LATE QUATERNARY EVENTS ON THE BURIN PENINSULA, NEWFOUNDLAND WITH REFERENCE TO THE ISLANDS OF ST. PIERRE ET MIQUELON (FRANCE)

by

(C) Christopher M. Tucker, B.Sc., M.Sc.

A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Doctor of Philosophy

McMaster University

1979

LATE QUATERNARY EVENTS ON THE BURIN PENINSULA, NEWFOUNDLAND

For Rocío

DOCTOR OF PHILOSOPHY (1979)
(Geography)

McMaster University
Hamilton, Ontario

TITLE: Late Quaternary Events on the Burin Peninsula, Newfoundland with reference to the Islands of St. Pierre et Miquelon (France).

AUTHOR: Christopher M. Tucker, B.Sc. (Hons.) (Memorial University of Newfoundland)
M.Sc. (Memorial University of Newfoundland)

SUPERVISORS: Dr. S.B. McCann
Dr. D.C. Ford
Dr. G.V. Middleton

NUMBER OF PAGES: xvi; 282

ABSTRACT

A revised and extended chronology of late Quaternary events on the southeastern coast of Newfoundland indicates that the oldest deposits are pre-Wisconsinan, that mid-Wisconsinan ice was limited, and that the late-Wisconsinan ice margin was near the mainland of Newfoundland. Evidence is derived from morphogenetic mapping of surficial deposits, and studies of infrequent multiple-till sections, raised glaciomarine features, periglacial forms and weathering phenomena.

Trace element and stratigraphic analyses suggest that the oldest till units may be Illinoian. A continuous Sangamonian bench at 4 m a.s.l. exists along both coasts of the peninsula. Early-Wisconsinan ice flow was from the island of Newfoundland to the southeast, across the Burin Peninsula and St. Pierre et Miquelon. Marine deposits on the Burin at Dantzic Cove and Salmonier Pond, and Petit Barachois, Langlade (Miquelon) contain foraminifera of proposed, mid-Wisconsinan age. The marine units on the Burin Peninsula are underlain by a silty till and overlain by a sandy till. On Langlade, they are underlain by a glaciomarine unit and capped by aeolian sands. Marine overlap during the mid-Wisconsinan is further indicated by 20 m a.s.l. raised benches on the Burin Peninsula, and a continuous wash limit at approximately the same elevation on St. Pierre et Miquelon.

Onshore-directed striae with sequentially weathered facets, and marine sands incorporated in till, indicate that a later ice movement (late, mid-Wisconsinan?) was from a shelf-centred cap on the south

coast of the peninsula, and from ice domed to the northeast on the Placentia Bay coast. A late-Wisconsinan, glacial limit, marked by eskers and general ice stagnation terrain, occurs between Terrenceville and Swift Current. The associated marine limit has been recorded at 18 m a.s.l. in upper Fortune Bay and 11 m a.s.l. at the head of Placentia Bay.

In situ wood found below high tide at Little St. Lawrence (1080 ± 50 B.P.), and peat covered by marine deposits, located near Point May (5360 ± 70 B.P.), show that the lower portion of the peninsula is submergent, partly as a result of forebulge collapse related to the late-Wisconsinan ice limit. Permafrost activity, following deglaciation, is indicated by the presence of fossil ice wedge casts situated in stratified deposits related to this event.

ACKNOWLEDGEMENTS

There are several individuals and organizations who helped in the completion of this thesis.

My supervisor, Dr. S. Brian McCann is thanked for his counsel and friendship during my tenure at McMaster. Thanks are also due to Dr. Phillip J. Howarth.

At the Geological Survey of Canada, Ottawa, I would like to thank Dr. Douglas R. Grant who initially suggested the research topic and who, in 1975, provided me with an opportunity to renew my ties with "the Rock". I also wish to express my appreciation to Dr. Weston Blake Jr., Dr. Robert J. Fulton, Dr. Sigrid Lichti-Federovich, Mr. Robert J. Mott and Dr. William W. Shilts, at the same institute, who variously provided research equipment and/or laboratory analyses of samples.

I am indebted to Dr. Gustavs Vilks at the Atlantic Geoscience Centre, Dartmouth, N.S., for his comments on the suites of foraminifera. They ultimately became the most important stratigraphic marker that was found.

The loan of field equipment by Mr. Douglas W. Fogwill, Newfoundland Department of Mines and Energy, St. John's and Dr. Joyce B. Macpherson, Memorial University of Newfoundland, St. John's is gratefully acknowledged.

McMaster student, James H. Ross, ably assisted during the 1977 field season, and fellow graduate student, Dale A. Leckie, who is currently studying the Quaternary history of the Hermitage Peninsula, helped with the winter, 1978, field work. Both Mr. Richard Clarke and Mr. Alec Turpin of Little St. Lawrence aided with their knowledge of the local area and its geology.

Special thanks are due to my parents, Mr. and Mrs. W.B. Tucker of Grand Falls, who proved to be the perfect expediters. They provided everything from long-term equipment storage, to replacement parts for a broken-down van, ... and a good scoff* when it was most needed.

Financial support was provided by National Research Council Grant No. A5082 and Energy Mines and Resources Research Agreement No. 2239-4-154-77, held by Dr. McCann.

Mrs. Sharon Wright, McMaster University, typed the thesis and Mrs. Usha Bella helped with the cartography.

* Newfoundland term for a hearty meal.

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CHAPTER 1

INTRODUCTION

1.1 Preamble

There has been a revived interest during the past several years on the extent of Wisconsinan ice in eastern and arctic North America. Essentially, this is a re-expression of ideas that have been dormant for the past five decades. The most recent synthesis of these debates occurred at the 1978 meeting of the Geological Association of Canada (see, Symposium: Limits of Wisconsinan Glaciation in eastern and northern Canada, 1978). A further synopsis is provided by Ives (1978), who discussed the evolution of ideas on limited, Wisconsinan ice cover along the east coast of North America. In this context, there is, perhaps, no other area that has received so little attention yet contains so much potential to significantly influence thinking on the sequence and scope of late-Quaternary events in eastern Canada as the island of Newfoundland. The Burin Peninsula lies at the extreme southeast corner of the island (Fig. 1.1) and is, therefore, one of the most strategic locales from which to revise and extend the glacial chronology of the island. It is the last terrestrial link between the west coast of Newfoundland where the Quaternary record has been studied in some detail by Brookes and Grant, and the continental shelf where work has been recently carried out by Slatt and Piper *et al.* Further, because it is surrounded by water on three sides,

