65		0.84	
Potamogeton													0.39
Nymphaeaceae													0.39
Eriocaulon													0.39

Table A.2: Concentration calculations based on observations from core BH I

Sample depth (cm)	438	435	432.5	430	427.5	425	422.5	420	417.5	415
Total pollen conc.	391.812	1627.7847	1872.7078	205.6452	1046.0864	692.0859	768.7812	703.182	950.3346	611.3696
Tree conc.	45.114	136.7292	177.4972	22.1232	132.296	99.2475	111.9987	89.7312	161.4706	102.3058
Shrub conc.	110.004	371.2905	329.1562	38.4642	289.038	137.6232	113.3814	82.8288	134.3534	83.8168
Herb conc.	69.834	203.9151	242.6544	30.168	120.792	68.8116	73.2831	26.7468	61.63	34.5128
Spore conc.	10.815	29.4675	26.9616	3.771	12.942	18.5262	5.5308	6.0396	20.9542	3.6978
Aquatic conc.	108.768	761.4402	898.724	59.8332	317.798	115.1271	146.5662	76.7892	112.1666	57.9322
Indeterminable conc.	47.277	124.9422	197.7184	51.2856	173.998	252.7503	318.021	421.0464	459.7598	329.1042
Picea	4.326	9.4296	8.9872	1.257	20.132	5.2932	13.827	13.8048	19.7216	17.2564
Abies balsamea		3.5361		0.2514		3.9699	2.7654	4.314	3.6978	4.9304
Pinus	3.09	1.1787	6.7404	2.2626	11.504	6.6165	8.2962	7.7652	6.163	3.6978
Betula (arboreal)	37.08	120.2274	158.3994	18.1008	99.222	83.3679	87.1101	63.8472	131.8882	76.4212
Acer										
Fagus			1.1234							
Juglans	0.618	1.1787	1.1234							
Populus		1.1787	1.1234							
Quercus										
Tilia				0.2514						
Tsuga										
Ulmus					1.438					
Betula (shrubs)	18.54	30.6462	53.9232	6.5364	47.454	21.1728	30.4194	19.8444	27.1172	16.0238
Myrica gale	63.345	252.2418	193.2248	23.6316	199.882	82.0446	58.0734	48.3168	93.956	48.0714
Coryloid	19.467	66.0072	64.0338	4.5252	21.57	30.4359	19.3578	9.4908	17.2564	13.5586
Alnus crispa	2.472	5.8935	7.8638	0.7542	2.876	2.6466	1.3827	2.5884	11.0934	2.4652
Alnus rugosa	0.618		1.1234	0.5028	2.876			0.8628		
Ericales	5.562	14.1444	8.9872	2.0112	12.942	1.3233	4.1481	1.7256	2.4652	3.6978
Salix		2.3574		0.5028	1.438				2.4652	
Caprifoliaceae										

Concentration values X 10^3 grain cm^{-3}

Table A.2: (continued)

Sample depth (cm)	438	435	432.5	430	427.5	425	422.5	420	417.5	415
Gramineae	14.214	36.5397	49.4296	6.0336	23.008	13.233	9.6789	1.7256	14.7912	4.9304
Cyperaceae	42.951	133.1931	161.7696	21.8718	87.718	48.9621	56.6907	18.1188	41.9084	27.1172
Compositae	6.798	30.6462	14.6042	1.0056	2.876	1.3233	1.3827	3.4512	1.2326	1.2326
Rosaceae	0.618	1.1787	3.3702	0.5028	1.438			0.8628		
Thalictrum	3.09	1.1787	6.7404	0.5028	5.752	3.9699	4.1481	2.5884	3.6978	1.2326
Urtica	1.545	1.1787	5.617	0.2514			1.3827			
Gentianaceae										
Leguminosae	0.309		1.1234			1.3233				
Saxifragaceae	0.309									
Umbelliferae										
Sphagnum	0.927		2.2468	0.5028		2.6466				
Lycopodium	9.888	29.4675	24.7148	3.2682	12.942	15.8796	5.5308	6.0396	20.9542	3.6978
Selaginella										
Osmunda										
Isoëtes	105.987	754.368	885.2392	58.8276	303.418	107.1873	136.8873	62.9844	104.771	51.7692
Typha	2.163	3.5361	2.2468	0.2514	11.504	3.9699	8.2962	6.9024		4.9304
Potamageton						1.3233				
Nymphaeaceae	0.618	3.5361	11.238	0.7542	2.876	2.6466		2.5884	7.3956	1.2326
Eriocaulon							1.3827	4.314		

Concentration values X 10^3 grains cm^{-3}

Table A.2: (continued)

Sample depth (cm)	412.5	410	407.5	405
Gramineae	5.5595	3.278	2.157	4.314
Cyperaceae	18.9023	15.0788	11.8635	83.404
Compositae	2.2238	0.6556		4.314
Rosaceae		3.9336	1.0785	2.876
Thalictrum	2.2238			1.438
Urtica			2.157	
Gentianaceae			4.314	
Leguminosae	1.1119			1.438
Saxifragaceae				
Umbelliferae				
Sphagnum	1.1119			
Lycopodium	5.5595	1.3112	3.2355	8.628
Selaginella				
Osmunda	1.1119		1.0785	
Isoëtes	5.5595	17.0456	3.2355	17.256
Typha	1.1119	0.6556	5.3925	2.876
Potamageton				
Nymphaeaceae	3.3357	1.3112	1.0785	
Eriocaulon				

Concentration values X 10^3 grains cm^{-3}

Table A.2: (continued)

Sample depth (cm)	412.5	410	407.5	405
Total pollen conc.	584.8594	361.8912	331.0995	468.788
Tree conc.	175.6802	133.7424	171.4815	99.222
Shrub conc.	72.2735	43.2696	34.512	46.016
Herb conc.	30.0213	22.946	21.57	97.784
Spore conc.	7.7833	1.3112	4.314	8.628
Aquatic conc.	10.0071	19.0124	9.7065	20.132
Indeterminable conc.	289.094	141.6096	89.5155	197.0
Picea	23.3499	18.3568	12.942	31.636
Abies balsamea	25.5737	5.9004	19.413	8.628
Pinus	6.6714	3.278	5.3925	5.752
Betula (arboreal)	118.9733	104.896	132.6555	53.206
Acer				
Fagus				
Juglans	1.1119	1.3112		
Populus				
Quercus				
Tilia				
Tsuga			1.0785	
Ulmus				
Betula (shrubs)	8.8952	7.8672	10.785	2.876
Myrica gale	51.1474	25.5684	11.8636	33.074
Coryloid	8.8952	6.556	8.628	7.19
Alnus crispa	1.1119	0.6556	1.0785	
Alnus rugosa	1.1119	0.6556		1.438
Ericales	1.1119	0.6556		1.438
Salix		0.6556	2.157	
Caprifoliaceae				