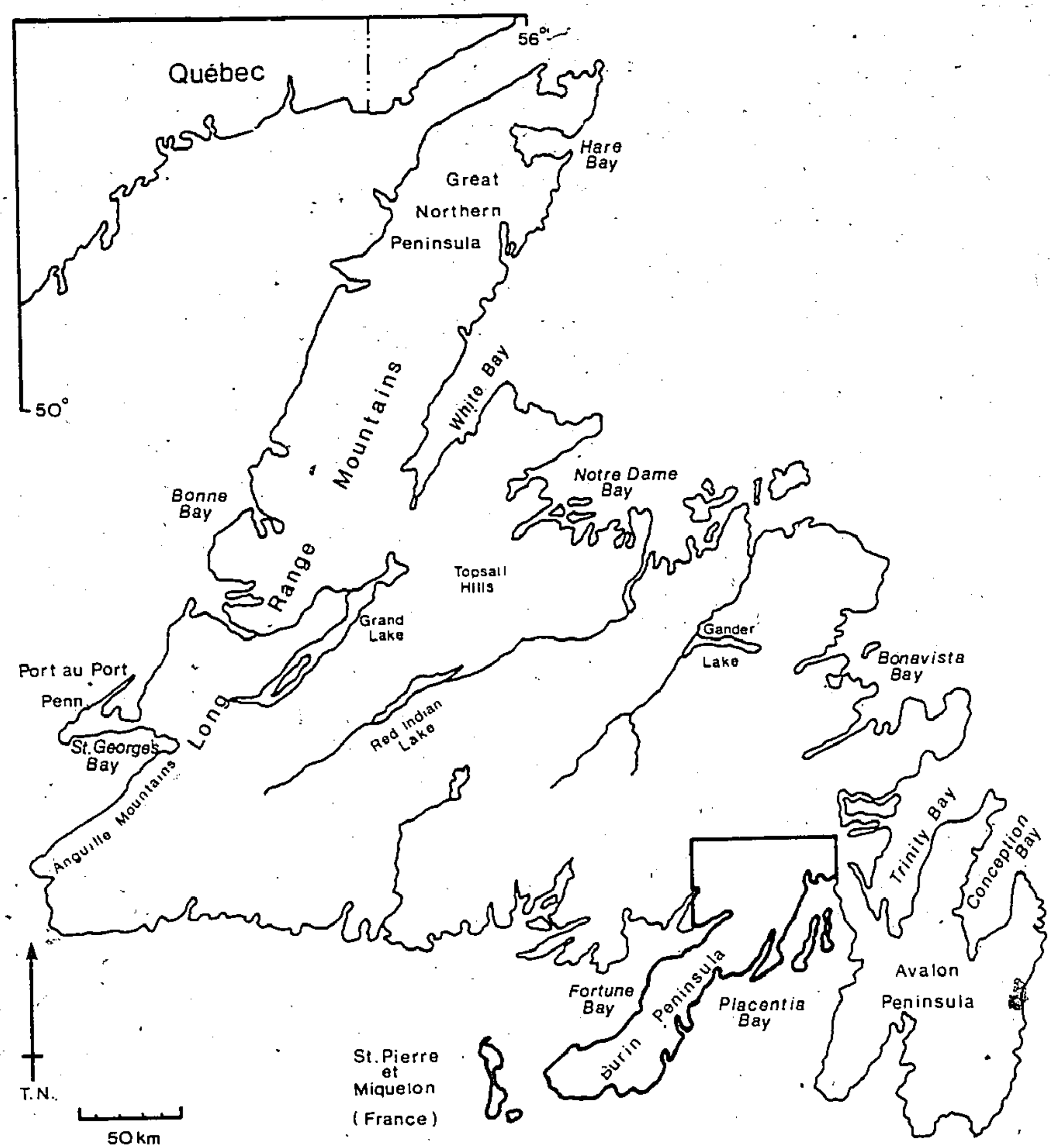


FIGURE 1.1: Newfoundland and Burin Peninsula location map.

it would follow that its ~870 km of coastline should provide ample opportunity to obtain stratigraphic evidence from unconsolidated deposits containing local and distant glacial components.

To help emphasize the rational for choosing the Burin Peninsula as an important aid in deciphering the still, little understood Quaternary record of Newfoundland, it is proposed to briefly summarize past studies and discuss their effect on the development of major glacial/deglacial models that are currently being debated. The most logical way to approach this summary is to discuss the past research chronologically under the headings; early application of glacial theory, the development and interpretations of glacial style, and recent investigations.

1.2 Early Application of Glacial Theory

As was common in European research of the period, first accounts of the Ice Age in Newfoundland contained references to the deluge or great flood. In a paper read to the Geological Society of London in 1874, Milne implied that submergence of at least 300 m and ploughing by drift ice from the Arctic gave the island topography its characteristic northeast-southwest lineation. Submergence was assumed to have been followed by local glaciation, which would explain anomalous radial striae and roches perchées that were recorded by Jukes (1843) on his excursions through Newfoundland. In 1876, referring to early observations made by Alexander Murray of the Newfoundland Geological Survey, Milne formalized his ideas.

> "If Newfoundland has been steadily rising during the past ages, as it now appears to have done, at no very remote geological period it may have been beneath the surface of the ocean. During the period when it was

> undergoing elevation, no doubt a considerable amount of debris and boulders were dropped by icebergs over its surface. When the Laurentian backbone, (Long Range Mountains), which would be the first land to emerge, reached the surface, it formed a barrier for the coast-ice which would carry its load of boulders and strew them with those of the bergs. After the final emergence, the climate of Newfoundland might still have been a cold one and the same highlands which gave birth to coast-ice probably next gave birth to glaciers which scooped and hollowed out a great portion of the remaining marine drift and left the island with its present contours. After the raising of the great North-East and South-East ranges, first coast-ice flowed East and West and afterwards the glaciers followed in a similar deviation, and thus perhaps the origin of the boulders, those which are so curiously perched being due to the latter than the former. Thus, it would seem that icebergs and coast-ice preceded glaciers but to say what might have come before the former of those agents would only be delving deeper into the depths of a sea of speculation."

In 1882 Alexander Murray compiled the results of his field seasons in Newfoundland and presented them in the form of a new glacial theory. Many of his ideas had been gleaned from Sir William Logan's studies around Lake Timiskaming, with whom Murray had worked in Ottawa, prior to his appointment to found the Geological Survey of Newfoundland (Baird, 1975). Murray proposed that a "sea of ice" flowing down the St. Lawrence River impinged on the west coast of Newfoundland, "scooping out of great holes" in Humber Arm and depositing supposed terminal and lateral moraines found along its banks. He considered that local glaciers occupied Grand Pond (Lake), Red Indian Lake and Gander Lake, as well as numerous other rock basins and deep depressions which occur in the bays, and that most of the fiords were cut by local glaciers flowing toward the northeast, except where deflected by local bedrock structure. He maintained that uplift of the island was in effect before the onset of glaciation and

and continued at a discontinuous rate to the present. Murray thus recognized the existence of isostatic rebound, though in light of modern theory, his interpretation of the evidence was only partially correct. Based on Kerr's (1870) discovery of a terminal moraine across the mouth of Conception Bay at a depth of 180 to 255 m, Murray hypothesized that a "grand" or terminal moraine for the whole island existed on the Grand Banks from which ice receded back to local glaciers, limited to the high ground. Perhaps of all the early reconnaissance work done in Newfoundland, that of Alexander Murray contained the most astute interpretation of field data.

1.3 The Development and Interpretations of Glacial Style

Soon after the turn of the century, glacial theory became dichotomous. It was divided between those who proposed limited ice cover during the ice age and those who argued that ice cover had been complete.

1.3.1 Limited Wisconsinan ice

In 1911, Fernald, reporting on an expedition to Newfoundland and Labrador, recognized the existence of exposed coastal plain refugia during the ice age. He also argued (1925, 1930) that plants similar to species of the Western Cordillera, found in eastern tablelands and ravines, such as the Shickshocks in New Brunswick and the Long Range of Newfoundland, must have survived in glacial refugia since they were not found along the Laurentide limit of America and throughout much higher mountain ranges in northern New England and New York. His botanical evidence was to be debated in ensuing years (see, Wynne-Edwards, 1937 and

Lindroth, 1963). Daly (1921) provided one of the earliest comprehensive studies of isostatic rebound in Newfoundland and Nova Scotia. His view was that the zero isobase crossed Newfoundland in St. Georges Bay near Robinsons Head and close to the axis of Bonavista Bay in the east. With maximum uplift in the order of 150 m near Forteau, Labrador, he concluded (1920) that his ideas corroborated those of Fernald since peripheral up-warping in Newfoundland from an ice dome centered over Labrador would have created a belt of elevated land extending more or less continuously south to New Jersey. Although he observed and noted the influence of foreign ice on isostatic downwarping of the island, his evidence from eastern and central Newfoundland is scanty and poorly developed. Coleman (1926) added further support to Fernald's hypothesis. He reported that there was no evidence for glaciation of the southern part of the Long Range Mountains during the Pleistocene, and that ice which invaded the Northern Peninsula and the rest of the island was probably of Kansan or Jerseyan age. His argument was based on evidence of deep weathering and lack of erratics around the Topsails, as well as a dearth of boulder clay and striae at various locations around Notre Dame Bay. He concluded that Wisconsinan ice covered less than half the island and was in the form of small, separate ice sheets and valley glaciers.

1.3.2 Complete, Wisconsinan ice cover

Little further information was added to knowledge of the Quaternary for over a decade until, with the aid of the Geological Society of America, a series of research projects from Princeton and Yale Universities was commenced in 1939. Because of either their straightforward logic or repetition of the same basic idea, the result of these studies effectively established a new glacial dogma that would influence the conclusions of others for the next thirty years. McClintock and Twenhofel (1940) alternately co-authored two papers on the erosional surfaces and glacial geology of Newfoundland. They proposed that the island had been completely glaciated during the (late) Wisconsin(an). They concluded that:

1. Newfoundland may have been completely glaciated by Labrador ice during the Wisconsin(an) stage.

2. In a late phase of the Wisconsin(an), the island supported its own ice cap, a remnant of which probably occupied the Avalon Peninsula during a deglacial phase. Dispersal centres of late, glacial ice were situated sequentially over Annieopsquotch Mountains and the Red Indian Lake area (Fig. 1.1).