Table A.2: (Continued)

Sample depth (cm)	402.5	400	395	390	380	370	360	350	340
Total pollen conc.	195.951	299.792	280.06	270.4888	90.0152	35.916	129.2148	133.2392	414.9042
Tree conc.	54.684	46.614	124.564	159.7283	50.1028	10.95	68.4684	77.1732	147.5903
Shrub conc.	12.9115	42.958	13.376	11.659	7.6428	7.446	7.2072	19.1284	47.4766
Herb conc.	50.127	71.292	18.392	10.4931	6.7936	3.723	1.5444	3.298	16.5136
Spore conc.	0.7595	1.828	2.508	4.6636	2.5476	0.438	8.2368	10.5536	119.7236
Aquatic conc.	5.3165	6.398	6.668	6.9954	2.123	1.314	2.0592	4.6172	8.2568
Indeterminable conc.	72.1525	130.702	114.532	76.9494	20.8054	12.045	41.6988	18.4688	75.3433
Picea	3.7975	5.484	24.244	10.4931	6.7936	0.876	5.6628	24.4052	48.5087
Abies balsamea	2.2785	1.828	20.064	47.8019	15.2856	1.095	18.5328	17.8092	20.642
Pinus	0.7595	5.484	9.196	10.4931	2.9722	0.438		0.6596	1.0321
Betula (arboreal)	47.8485	33.818	71.06	90.9402	25.0514	8.103	44.2728	34.2992	77.4075
Acer									
Fagus									
Ilex									
Juglans						0.219			
Populus									
Quercus									
Tilia									
Tsuga									
Ulmus						0.219			
Betula (shrubs)		2.742			0.8492	0.219	1.0296		6.1926
Myrica gale	9.114	31.99	7.524	5.8295	5.5198	5.256	3.6036	11.2132	25.8025
Coryloid	3.038	6.398	1.672	2.3318		0.438	0.5148	2.6384	6.1926
Alnus crispa		0.914	0.836	1.1659	0.8492	0.657		2.6384	
Alnus rugosa			0.836	2.3318		0.219		0.6596	
Ericales	0.7595	0.914	2.508		0.4246	0.438	2.0592	1.3192	8.2568
Salix								0.6596	1.0321
Caprifoliaceae						0.219			

Concentration values X 10^{-3}

Table A.2: (continued)

Sample depth (cm)	402.5	400	395	390	380	370	360	350	340
Gramineae	0.7595	4.57				1.314	0.5148		2.0642
Cyperaceae	47.089	64.894	14.212	8.1613	4.246	1.752	1.0296	2.6384	11.3531
Compositae			0.836	2.3318	0.8492	0.219		0.6596	1.0321
Rosaceae	1.519		0.836		0.4246				
Thalictrum	0.7595				0.4246	0.438			
Urtica		1.828	0.836						2.0642
Gentianaceae					0.4246				
Leguminosae					0.4246				
Plantago									
Ranunculaceae									
Saxifragaceae			0.836						
Umbelliferae			0.836						
Sphagnum		0.914	0.836	1.1659	2.5476		6.1776	9.894	117.6594
Lycopodium	0.7595	0.914	1.672	3.4977		0.438	2.0592	0.6596	2.0642
Selaginella									
Osmunda									
Isoëtes	5.3165	5.484	5.016	6.9954	2.123	1.314	1.5444	3.9576	8.2568
Typha		0.914	1.672				0.5148	0.6596	
Potamogeton									
Nymphaeaceae									
Eriocaulon									

Concentration values X 10^3 grains cm^{-3}

Table A.2: (continued)

Sample depth (cm)	330	320	310	300
Total pollen conc.	290.3022	300.0026	351.9995	361.4583
Tree conc.	96.4971	119.3441	155.8995	181.2216
Shrub conc.	19.4616	38.3215	44.1225	23.6376
Herb conc.	6.4872	6.5694	21.571	32.5017
Spore conc.	122.4459	87.592	0.9805	2.9547
Aquatic conc.	3.2436	3.2847	11.766	17.7282
Indeterminable conc.	42.1668	44.8909	117.66	103.4145
Picea	34.8687	43.796	52.947	81.7467
Abies balsamea	15.4071	6.5694	20.5905	9.849
Pinus	4.0545	5.4745	6.8635	
Betula (arboreal)	42.1668	63.5042	71.5765	88.641
Acer			0.9805	
Fagus				
Ilex				
Juglans			0.9805	
Populus				
Quercus				0.9849
Tilia				
Tsuga				
Ulmus			1.961	
Betula (shrubs)	0.8109	1.0949	1.961	1.9698
Myrica gale	11.3526	24.0878	26.4735	18.7131
Coryloid	2.4327	3.2847	7.844	
Alnus crispa	0.8109	2.1898	4.9025	0.9849
Alnus rugosa	0.8109	2.1898	0.9805	
Ericales	3.2436	5.4745	1.961	
Salix				1.9698
Caprifoliaceae				

Concentration values X 10^{-3}

Table A.2: (continued)

Sample depth (cm)	330	320	310	300
Gramineae		2.1898	2.9415	8.8641
Cyperaceae	4.0545	4.3796	16.6685	10.8339
Compositae	0.8109			11.8188
Rosaceae	0.8109		0.9805	
Thalictrum	0.8109			
Urtica				
Gentianaceae				0.9849
Leguminosae			0.9805	
Plantago				
Ranunculaceae				
Saxifragaceae				
Umbelliferae				
Sphagnum	122.4459	85.4022	0.9805	1.9698
Lycopodium		1.0949		0.9849
Selaginella		1.0949		
Osmunda				
Isoëtes	2.4327	3.2847	9.805	14.7735
Typha	0.8109		1.961	
Potamogeton				0.9849
Nymphaeacea				0.9849
Eriocaulon				0.9849

Concentration values X 10^3 grains cm^{-3}

Table A.3: Percentage calculations based on observations from core NEP I

Sample depth (cm)	453	450	447.5	445	442.5	440	437.5	436	434	432.5	430	427.5	425	422.5
Land pollen sum (1)	298	209	245	292	567	365	377	415	17	55	21	45	17	28
Tree % (1)	86.02	83.52	84.87	81.6	84.42	86.94	91.53	75.84		14.4	42.84	33.3	29.4	39.27
Shrub % (1)	12.92	11.52	12.71	14.28	15.12	7.83	7.02	20.4	41.16	68.4	42.84	55.5	58.8	53.55
Herb % (1)	2.38	5.28	2.87	3.4	2.52	3.78	3.24	3.22	58.8	16.2	14.28	11.1	11.76	7.14
Spore % (2)	2.97	2.35	6.08	4.62	6.97	2.97	1.82	1.68		18.	4.55	6.24	15.	22.24
Aquatic % (3)	7.13	3.68	6.84	4.8	6.46	7.25	6.0	7.04	10.52			2.17		12.52
Indeterminable % (4)	17.82	25.2	17.82	23.92	17.85	21.21	15.4	18.2	26.1	2.9	4.35	15.12	29.9	24.3
Picea	30.16	32.16	30.75	23.12	33.12	29.7	34.29	10.56			9.52	2.22		7.14
Abies balsamea	17.0	15.84	20.91	15.3	8.82	6.75	7.83	2.4				2.22		
Pinus	6.12	3.36	3.69	5.44	4.14	4.59	4.86	3.36		9.1		11.1	11.76	21.42
Betula (arboreal)	32.3	31.68	28.7	37.4	38.16	45.63	44.28	59.52		5.46	28.56	17.76	11.76	10.71
Acer														
Fagus			0.82	0.34		0.27	0.27				4.76			
Aquifoliaceae														
Juglans													5.88	
Tilia					0.18									
Tsuga														
Ulmus		0.48												
Betula (shrubs)	0.68			0.68	0.9	1.89	2.43	6.0	17.64	21.84	14.28	15.54	11.76	
Myrica gale	4.08	2.4	4.51	4.76	6.3	2.97	2.43	8.16				6.66	23.52	14.28
Coryloid	2.04	0.48	1.64	1.02	2.52	0.81	0.27	2.64						
Alnus crispa	4.42	5.76	4.51	6.46	4.14	1.08	1.08	1.92				2.22		10.71
Alnus rugosa	1.36	1.92	0.82	0.68	0.9	1.08	0.54	1.2						
Ericales			1.23	0.68	0.36		0.27	0.48	5.88	23.66	23.8		23.52	10.71
Salix	0.34	0.96							17.64	14.56	9.52	6.66		17.85
Juniperus												6.66		14.28

Table A.3: (continued)

Sample depth (cm)	453	450	447.5	445	442.5	440	437.5	436	434	432.5	430	427.5	425	422.5
Gramineae		0.96	0.82	0.34		0.27		0.96	41.16	5.46	9.52	2.22	11.76	7.14
Cyperaceae		0.96	0.82	1.02	1.08	0.54	0.54			5.46		2.22		
Compositae	0.34				0.18		0.27	0.48	5.88	1.82		2.22		
Rosaceae	1.36	2.88		0.68	0.54	1.62	1.35	1.44	11.76	3.64				
Thalitrum				0.34	0.36	1.08	0.54	0.24						
Urtica	0.68	0.48	0.82	0.34	0.18	0.27	0.27	0.24						
Chenopodiaceae														
Gentianaceae														
Leguminosae			0.41	0.68	0.18							2.22		
Ranunculaceae												2.22		
Umbelliferae							0.27							
Sphagnum	0.99	1.41	3.8	2.64	3.68	1.35	0.78	0.24		13.41	4.55	4.16	5.0	8.34
Lycopodium	0.66	0.96	0.38	0.99	1.44	0.81	1.04	1.44		4.47		2.08	10.0	13.9
Selaginella	0.66													
Osmunda	0.66		1.9	0.99	1.44	0.81								
Isoëtes	7.59	2.76	4.18	4.8	5.67	7.0	6.0	6.82	10.52			2.17		12.52
Typha					0.15									
Nymphaeaceae														
Eriocaulon		0.92	1.14		0.64	0.25		0.22						
Myriophyllum			1.52											

Table A.3: (continued)

Sample depth (cm)	420	417.5	415	412.5	410	407.5	405	402.5	400
Land pollen sum (1)	23	10	64	882	416	680	644	493	553
Tree % (1)	25.08	20.0	20.28	37.51	37.44	65.55	72.48	61.2	52.74
Shrub % (1)	51.6	60.0	73.36	48.07	51.6	31.2	25.6	30.8	37.26
Herb % (1)	21.5	20.0	6.2	11.44	10.8	5.4	5.28	6.6	9.54
Spore % (2)	11.4		9.87	15.4	13.86	7.14	5.55	7.6	6.63
Aquatic % (3)	4.17	16.66	46.44	66.0	55.1	15.1	14.17	22.95	26.78
Indeterminable % (4)	17.85	52.36	10.15	11.0	19	16.68	13.02	16.49	20.86
Picea		10.0	1.6	1.54	2.16	10.8	9.12	8.4	3.78
Abies balsamea				0.22		3.0	3.04	2.0	0.72
Pinus	12.9	10.0	3.2	3.41	3.12	3.45	3.52	4.0	4.68
Betula (arboreal)	8.6		14.4	32.01	31.92	48.15	56.32	46.6	43.38
Acer	4.3								
Fagus				0.11					
Aquifoliaceae									
Juglans			1.6						
Tilia				0.22					
Tsuga							0.16		
Ulmus					0.24	0.15		0.2	0.18
Betula (shrubs)	12.9	20.0	12.8	5.72	6.48	6.3	5.76	6.4	5.76
Myrica gale	4.3	20.0	56.0	35.75	35.28	17.1	14.4	15.2	24.12
Coryloid				1.76	5.28	2.4	1.92	5.6	2.52
Alnus crispa		10.0	1.6	2.09	3.12	3.15	1.44	2.0	2.52
Alnus rugosa				0.44	0.48	0.45	0.96	0.8	0.54
Ericales	25.8	10.0	3.2	2.09	0.96	1.35	0.96	0.8	1.62
Salix	8.6		1.6	0.22		0.3	0.16		0.18
Juniperus									

Table A.3: (continued)