3. Limited deglaciation occurred along the southwest coast which allowed deposition of fines and glacio-marine sediment.

4. Following this, a slight readvance in St. George's Bay deposited till and gravel (Robinson's Head Drift) over the marine beds and earlier drift, and formed a "strong continuous moraine from the Anguille Mountains to Port au Port".

Tanner (1940) attempted to resolve the dichotomy posed by the McClintock-Twenhofel and Fernald-Coleman arguments. From observations made on a brief aeroplane flight from St. Anthony to Port Saunders, he concluded that Laurentide ice had totally over-run the Northern Peninsula, including its highest summits "at least as far south as 50° 30' latitude". This did little, however, to resolve the question posed by Fernald as to the extent of glaciation in the southern Long Range.

R.F. Flint (1940) concerned himself with the topic of postglacial crustal warp on the west and north-central coasts of the island. He determined (Fig. 1.2) that isostatic rebound increases to the northwest,

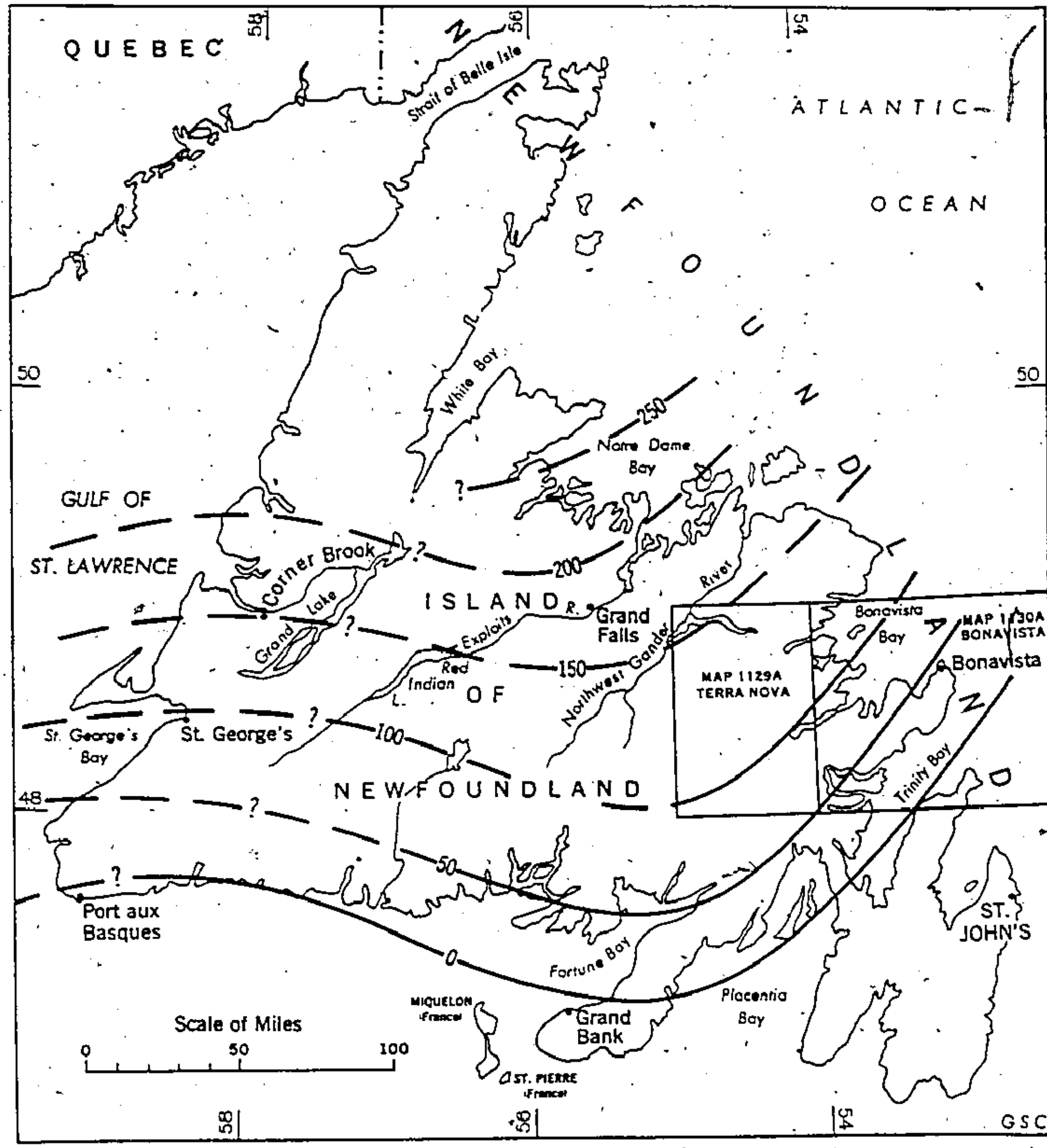


FIGURE 1.2: Isobases in eastern and western Newfoundland (Flint, 1940; Jenness, 1960).

which implies invasion of the island by Laurentide-Labradorian ice to, at least, "the northern extremity of the Long Range Mountains". Flint found no evidence of rebound along the southwest coast of the island, indicating submergence of the area. He did note that Widmer (pers. comm.) recorded elevated deltas in Belle Bay, Fortune Bay. Flint interpretedthese features as pre-dating deglaciation and uplift of the west coast, especially since it was determined that piedmont glaciers were still present around St. Georges Bay while overall deglaciation and development of marine features were active. This so called "Bay of islands Surface", stretching from Port au Port Bay northward to Bonne Bay, was attributed to marine erosion during a lengthy standstill following deglaciation, which allowed bench cutting as wide as 60 m to be developed in sedimentary rock. Although it is not dated specifically, Flint envisaged a time span of at least 5,000 years to cut the surface.

Following the 1940 Princeton-Yale field work, little else was published until the end of the decade. When research resumed, study shifted from the west and northwest coast to the south and east coasts.

Van Alstine (1948), in a report on the geology and mineral deposits, described the morphology and genesis of surficial deposits in the St. Lawrence, Burin Peninsula area. He concurred with MacClintock and Twenhofel (1940) that the Burin Peninsula was covered by ice originating in central Newfoundland. This was similar to the findings of Aubert de la Rüe (1932) for the nearby islands of St. Pierre et Miquelon. More significantly, Van Alstine reported intensely red, hematitic and calcareous, stratified clays, sands and gravels interbedded with a deeply weathered, red, clayey-sandy till, and overlain by a fresher, grey-brown, noncalcareous till and outwash. He suggested that because of a profound weathering in the red till, it was of pre-Wisconsin(an) age. While his conclusions did not measureably aid in determining the extent of ice in Newfoundland, they did add to the glacial chronology. Walthier (1948) described the stratigraphy from coastal sections near Fortune on the Burin Peninsula. He recorded cross-bedded sands, varved clays and red, sandy gravel capped by till, which he interpreted as being kame terraces formed when Fortune and Placentia Bays were filled with ice. Potter (1949) extended and detailed Walthier's kame terraces north and east through Fortune valley. He also took issue with the map of postglacial warping proposed by Flint (1940) and suggested that the zero isobase be repositioned to an area south and east of the Burin Peninsula. By now the concept of limited (late?) Wisconsinan ice had become unpopular and all deposits were relegated to this sub-stage.

Also in 1949, Summers following the ideas of MacClintock and Twenhofel, submitted an M.Sc. thesis to McGill University of the physical geography of the Avalon Peninsula in which he proposed a seris of residual ice centres. A year later, Widmer (1950) in his Ph.D. dissertation to Princeton University, presented a very detailed study of the geology of the southeast coast of the island. He developed the following scheme, with references to previous notes by Jewell (1939) and Van Alstine (1948):

1. During the Sangamon(ian) interglacial, wave-cut benches were formed at two levels (the relationships of which are unclear).