Sample depth (cm)	420	417.5	415	412.5	410	407.5	405	402.5	400
Gramineae	8.6		4.8	3.41	4.32	2.25	1.92	1.8	3.96
Cyperaceae	4.3			2.2	2.88	0.6	0.16	1.4	0.72
Compositae	8.6	10.0	1.6	1.32	0.96	0.6	0.8	0.4	0.54
Rosaceae		10.0		1.54	0.96	0.6	0.64	1.8	1.8
Thalictrum				1.32	0.96	0.9	1.28	0.2	1.26
Urtica				1.65	0.72	0.3	0.16	1.0	1.26
Chenopodiaceae						0.15			
Gentianaceae							0.16		
Leguminosae							0.16		
Ranunculaceae									
Umbelliferae									
Sphagnum	11.4		1.4	1.2	0.84	0.7	0.75	1.33	0.34
Lycopodium			8.4	14.1	13.02	6.9	4.8	6.08	6.12
Selaginella				0.1					
Osmunda								0.19	
Isoetës	4.17	16.66	46.44	66.0	55.1	15.34	14.17	22.8	26.52
Typha									
Nymphaeaceae						0.26		0.15	
Eriocaulon									0.13
Myriophyllum									0.13

Table A.4: Concentration calculations based on observations from core NEP I

Sample depth (cm)	453	450	447.5	445	442.5	440	437.5	436	434	432.5
Total pollen conc.	235.3032	144.8028	124.2756	265.9307	361.845	489.4538	219.3542	374.3605	26.435	23.1495
Tree conc.	150.3326	86.2866	77.2524	154.536	221.837	311.4706	155.5671	217.0604		2.684
Shrub conc.	22.5796	11.9016	11.5692	27.0438	39.732	28.0517	11.9314	58.3865	7.4018	12.749
Herb conc.	4.1594	5.4549	2.6124	6.439	6.622	13.5422	5.5068	9.6166	10.574	3.0195
Spore conc.	5.3478	2.4795	5.9712	9.0146	19.393	10.6403	3.2123	4.8083		4.026
Aquatic conc.	13.6666	3.9672	6.7176	9.6585	17.974	28.0517	11.0136	21.9808	2.1148	
Indeterminable conc.	39.2172	34.713	20.1528	59.2388	56.287	97.6973	32.123	62.5099	6.3444	0.671
Picea	53.478	33.2253	27.99	43.7852	87.032	106.403	58.2803	30.2236		
Abies balsamea	29.71	16.3647	19.0332	28.9755	23.177	24.1825	13.3081	6.869		
Pinus	10.6956	3.4713	3.3588	10.3024	10.879	16.4441	8.2602	9.6166		1.6775
Betula (arboreal)	56.449	32.7294	26.124	70.829	100.276	163.4737	75.2596	170.3512		1.0065
Acer										
Fagus			0.7464	0.6439		0.9673	0.4589			
Aquifoliaceae										
Juglans										
Tilia					0.473					
Tsuga										
Ulmus		0.4959								
Betula (shrub)	1.1884			1.2878	2.365	6.7711	4.1301	17.1725	3.1722	4.026
Myrica gale	7.1304	2.4795	4.1052	9.0146	16.555	10.6403	4.1301	23.3546		
Coryloid	3.5652	0.4959	1.4928	1.9317	6.622	2.9019	0.4589	7.5559		
Alnus crispa	7.7246	5.9508	4.1052	12.2341	10.879	3.8692	1.8356	5.4952		
Alnus rugosa	2.3768	1.9836	0.7464	1.2878	2.365	3.8692	0.9178	3.4345		
Ericales			1.1196	1.2878	0.946		0.4589	1.3738	1.0574	4.3615
Salix	0.5942	0.9918							3.1722	2.684
Juniperus										

Concentration values X 10^3 grains cm^{-3}

Table A.4: (continued)

Sample depth (cm)	453	450	447.5	445	442.5	440	437.5	436	434	432.5
Gramineae		0.9918	0.7464	0.6439		0.9673		2.7476	7.4018	1.0065
Cyperaceae		0.9918	0.7464	1.9317	2.838	1.9346	0.9178			1.0065
Compositae	0.5942				0.473		0.4589	1.3738	1.0574	0.3355
Rosaceae	2.3768	2.9754		1.2878	1.419	5.8038	2.2945	4.1214	2.1148	0.671
Thalictrum				0.6439	0.946	3.8692	0.9178	0.6869		
Urtica	1.1884	0.4959	0.7464	0.6439	0.473	0.9673	0.4589	0.6869		
Chenopodiaceae										
Gentianaceae										
Leguminosae			0.3732	1.2878	0.473					
Ranunculaceae										
Umbelliferae							0.4589			
Sphagnum	1.7826	1.4877	3.732	5.1512	10.879	4.8365	1.3767	0.6869		3.195
Lycopodium	1.7826	0.9918	0.3732	1.9317	4.257	2.9019	1.8356	4.1214		1.0065
Selaginella	1.1884									
Osmunda	1.1884		1.866	1.9317	4.257	2.9019				
Isoëtes	13.6666	2.9754	4.1052	9.6585	14.19	27.0844	11.0136	21.2939	2.1148	
Typha					1.419					
Nymphaeaceae										
Eriocaulon		0.9918	1.4928		1.892	0.9673		0.6869		
Myriophyllum			1.1196							

Concentration values X 10^3 grains cm^{-3}

Table A.4: (Continued)

Sample depth (cm)	430	427.5	425	422.5
Total pollen conc.	20.4999	24.396	30.8151	31.9333
Tree conc.	8.0217	6.42	5.7065	7.1687
Shrub conc.	8.0217	10.7	11.413	9.7755
Herb conc.	2.6739	2.14	2.2826	1.3034
Spore conc.	0.8913	1.284	3.4239	5.2136
Aquatic conc.		0.428		2.6068
Indeterminable conc.	0.8913	3.424	7.9891	5.8653
Picea	1.7826	0.428		1.3034
Abies balsamea		0.428		
Pinus		2.14	2.2826	3.9102
Betula (arboreal)	5.3478	3.424	2.2826	1.9551
Acer				
Fagus	0.8913			
Aquifoliaceae				
Juglans			1.1413	
Tilia				
Tsuga				
Ulmus				
Betula (shrub)	2.6739	2.996	2.2826	
Myrica gale		1.284	4.5652	2.6068
Coryloid				
Alnus crispa		0.428		1.9551
Alnus rugosa				
Ericales	4.4565	3.424	4.5652	1.9551
Salix	0.8913	1.284		0.6517
Juniperus		1.284		2.6068

Concentration values X 10^3 grains cm^{-3}

Table A.4: (continued)

Sample depth (cm)	430	427.5	425	422.5
Gramineae	1.7826	0.428	2.2826	1.3034
Cyperaceae		0.428		
Compositae		0.428		
Rosaceae				
Thalictrum				
Urtica				
Chenopodiaceae				
Gentianaceae				
Leguminosae		0.428		
Ranunculaceae		0.428		
Umbelliferae				
Sphagnum	0.8913	0.856	1.1413	1.9551
Lycopodium		0.428	2.2826	3.2585
Selaginella				
Osmunda				
Isoëtes		0.428		2.6068
Typha				
Nymphaeaceae				
Eriocaulon				
Myriophyllum				

Concentration values X 10^3 grains cm^{-3}

Table A.4: (continued)

Sample depth (cm)	420	417.5	415	412.5	410	407.5	405	402.5	400
Total pollen conc.	26.7597	35.3892	102.3765	543.9996	908.5527	448.664	414.9217	436.4442	557.4778
Tree conc.	4.8654	3.3704	10.1595	75.2246	125.0964	215.7032	212.8647	170.5644	172.6649
Shrub conc.	9.7308	10.1112	36.7305	96.4022	172.4085	102.6688	75.184	85.8396	121.9851
Herb conc.	4.0545	3.3704	3.126	22.9424	36.0855	17.7696	15.5067	18.3942	31.2329
Spore conc.	2.4327		5.4705	33.9724	52.9254	25.1736	17.3863	22.296	22.9827
Aquatic conc.	0.8	3.3704	42.201	291.192	441.8469	59.232	51.2191	85.2822	121.3958
Indeterminable conc.	4.0545	15.1668	5.4705	24.266	80.19	68.6104	43.7007	54.0678	87.8057
Picea		1.6852	0.7815	3.0884	7.2171	35.5392	26.7843	23.4108	12.3753
Abies balsamea				0.4412		9.872	8.9281	5.574	2.3572
Pinus	2.4327	1.6852	1.563	6.8386	10.4247	11.3528	10.3378	11.148	15.3218
Betula (arboreal)	1.6218		7.0335	64.1946	106.6527	158.4456	165.4048	129.8742	142.0213
Acer	0.8109								
Fagus				0.2206					
Aquifoliaceae									
Juglans			0.7815						
Tilia				0.4412					
Tsuga							0.4699		
Ulmus					0.8019	0.4936		0.5574	0.5893
Betula (shrubs)	2.4327	3.3704	6.252	11.4712	21.6513	20.7312	16.9164	17.8368	18.8576
Myrica gale	0.8109	3.3704	27.3525	71.695	117.8793	56.2704	42.291	42.3624	78.9662
Coryloid				3.5296	17.6418	7.8976	5.6388	15.6072	8.2502
Alnus crispa		1.6852	0.7815	4.194	10.4247	10.3656	4.2291	5.574	8.2502
Alnus rugosa				0.8824	1.6038	1.4808	2.8194	2.2296	1.7679
Ericales	4.8654	1.6852	1.563	4.1914	3.2076	4.4424	2.8194	2.2296	5.3037
Salix	1.6218		0.7813	0.4412		0.9872	0.4699		0.5893
Juniperus									

Concentration values X 10^3 grains cm^{-3}

Table A.4: (continued)

Sample depth (cm)	420	417.5	415	412.5	410	407.5	405	402.5	400
Gramineae	1.6218		2.3445	6.8386	14.4342	7.404	5.6388	5.0166	12.9646
Cyperaceae	0.8109			4.412	9.6228	1.9744	0.4699	3.9018	2.3572
Compositae	1.6218	1.6852	0.7815	2.6472	3.2076	1.9744	2.3495	1.1148	1.7679
Rosaceae		1.6852		3.0884	3.2076	1.9744	1.8796	5.0166	5.893
Thalictrum				2.6472	3.2076	2.9616	3.7592	0.5574	4.1251
Urtica				3.309	2.4057	0.9872	0.4699	2.787	4.1251
Chenopodiaceae						0.4936			
Gentianaceae							0.4699		
Leguminosae							0.4699		
Ranunculaceae									
Umbelliferae									
Sphagnum	2.4327		0.7815	2.6472	3.2076	2.468	2.3495	3.9018	1.1786
Lycopodium			4.689	31.1046	49.7178	22.7056	15.0368	17.8368	21.2148
Selaginella				0.2206					
Osmunda								0.5574	
Isoëtes	0.8	3.3704	42.201	291.192	441.8469	58.2448	51.2191	84.7248	120.2172
Typha									
Nymphaeaceae						0.9872		0.5574	
Eriocaulon									0.5893
Myriophyllum									0.5893

Concentration values X 10^3 grains cm^{-3}

Table A.5: Percentage calculations based on observations from core NEP II

Sample depth (cm)	526	520	515	510	505	500	495	490	485	480	470	450	440	430
Land pollen sum (1)	364	334	350	346	354	259	503	267	261	448	545	259	353	350
Tree % (1)	40.5	39.9	49.3	38.28	62.44	66.69	60.4	79.55	73.34	75.68	70.92	76.05	77.28	76.56
Shrub % (1)	49.41	11.4	45.82	53.36	34.44	28.86	32.8	16.65	25.46	20.9	22.86	22.3	18.48	23.78
Herb % (1)	8.37	11.4	6.38	7.83	2.24	5.46	7.4	2.59	0.38	1.98	4.32	2.73	3.08	1.16
Spore % (2)	12.24	11.34	8.37	9.18	4.59	4.07	5.2	1.11	2.22	1.1	2.34	1.52	7.02	1.12
Aquatic % (3)	31.73	22.27	17.48	32.4	19.09	23.7	15.13	10.2	9.1	9.4	10.03	9.45	5.67	3.36
Indeterminables (4)	19.8	25.3	27.8	31.6	34.96	27.16	26.74	18.6	23.49	14.25	28.6	24.65	30.4	21.39
Picea	5.4	7.5	8.7	11.02	7.28	19.89	6.4	17.39	17.48	22.0	19.08	31.2	38.08	32.48
Abies balsamea	1.08	1.8		1.74	2.24	4.29	0.6	2.59	3.04	5.94	1.8	3.9	1.12	4.93
Pinus	2.16	4.5	2.61	4.64	6.44	3.9	3.8	3.33	4.94	4.84	3.06	4.29	3.08	2.9
Betula (arboreal)	30.51	25.8	37.41	20.59	46.2	38.22	49.6	55.87	47.88	42.9	46.8	36.66	35.0	35.96
Acer														
Fagus														
Aquifoliaceae														
Juglans	1.35	0.3	0.29	0.29	0.28	0.39								
Tilia								0.37						
Tsuga														
Ulmus			0.29								0.18			0.29
Betula (shrubs)	11.07	11.4	13.63	15.37	12.88	3.51	10.0	4.81	8.36	5.06	3.24	8.97	5.32	5.22
Myrica gale } Coryloid	33.21	33.9	26.97	32.77	16.52	21.84	19.6	11.1	14.82	13.64	15.3	10.92	10.36	5.8
Alnus crispa	1.89	1.5	2.9	0.29	2.24	1.95	2.4		1.52	1.32	2.7	1.17	1.4	8.41
Alnus rugosa	0.54	0.3		0.58	1.96	0.39	0.4			0.88	1.26	1.17		3.77
Ericales	2.16	0.9	2.32	3.48	0.84	0.78	0.2		0.76				0.28	
Salix	0.54	0.9		0.87		0.39	0.2	0.74			0.36		1.12	0.58