2. The Wisconsin(an) ice advanced to, and probably beyond, the Burin Peninsula, covering the entire Fortune Bay region.

3. Stagnation and removal of the ice in the late-Wisconsin(an) culminated in a stand north of Fortune Bay.

4. A late-Wisconsin(an) readvance caused blockage of Baie d'Espoir and Hermitage Bay, and a build-up of fresh water lakes behind the ice dams, with eventual terracing at various water levels.

5. In the following withdrawal of ice, strandlines were again cut in moraines and outwash trapped in local valley situations.

The most controversial of Widmer's proposals was the damming of fresh water lakes across Baie d'Espoir, Fortune Bay and possibly behind a morainal dam in "Lake Placentia" (Fig. 1.3). The system of lakes was devised to explain an extensive set of varves at Conne River, Baie d'Espoir, and the various sets of terrace and bench levels around the coast. Though Widmer also assumed an advance of ice onto the Grand Banks, its extent and dynamics were not resolved.

Murray (1955) compiled a series of striae measurements from south-central Newfoundland which described three radial outflow patterns: one with flow south and west from the Annieopsquotch Mountains, a second trending northeast in a wide band from the same source, and a third directed south to the coast from the central granite plateau. From these patterns he concluded that the Annieopsquotch Mountains had acted as a centre of accumulation during the Wisconsin(an) and agreed with MacClintock and Twenhofel that the assignment of glacial deposits in central Newfoundland to that stage seemed valid.

1.4 Recent Investigations

Several years later, Jenness (1960, 1963) published a

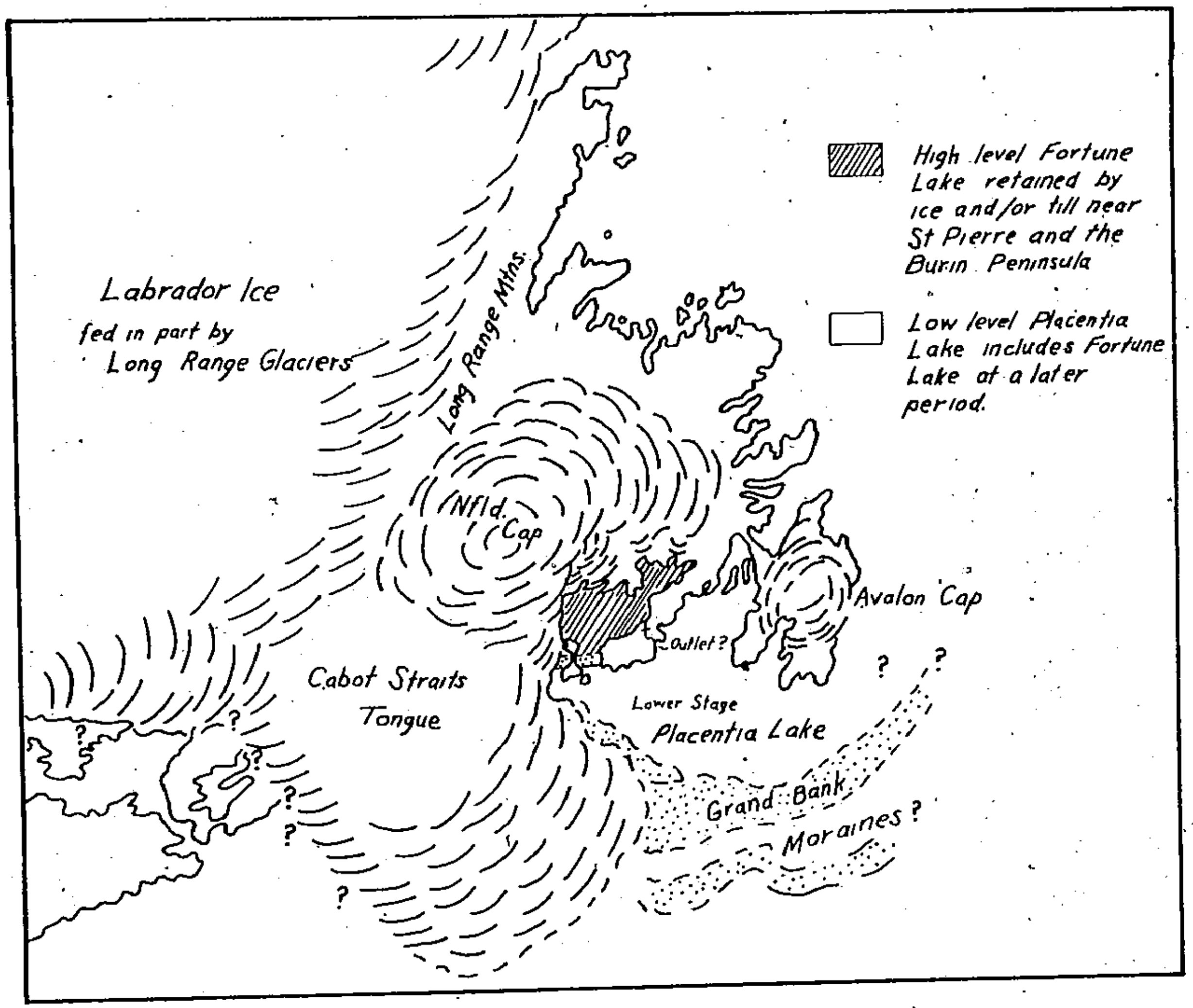


FIGURE 1.3: Fortune ice blocked lake (Widmer, 1950).

deglaciation chronology for the Terra Nova-Bonavista map area on the east coast, which he hoped would "renew interest in the glacial geology of the province". He proposed the following sequence of events:

1. Late Pleistocene ice from west of longitude 56° flowed across all of eastern Newfoundland but stopped before reaching the Avalon Peninsula. Ice existed on the Avalon at about the same time.

2. The ice front subsequently retreated, with brief halts or re-advances, until it reached a position well inland.

3. The ice sheet then developed an extensive end moraine that encircles much of eastern Newfoundland just inside the coast (Fig. 1.4). The area outside this position is termed the outer drift zone.

4. Final melting of the ice sheet produced glaciofluvial deposits behind the end moraine (inner drift zone), and outwash that radiates coastward from the end moraine and terminates as deltas at the coast. Small valley glaciers existed in the high terrain around Fortune Bay.

5. Large fresh-water lakes developed at the heads of Fortune and Bonavista Bays and Baie d'Espoir as a result of ice forming blockades across the headlands. Varved deltaic deposits accumulated where river valleys entered these lakes.

6. Removal of the ice resulted in upwarping towards the northwest. Isobases drawn on the upper levels of deltaic sediments associated with outwash are concave towards the northwest (Fig. 1.2).

Lundqvist (1965) attempted to trace the Jenness inner-outer drift zone boundary in north central Newfoundland (Fig. 1.4). A discrepancy between the two interpretations was obvious since Lundqvist proposed that the ice margin in north-central Newfoundland be positioned at the delta interfaces in Halls Bay while Jenness located his margin farther inland. Dyke (1972) took issue with Jenness' proposals and determined that the Eastport Bonavista Bay delta was glaciomarine in origin and had been

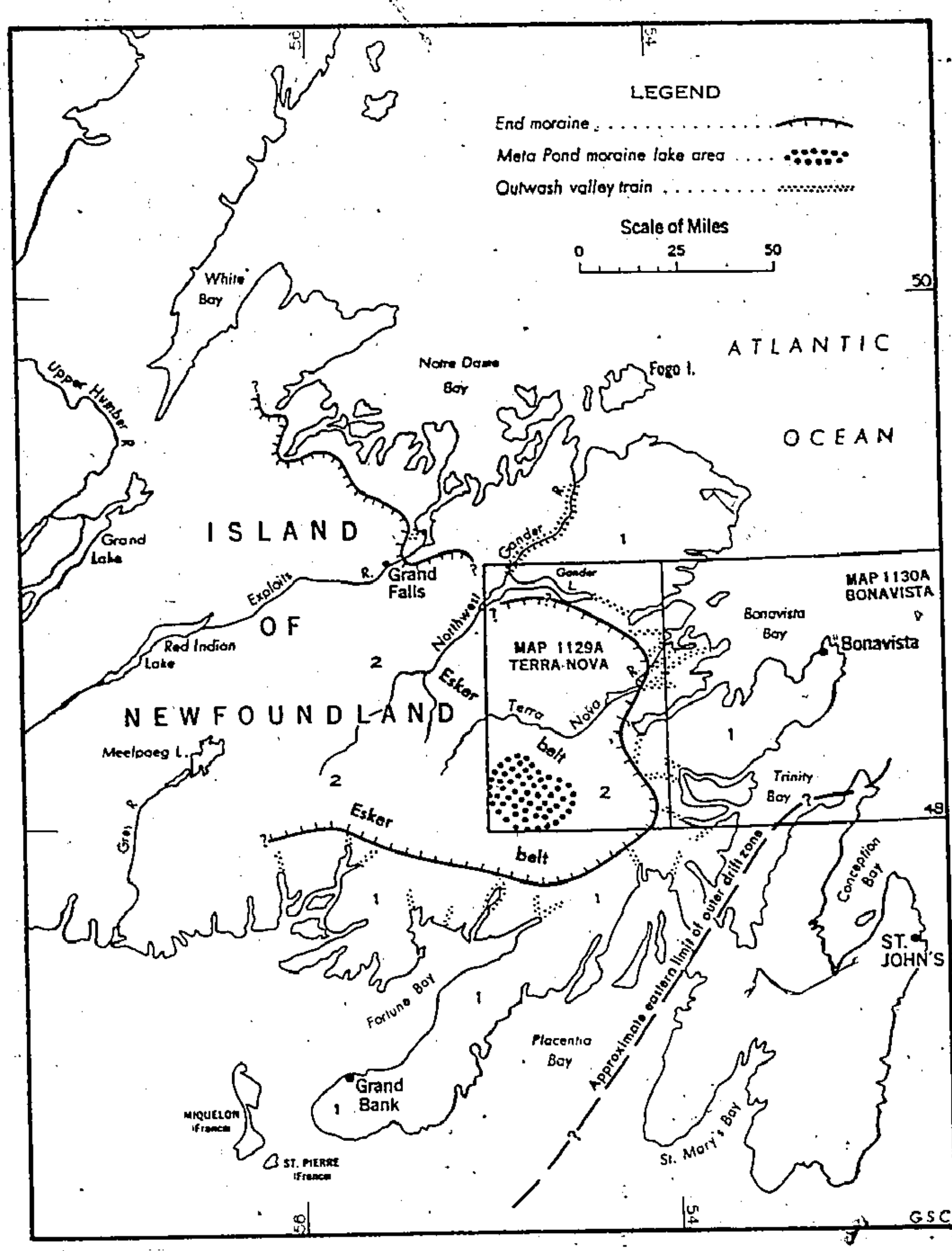


FIGURE 1.4: General distribution of glacial deposits in east-central Newfoundland (Jenness, 1963; Lundqvist, 1965).

formed when the ice front was less than 2 km from the marine limit, not at the position of the inland terminal moraine. Lundqvist also suggested that the Halls Bay deltas were glaciolacustrine, but Tucker (1974a) concluded that the features were in fact glaciomarine. As a point of interest, the idea of glaciolacustrine deltas seems to have originated with Widmer (1950) and been re-emphasized by Jenness (1960) and Lundqvist (1965). Later C^{14} dating and detailed studies have completely resolved this dilemma on the north-central coast of the island. Though Lundqvist (1965) and Tucker (1974a, b) found no deposits older than Wisconsinan in north-central Newfoundland, Alley (1975) and Alley and Slatt (1975, 1976) did discover two till deposits of indeterminate age near Sheffield Lake. Grant and Tucker (1976) also report dissimilar tills in south-central Newfoundland.

While Lundqvist and others concerned themselves with the east coast, Brookes (1969, 1970a, b) detailed the glacial chronology of the southwest coast. In 1974 he published a series of ice marginal positions for the area which were based on field work supported by several C^{14} dates obtained over the previous decade. The sequence of events proposed by Brookes was roughly similar to that described by MacClintock and Twenhofel (1940), but differed in that he proposed:

1. Ice flowed from the western mountains into the Gulf of St. Lawrence at the last glacial maximum (before about 14,000 B.P.), and that no Labradorian ice invaded the region.

2. Following marine overlap around 13,500 B.P., ice re-advanced selectively from the Long Range Mountains onto the lowlands between 13,000 and 12,700 B.P.

Further north, Grant (1969a, b) resolved late Quaternary events which, though similar to those outlined in the south, varied both in detail and chronology. Grant listed a four-phase glacial sequence:

1. Laurentide ice from Labrador advanced southeastward at least over the lowland portion of the Northern Peninsula, and perhaps 300 m up the flanks of the Long Range Mountains.

2. Later retreat, influenced mainly by a calving bay enlarging northeastward up the Strait of Belle Isle, proceeded concentrically inland to an ice divide near Hare Bay while the sea was about 90 m higher than present.

3. As the lowland ice mass was retreating, Long Range ice re-advanced down onto the lowlands. A lobe moved westward into Ten Mile Lake basin and built the end moraine which has been dated at a maximum of 10,900 yrs. B.P., and may correlate with events across the Strait of Belle Isle.

4. Active ice continued during final retreat which culminated from a divide on the median line of the Long Range Plateau, several hundred feet lower than the topographic divide. Evidence of pre- or early-Wisconsin(an) ice is afforded by the presence of old cirques that appear to have been overridden and not re-occupied by glaciers.

To this date, neither Brookes nor Grant attached any particular significance to the Long Range nunataks despite well documented evidence for limited, late-Wisconsinan ice in Labrador (Coleman, 1920; Ives, 1957, 1958a, b; Løken, 1962a, b). For example, Grant (1969b) concluded that Long Range summits, which seemed to have been nunataks during a late-Wisconsin(an) readvance, bore 'fresh-looking' igneous erratics probably emplaced during Wisconsin(an) time by either Labradorian or Long Range ice. Subsequently, Grant (1970a, 1971, 1972a,b,c, 1973a,b, 1974a, 1975a) published notes that detailed Quaternary events as far south as Bonne Bay.

Prest *et al.* (1967) depict a considerable body of Quaternary information for the island on the Glacial Map of Canada. They show northeasterly directed ice flow on the Bonavista Peninsula, in the Gander Lake area and north-central Newfoundland; with southerly to southeasterly flow patterns across the Burin Peninsula and south coast. Striae measurements indicate radial flow from the coasts, the Annieopsquotch Mountains and the Avalon Peninsula. Areas of ribbed moraine, transverse to the ice flow, cover large portions of the south-central to northeast-central part of the island and the central Avalon Peninsula. Smaller patches of similarily classified terrain are located near the Burlington Peninsula and Gander Bay-Gambo perimeter. Marine overlap is recorded on the west coast andincreases towards the tip of the Great Northern Peninsula. Prest (1970), in a comprehensive work on the Quaternary of Canada, discussed the above patterns as specific events and supported the concept of an active Newfoundland ice cap in late-Wisconsinan time.

In 1972 E.P. Henderson produced an extensive memoir on the surficial geology of the Avalon Peninsula for which a preliminary map was published in 1959. From his research on the attrition of Avalon tills, Slatt (1972) agreed with Henderson (1959) that the peninsula supported its own ice cap, and had not been affected by an all encompassing island ice sheet. Rogerson and Tucker (1972) took issue with several morphological implications of Henderson's preliminary analysis as they related to deglaciation, however, in the later manuscript (1972) he revised his ideas and proposed (Fig. 1.5) that:

1. At the glacial maximum southward flow of ice centred over the Avalon was restricted by ice pouring out the Cabot Strait.