Table A.5: (continued)

Sample depth (cm)	526	520	515	510	505	500	495	490	485	480	470	450	440	430
Gramineae	5.13	6.3	2.03	3.19	1.12	0.78	3.0			0.22	0.54		0.28	
Cyperaceae	0.54	0.6	0.58	1.16		0.78	0.4	0.74	0.38	0.66	0.54	0.39	0.56	0.29
Compositae	1.08	1.5	0.87	0.87	0.28	0.78	0.8				0.18	0.39		
Rosaceae		1.2	0.58	0.29	0.28	1.56	1.0	0.37		0.22	1.8		0.28	0.29
<u>Thalictrum</u>	0.54	0.9	2.32	0.58		0.78	1.8	0.37		0.22	1.0		0.84	
<u>Urtica</u>	0.54	0.3		1.74	0.28	0.78	0.4	0.74		0.22				
Leguminosae	1.08	0.6		0.29	0.28			0.37		0.44	0.36	1.59	1.12	0.58
Ranunculaceae														
Saxifragaceae				0.58										
Umbelliferae														
<u>Sphagnum</u>		0.27	0.31	0.52	1.08		0.8			0.22	0.36	1.14	3.9	0.84
<u>Lycopodium</u>	12.24	11.07	8.06	8.32	3.51	4.07	4.4	1.11	2.22	0.88	1.98	0.38	0.78	0.28
<u>Osmunda</u>													2.34	
<u>Isoëtes</u>	31.73	22.27	17.48	32.4	19.09	23.1	15.13	10.2	9.1	9.0	1.04	9.45	5.4	3.36
<u>Typha</u>														
<u>Potamogeton</u>														
Nymphaeaceae						0.6							0.27	
<u>Eriocaulon</u>										0.2	0.17			
<u>Myriophyllum</u>										0.2				

Table A.5: (continued)

Sample depth (cm)		420	410	400	390	380	370	360	350	340	330	320	310	300
Land pollen sum	(1)	261	303	215	292	217	150	194	208	266	305	170	168	217
Tree %	(1)	72.2	78.21	73.79	70.04	79.58	75.04	58.24	75.84	82.08	83.49	81.42	76.2	77.74
Shrub %	(1)	22.8	17.82	25.85	28.56	18.4	22.78	41.6	22.08	15.2	14.19	18.29	23.4	19.32
Herb %	(1)	4.18	3.96	1.41	0.68	1.84	2.68	1.04	1.92	3.8	2.97	0.59	1.2	2.76
Spore %	(2)	4.44	8.7	5.72	10.23	5.59	10.2	4	3.68	2.22	5.89	4.48	3.99	4.4
Aquatic %	(3)	6.84	10.73	12.3	8.68	14.43	23.97	12.6	9.24	5.6	3.84	9.01	9.72	10.25
Indeterminable %	(4)	21.6	31.68	38.92	33.12	32.86	25.5	20.91	21.66	25.48	22.5	39.24	33.54	34.1
<u>Picea</u>		28.5	32.34	24.91	28.9	25.3	33.5	18.2	18.24	19.76	28.05	20.06	24.0	28.52
<u>Abies balsamea</u>		6.08	3.63	6.58	7.48	8.76	4.02	8.32	12.48	6.84	11.22	13.57	15.0	9.66
<u>Pinus</u>		3.8	5.94	4.7	6.46	7.36	4.69	7.8	5.76	10.26	7.59	5.31	3.60	5.06
<u>Betula</u> (arboreal)		33.44	36.3	37.13	27.2	37.26	32.83	22.36	39.36	44.84	36.63	41.3	32.4	33.58
<u>Acer</u>								0.52					0.6	0.46
<u>Fagus</u>												0.59	0.6	
Aquifoliaceae								0.52				0.59		
<u>Juglans</u>				0.47		0.92								
<u>Tilia</u>														
<u>Tsuga</u>														
<u>Ulmus</u>		0.38						0.52		0.38				0.46
<u>Betula</u> (shrubs)		6.84	3.3	2.35	4.76	5.98	3.35	6.04	7.68	7.6	4.29	7.67	7.8	6.44
<u>Myrica gale</u> / Coryloid		5.7	6.27	7.05	12.24	4.6	8.04	7.8	2.88	2.66	4.62	5.31	6.0	5.98
<u>Alnus crispa</u>		6.46	4.29	15.04	9.86	6.44	9.38	24.44	9.12	3.42	3.96	4.72	6.6	5.52
<u>Alnus rugosa</u>		3.04	2.97	1.41	1.7	0.92	2.01	3.12	2.4	1.14	0.66	0.59	1.8	1.38
Ericales		0.76	0.99								0.33		0.6	
<u>Salix</u>						0.46				0.38	0.33		0.6	

Table A.5: (continued)