2. Later thinning of Cabot Strait ice resulted in southerly and radial flow out of St. Mary's Bay and a reduction of flow in Trinity and Conception

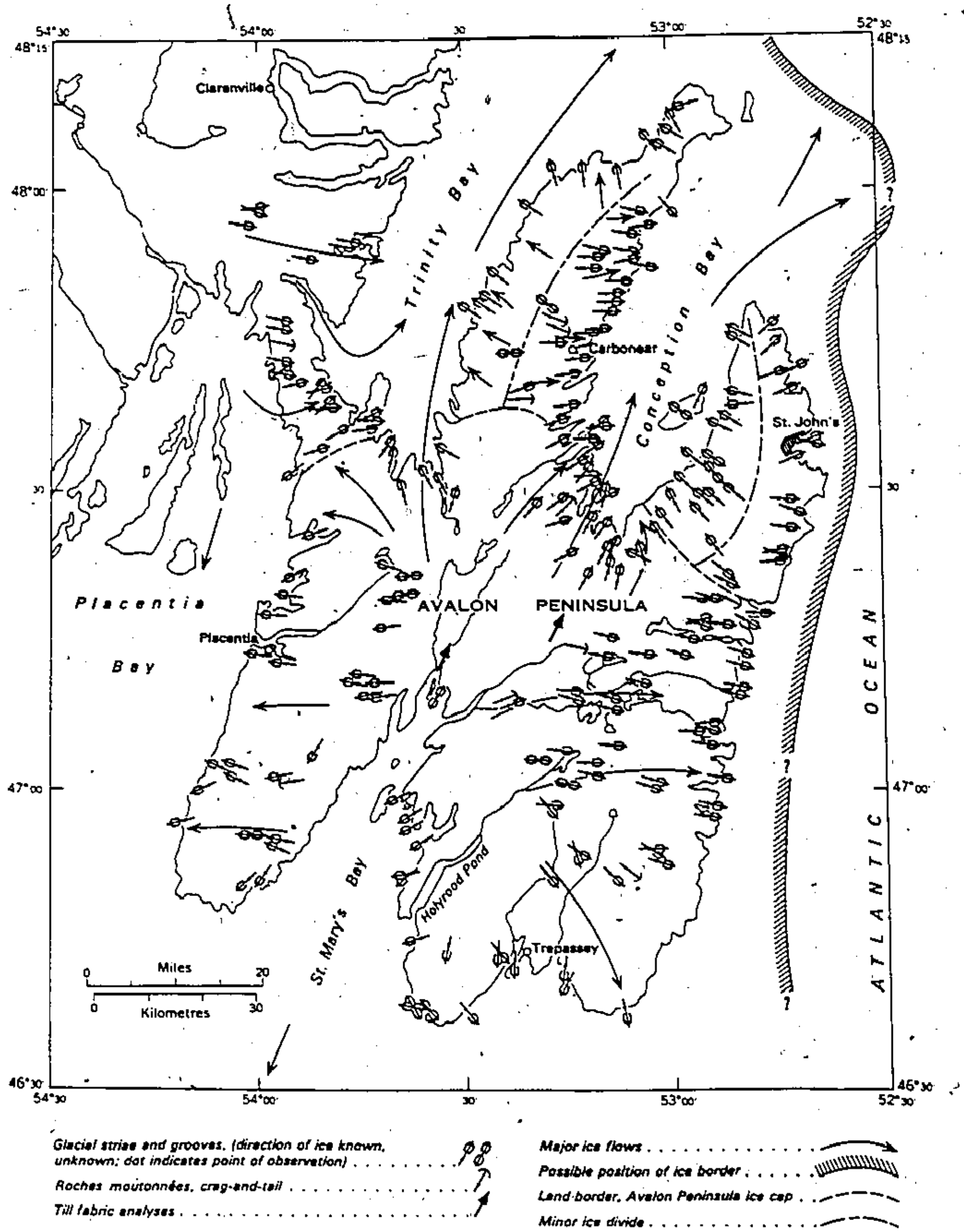


FIGURE 1.5: Glacial indicators on the Avalon Peninsula (Henderson, 1972).

Bays. At the same time, ice flow to the east and north from the main Newfoundland cap ceased, for similar reasons.

3. As deglaciation continued, ice thickness was sufficient to allow axial flow into Placentia and Trinity Bays.

4. Finally, as ice thinned, divides on the various subpeninsulas shifted westward. Ice stagnated in St. Mary's Bay and final active ice was located to the east of the Trepassey Peninsula highlands.

In 1974, Slatt published preliminary analyses of Quaternary sediments dredged from the Grand Banks and summarized that the relict sediments, dated at 17,000 B.P., including littoral material and reworked glacio-fluvial sediments, now covered by more than 90 m of water, defined a Wisconsinan ice limit at somewhat less than 150 km from the present coastline. The following year, Grant (1975c) produced a short paper on glacial features of the Hermitage-Burin Peninsula area (Fig. 1.6) in which he largely republished stratigraphic information presented earlier by Van Alstine (1948); Walthier (1948); Potter (1949) and Widmer (1950). His major findings were, however, significant in that they were the first indication of a change in attitude on the extent of Wisconsinan ice in Newfoundland. He concluded that:

1. Late-Wisconsin(an) glaciers moved mainly north and west, that is to say, onshore from a source centred in Placentia Bay or on the banks beyond.

2. Weathered, bevelled striated outcrops indicate a nonglacial period of weathering intervened between the first phase of outflow across the peninsula from the interior and the maximal, presumably final, glacial phase that stemmed from an offshore source.

Unfortunately, these conclusions were not firmly fixed, and extensive revisions were soon offered. Grant (1976b) modified his ideas on

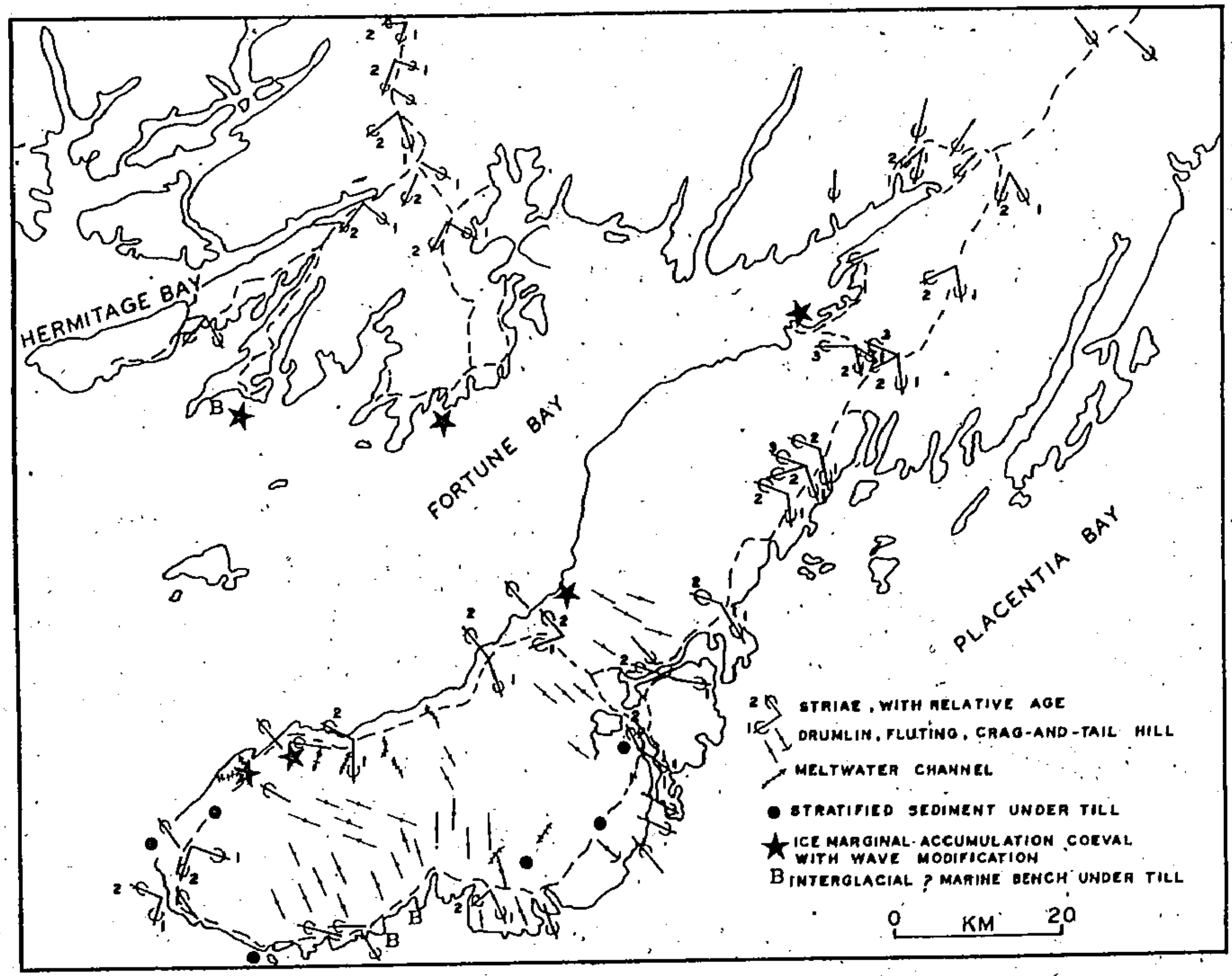


FIGURE 1.6: Glacial features of the Burin Peninsula Hermitage area (Grant, 1975c).

the limits of late-Wisconsinan ice in Newfoundland:

1. The Burin Peninsula was essentially ice free during the late-Wisconsinan, the lower portion having been glaciated by northward moving ice during an earlier stage.