Sample depth (cm)	420	410	400	390	380	370	360	350	340	330	320	310	300
Gramineae	1.52	0.99	0.47		0.46	0.67			0.76	1.32		1.2	
Cyperaceae	1.14	0.99	0.94			1.34	0.52	0.48	1.52	0.99			0.46
Compositae	0.38	0.33			0.46		0.52	0.48	0.38	0.33			
Rosaceae		1.32		0.34		0.67		0.96	0.76	0.33	0.59		
Thalictrum				0.34	0.92								
Urtica													
Leguminosae	0.76								0.38				2.84
Ranunculaceae		0.33											
Saxifragaceae													
Umbelliferae													0.46
Sphagnum	2.59	5.4	3.96	5.58	3.44	7.2	2.5	2.76	1.85	4.65	3.36	2.28	2.2
Lycopodium	0.37	0.6	0.88	0.93	0.43	1.8	0.5	0.46	0.37	0.62			0.88
Osmunda	1.48	2.7	0.88	3.72	1.72	1.2	1.0	0.46		0.62	1.12	1.71	1.32
Isoëtes	6.84	9.28	11.07	8.68	13.26	22.44	11.7	8.8	5.25	3.84	7.95	8.64	7.79
Typha		0.58											
Potamogeton							0.9	0.44					0.82
Nymphaeaceae			0.41		0.39						0.53	0.54	
Eriocaulon		0.87	0.32		0.78	1.53			0.35		0.53	0.54	1.64
Myriophyllum													

Table A.6: Concentration calculations based on observations from core NEP II

Sample depth (cm)	526	520	515	510	505	500	495	490	485	480	470
Total pollen conc.	751.0272	775.5096	834.6016	939.6257	479.5208	493.3652	520.9151	453.9842	510.5848	600.6032	902.7045
Tree conc.	167.64	165.8244	239.666	177.9492	167.6068	189.1602	194.4578	269.6315	363.4836	363.7456	424.929
Shrub conc.	204.5208	203.2284	222.7484	248.0504	92.4468	81.8588	105.5996	56.4345	91.4684	100.453	136.9695
Herb conc.	34.6456	47.3754	31.0156	36.3987	6.0128	15.4868	23.8243	8.7787	1.3652	9.5166	25.884
Spore conc.	56.9976	52.3656	38.0646	45.8354	12.7772	12.1682	16.7414	3.7623	8.1912	5.287	14.0205
Aquatic conc.	186.6392	163.3308	107.1448	218.3922	62.3828	87.3898	57.3071	37.623	35.4952	49.6978	63.6315
Indeterminable conc.	100.584	143.382	195.9622	212.9998	138.2944	107.3014	122.9849	77.7542	110.5812	79.305	237.27
Picea	22.352	31.17	42.294	51.2278	19.5416	56.4162	20.6048	58.9427	62.7992	105.74	114.321
Abies balsamea	4.4704	7.4808		8.0886	6.0128	12.1682	1.9317	8.7787	10.9216	28.5498	10.785
Pinus	8.9408	18.702	12.6883	21.5696	17.2868	11.062	12.2341	11.2869	17.7476	23.2628	18.3345
Betula (arboreal)	126.2888	107.2248	181.8642	95.7151	124.014	108.4076	159.6872	189.3691	172.0152	206.193	280.41
Acer											
Fagus											
Aquifoliaceae											
Juglans	5.588	1.2468	1.4098	1.3481	0.7516	1.1062					
Tilia								1.2541			
Tsuga											
Ulmus			1.4098								1.0785
Betula (shrubs)	45.8216	47.3784	66.2606	71.4493	34.5736	9.9558	32.195	16.3033	30.0344	24.3202	19.413
Myrica gale / Coryloid	137.4648	140.8884	131.114	152.3353	44.3444	61.9472	63.1022	37.623	53.2428	65.5588	91.6725
Alnus *crispa*	7.8232	6.234	14.098	1.3481	6.0128	5.531	7.7268		5.4608	6.3444	16.1775
Alnus rugosa	2.2352	1.2468		2.6962	5.2612	1.1062	1.2878			4.2296	7.5495
Ericales	8.9408	3.7404	11.2784	16.1172	2.2548	2.2124	0.6439		2.7304		
Salix	2.2352	3.7404		4.0443		1.062	0.6439	2.5082			2.157

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	526	520	515	510	505	500	495	490	485	480	470
Gramineae	21.2344	26.1828	9.8686	14.8291	3.0064	2.2124	9.6585			1.0574	3.2355
Cyperaceae	1.1176	2.4936	2.8196	5.3924		2.2124	1.2878	2.5082	1.3652	3.1722	3.2355
Compositae	4.4704	6.234	4.2294	4.0443	0.7516	2.2124	2.5756				1.0785
Rosaceae		4.9872	2.8196	1.3481	0.7516	4.4248	3.2196	1.2541		1.0574	10.785
Thalictrum	2.2352	3.7404	11.2784	2.6962		2.2124	5.7951	1.2541		1.0574	5.3925
Urtica	1.1176	1.2468		8.0886	0.7516	2.2124	1.2878	2.5082		1.0574	
Leguminosae	4.4704	2.4936		1.3481	0.7516			1.2541		2.1148	2.157
Ranunculaceae											
Saxifragaceae				2.6962							
Umbelliferae											
Sphagnum		1.2468	1.4098	2.6962	3.0064		2.5756			1.0574	2.157
Lycopodium	56.9976	51.1188	36.6548	43.1392	9.7708	12.1682	14.1658	3.7623	8.1912	4.2296	11.8635
Osmunda											
Isoëtes	186.6392	163.3308	107.1448	218.3922	62.3828	85.1774	57.3071	37.623	35.4952	47.583	62.553
Typha											
Potamogeton											
Nymphaeaceae						2.2124					
Eriocaulon										1.0574	1.0785
Myriophyllum										1.0574	

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	450	440	430
Total pollen conc.	511.95	587.4231	409.1067
Tree conc.	266.214	288.9996	235.3032
Shrub conc.	77.8164	69.1086	73.0866
Herb conc.	9.5564	11.5181	3.5652
Spore conc.	5.4608	28.2717	3.5652
Aquatic conc.	36.8604	21.9891	10.6956
Indeterminable conc.	116.042	167.536	82.8909
Picea	109.216	142.4056	99.8256
Abies balsamea	13.652	4.1884	15.1521
Pinus	15.0172	11.5181	8.913
Betula (arboreal)	128.3288	130.8875	110.5212
Acer			
Fagus			
Aquifoliaceae			
Juglans			
Tilia			
Tsuga			
Ulmus			0.8913
Betula (shrubs)	31.3996	19.8949	16.0434
Myrica gale / Coryloid	38.2256	38.7427	17.826
Alnus crispa	4.0956	5.2355	25.8477
Alnus rugosa	4.0956		11.5869
Ericales		1.0471	
Salix		4.1884	1.7826