2. Inland ice skirted the Hermitage Peninsula except where separate small valley glaciers were drawn down into Hermitage and Fortune Bays.

3. At the Avalon Isthmus, inland ice merged with a separate small ice cap complex on the Avalon Peninsula.

4. On the west coast, hills above 300-500 m existed as nunataks and ice may have splayed around the high terminal portion of the Port au Port Peninsula.

5. The Buchans Plateau, Topsail Hills and Bonavista Peninsula all remained as nunataks.

1977 marked what was probably the most prolific year in the field of Quaternary research in Newfoundland since the Princeton-Yale studies of 1940. Vanderveer (1977) disagreed with several of Grant's (1976b) findings and suggested that:

1. During the last stages of the Wisconsin(an) the lower portion of the Burin supported its own ice cap from which there was radial flow.

2. Late, weak flow towards Fortune Bay allowed marine overlap to approximately 18 m in the Fortune to Garnish areas while the south and southeast coasts remained ice covered.

Grant (1977a,b) again changed his inferred vertical and horizontal limits of late Wisconsinan glaciers (Fig. 1.7), and Brookes (1977a,b) also revised his previous work on the west coast of the island. He concluded that earlier ideas of all-encompassing Wisconsinan ice should be abandoned and that for the lower west coast, the following chronology existed:

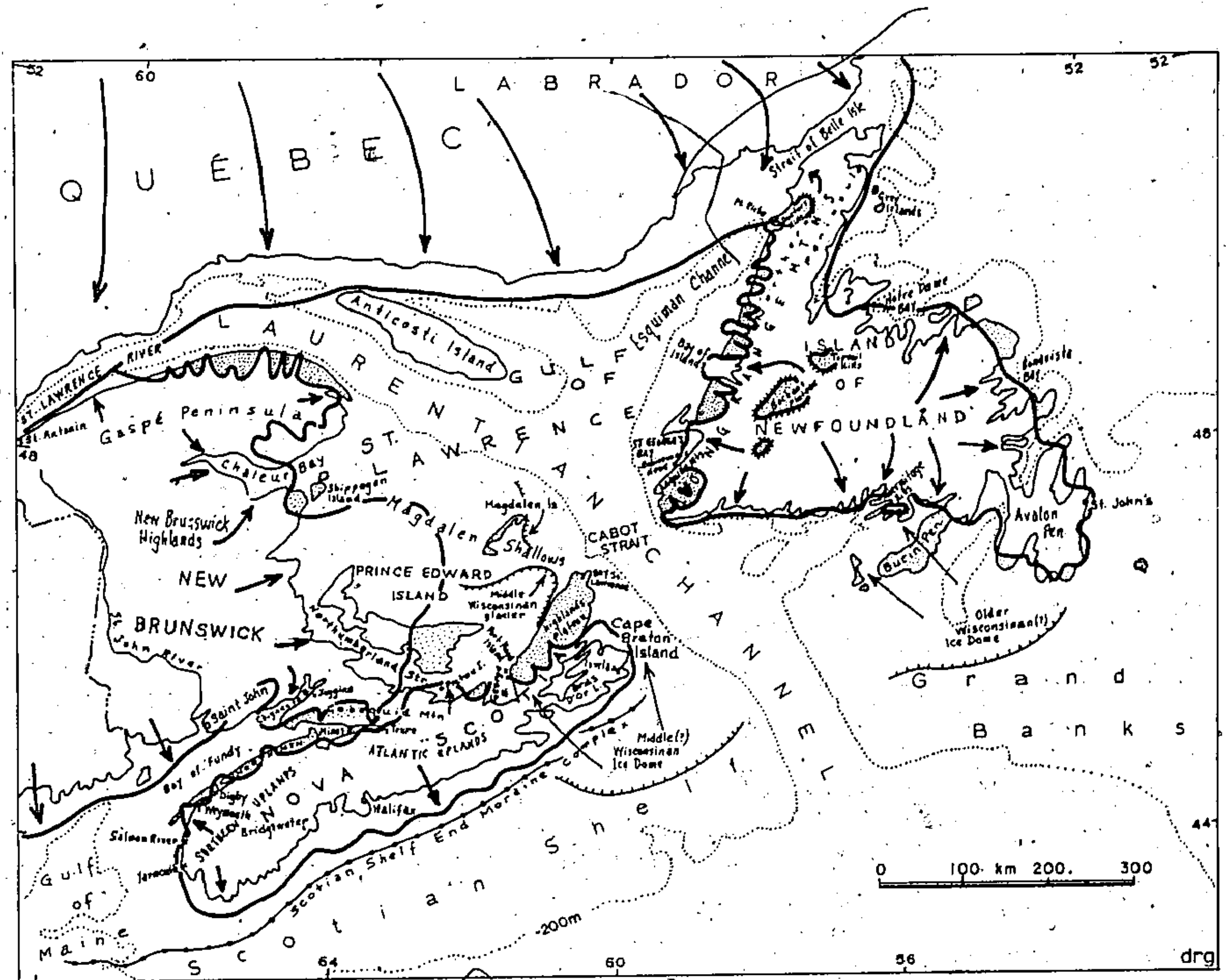


FIGURE 1.7: Late-Wisconsinan limits in eastern Canada (Grant 1977b).

1. Within the early-Wisconsinan, ice from a Newfoundland ice sheet covered the southwest sector of the island, except for the highest summit plateaus of the Long Range Mountains. These may have escaped glaciation entirely or have been covered by cold-based, non-erosive ice.

2. Late-Wisconsinan ice was much more restricted; the Anguille Mountains and western Long Range Plateau were entirely ice free except for a glacier in Little Codroy Pond valley.

3. Ice from the Long Range Mountains moved onto the Codroy Lowland and before 14,000, extended beyond the present coast of Cabot Strait.

4. By 13,800 B.P. the coast had been deglaciated and submerged beneath rising sea level.

5. By 12,600 B.P. ice had readvanced down Codroy Lowland to build an end moraine bordering Little Codroy River estuary.

6. Isostatic rebound elevated late-Wisconsinan marine sediments 5-10 m a.s.l. rapidly, but presently, the Cabot Strait littoral zone is submerging.

7. A 10 m a.s.l. wave-out bench at Cape Ray does not represent a Holocence eustatic sea level surge (Flint, 1940), but relates to a Sangamonian sea level stand.

Brookes' work is significant in that it was the first detailed presentation that countered the philosophy put forward by MacClintock and Twenhofel. However, both Brookes and Grant were breaking new ground on the west coast by proposing a tripartite system for vertical limits of Wisconsinan glaciation. In descending order, Brookes' zone 3 remained unglaciated, zone 2b was pre-/(?) early-Wisconsinan in age, zone 2a, early-Wisconsinan, and zone 1 was covered by late-Wisconsinan ice. Grant's zone C correlates with Brookes' zone 3, zone B with zone 2a and b, and zone A with zone 1.

In contrast, Eyles and Slatt (1977) rejected the idea of multiple glaciation in their study of the Holyrood Pond, Avalon Peninsula area. Rogerson and Tucker (1972) had earlier interpreted the drift sequence as two discrete till sheets separated by a marine outwash delta, and Grant (1977b) had placed the area outside the zone affected by late-Wisconsinan ice. Eyles and Slatt concluded that:

1. Thick Pleistocene drift sections along part of the southern Avalon Peninsula comprises imbricated sheets of grey and tan melt-out till underlain by lodgement till, subglacial fluvial sediment and periglacial rubble and flow tills which interfinger with and grade laterally into supraglacial outwash and rhythmites.

2. The sequence is similar to those described for certain cold Arctic glaciers (Boulton, 1972) and indicates southward flowing Wisconsinan glacier lobes were of the cold Arctic type in southeastern Newfoundland.