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	450	440	430
Gramineae		1.0471	
Cyperaceae		2.1542	0.8913
Compositae	1.3652		
Rosaceae		1.0471	0.8913
Thalictrum		3.1413	
Urtica			
Leguminosae	6.826	4.1883	1.7826
Ranunculaceae			
Saxifragaceae			
Umbelliferae			
Sphagnum	4.0956	15.7065	2.6739
Lycopodium	1.3652	3.1413	0.8913
Osmunda		9.4239	
Isoëtes	36.8604	8.3768	10.6956
Typha			
Potamogeton			
Nymphaeaceae		1.0471	
Eriocaulon			
Myriophyllum			

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	420	410	400	390	380	370	360	350	340	330
Total pollen conc.	449.7584	464.9319	417.7234	394.121	303.107	317.4916	222.833	271.0092	298.6578	394.3908
Tree conc.	234.764	214.7931	165.1954	163.358	141.341	135.7216	88.816	145.6444	170.6616	234.2274
Shrub conc.	74.136	48.9402	57.871	66.612	32.68	41.2012	63.44	42.4028	31.604	39.8094
Herb conc.	13.5916	10.8756	3.1566	1.586	8.268	4.8472	1.586	3.6872	7.901	8.3322
Spore conc.	14.8272	26.2827	13.6786	26.169	10.621	20.6006	6.344	7.3744	4.7406	17.5902
Aquatic conc.	23.4764	33.5331	31.566	22.204	30.229	56.9546	22.204	19.3578	12.6416	11.1096
Indeterminable conc.	88.9632	130.5072	146.2558	114.192	32.86	61.8018	40.443	52.5426	71.8991	83.322
Picea	92.67	88.8174	55.7666	67.405	44.935	60.59	27.755	35.0284	41.0852	78.693
Abies balsamea	19.7696	9.9693	14.7308	17.446	15.523	7.2708	12.688	23.9668	14.2218	31.4772
Pinus	12.356	16.3134	10.522	15.067	13.072	8.4826	11.895	11.0616	21.3327	21.2934
Betula (arboreal)	108.7328	99.693	83.1238	63.44	66.177	59.3782	34.099	75.5876	93.2318	102.7638
Acer							0.793			
Fagus										
Aquifoliaceae							0.793			
Juglans			1.0522		1.634					
Tilia										
Tsuga										
Ulmus	1.2356						0.793		0.7901	
Betula (shrubs)	22.2408	9.063	5.261	11.102	10.621	6.059	9.516	14.7488	15.802	12.0354
Myrica gale / *Coryloid*	18.534	17.2197	15.783	28.548	8.17	14.5416	11.895	5.5308	5.5307	12.9612
Alnus crispa	21.0052	11.7819	33.6704	22.997	11.438	16.9652	37.271	17.5142	7.1109	11.1096
Alnus rugosa	9.8848	8.1567	3.1566	3.965	1.634	3.6354	4.758	4.609	2.3703	1.8516
Ericales	2.4712	2.7189								0.9258
Salix					0.817				0.7901	0.9258

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	420	410	400	390	380	370	360	350	340	330
Gramineae	4.9424	2.7189	1.0522		0.817	1.2118			1.5802	3.7032
Cyperaceae	3.7068	2.7189	2.1044			2.4236	0.793	0.9218	3.161	2.7774
Compositae	1.2356	0.9063			0.817		0.793	0.9218	0.7901	0.9258
Rosaceae		3.6253		0.793		1.2118		1.8436	1.5802	0.9258
Thalictrum				0.793	1.634					
Urtica										
Leguminosae	2.4712								0.7901	
Ranunculaceae		0.9063								
Saxifragaceae										
Umbelliferae										
Sphagnum	18.6492	16.3134	9.4698	14.274	6.536	14.5416	3.965	5.5308	3.9505	13.887
Lycopodium	1.2356	1.8126	2.1044	2.379	0.817	3.6354	0.793	0.9218	0.7901	1.8516
Osmunda	4.9424	8.1567	2.1044	9.516	3.268	2.4236	1.586	0.9218		1.8516
Isoëtes	23.4764	29.0016	96.8024	22.204	27.778	53.3192	20.618	18.436	11.8515	11.1096
Typha		1.8126								
Potamogeton							1.586	0.9218		
Nymphaeaceae			1.0522		0.817					
Eriocaulon		2.7189	2.1044		1.634	3.6354			0.7901	
Myriophyllum										

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	320	310	300
Total pollen conc.	366.32	378.4914	303.8266
Tree conc.	166.29	172.2882	141.8417
Shrub conc.	37.355	52.9074	35.2506
Herb conc.	1.205	2.7132	5.0358
Spore conc.	9.64	9.4962	8.393
Aquatic conc.	20.485	24.4188	20.9825
Indeterminable conc.	131.345	116.6676	92.323
Picea	40.97	54.264	52.0366
Abies balsamea	27.715	33.915	17.6253
Pinus	10.845	8.1396	9.2323
Betula (arboreal)	84.35	73.2564	61.2689
Acer		1.3566	0.8393
Fagus	1.205	1.3566	
Aquifoliaceae	1.205		
Juglans			
Tilia			
Tsuga			
Ulmus			0.8393
Betula (shrubs)	15.665	17.6358	11.7502
Myrica gale / Coryloid	10.845	13.566	10.9109
Alnus crispa	9.64	14.9226	10.9109
Alnus rugosa	1.205	4.0698	2.5179
Ericales		1.3566	
Salix		1.3566	

Concentration values X 10^3 grains cm^{-3}

Table A.6: (continued)

Sample depth (cm)	320	310	300
Gramineae		2.7132	
Cyperaceae			0.8393
Compositae			
Rosaceae	1.205		
Thalictrum			
Urtica			
Leguminosae			3.3572
Ranunculaceae			
Saxifragaceae			
Umbelliferae			0.8393
Sphagnum	7.23	5.4264	4.1965
Lycopodium			1.6786
Osmunda	2.41	4.0698	2.5179
Isoëtes	18.075	21.7056	15.9467
Typha			
Potamogeton			1.6786
Nymphaeaceae	1.205	1.3566	
Eriocaulon	1.205	1.3566	3.3572
Myriophyllum			

Concentration values X 10^3 grains cm^{-3}

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