3. The drift was deposited during one episode of glaciation and is the product of thrusting and stacking of englacial debris along ice-marginal shear planes and subsequent *in situ* melting out of englacial debris, accompanied by flow of water-soaked supraglacial till from ice cores into intervening supraglacial fluvial channels.

Similarly, Piper and Slatt (1977) and Slatt (1977) assumed complete late-Wisconsinan ice cover for Newfoundland, domed over the central part of the island and the Avalon Peninsula. The latter paper concluded that Avalon ice probably did cross the Avalon Channel and lap onto the western bank edge in a manner analogous to late-Wisconsinan, Labradorian ice that crossed the Strait of Belle Isle and advanced onto the northernmost coast of northwest Newfoundland (Grant, 1969a). Stow (1977) appears to have satisfied both schools of thought. He showed late-Wisconsinan ice extending onto the Grand Banks and across Placentia Bay from a dispersal centre located on the Avalon, and Newfoundland centred ice touching the west coast of the Burin Peninsula. Thus, the Burin is considered to be ice free during the interval suggested by Grant (1975c), yet is surrounded by ice on its east and west coasts.

Wightman and Cooke (1978) have provided an updated summary of postglacial emergence in Atlantic Canada (Fig. 1.8). The authors depicted an isopleth of zero emergence falling to the south and east of the Burin Peninsula and 150 m of emergence along the northwest tip of the Northern Peninsula, and while they are loath to refer to the lines as isobases, they assume a general deglaciation for Atlantic Canada between 14,000 and 11,500 B.P.

1.5 Discussion

It becomes clear from the above resumé that there is still a profound difference of opinion as to the extent of Wisconsinan ice in Newfoundland. Ives (1978) considered Brooke's (1977a,b) and Grant's (1977a,b) work indicative that a glacial maximum did not occur in Newfoundland during the Wisconsinan and that summits underlain today by mature mountain-top detritus either remained as nunataks or else were covered by thin, stagnant and/or cold based ice.

Opposing this view are Henderson (1972), Slatt (1974a,b, 1977), Piper and Slatt (1977), Eyles and Slatt (1977), Vanderveer (1977), and Wightman and Cooke (1978). Collectively, their view is that even late-Wisconsinan ice cover was complete, that ice shrank back to a series of residual ice caps, and that deglaciation of the island was approximately contemporaneous. Further, the conclusions of Eyles and Slatt (1977) counter those of Sugden (1977); the former believed that Avalon Peninsula

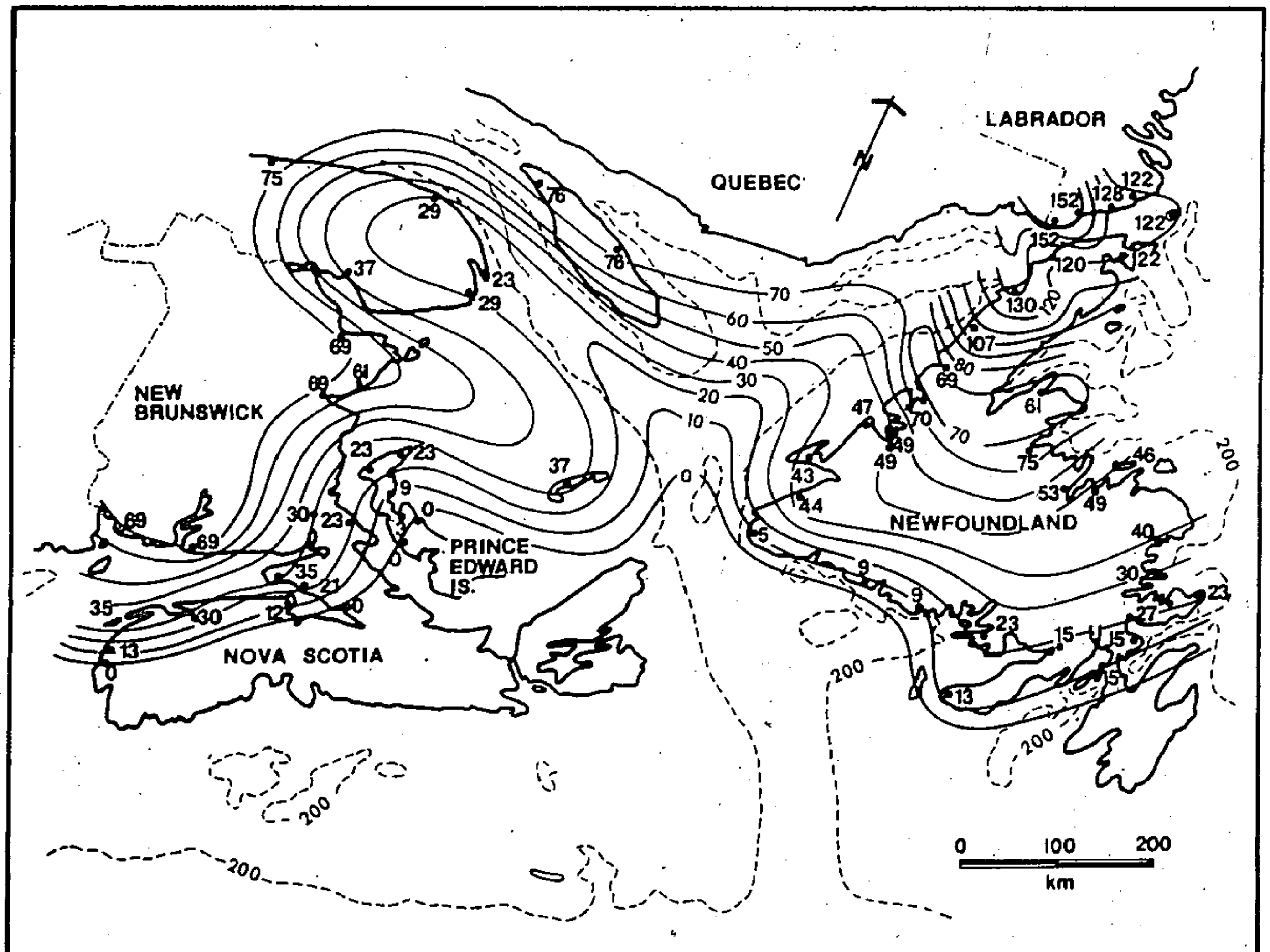


FIGURE 1.8; Isopleths of postglacial emergence in Atlantic Canada. Elevations in metres; contour interval, 10 m; dashed lines show 200 m bathymetric contour (Wightman and Cooke, 1978).

ice was cold based while Sugden was of the opinion that in Newfoundland, "the Laurentide ice sheet" was cold-based over northern and western sections of the island and warm-melting over the central portion and east coast.

The dilemma over timing of Wisconsinan events is less confusing now that it was. Coleman (1926), MacClintock and Twenhofel (1940) and others of the period believed that the Wisconsinan was a simple stage without the series of major advances and retreats that are now recognized (Dreimanis and Goldthwait, 1973; Dreimanis and Raukas, 1975). Hence, any "older looking" deposits had to be relegated to the Illinoian or even older stages. This proved difficult since the amount of weathering observed could not be reconciled with what was considered to be a logical time period for a phenomena to occur.

Earlier investigations on the Quaternary of the Burin Peninsula concluded that it had been glaciated only by ice moving south and southeast from the centre of the island. More recent work (Grant, 1975c) has revealed that although initial flow was from Newfoundland, it was followed by west to northwest flow out of Placentia Bay and radial flow from the Fortune Bay coast. Reports of as many as three separate till sheets (Van Alstine, 1948; Potter, 1949), and observations on well-developed periglacial and weathering phenomena (Walthier, 1948; Potter, 1949) indicate that the Burin Peninsula was subjected to several glaciations with significant non-glacial intervals.

A series of wave-cut terraces and benches along the coast of the peninsula (Van Alstine, 1948; Widmer, 1950; Grant, 1975c; Vanderveer, 1977), complicate the deglacial record. Previous research has not clarified which benches if any, are interglacial (Sangamonian), which are postglacial and what are their geneses. If the peninsula was not significantly glaciated during late-Wisconsinan time, then many of the erosional terraces which have been used in the past to describe post-glacial emergence (Flint, 1940; Widmer, 1950; Jenness, 1960, 1963; Wightman and Cooke, 1978), must be viewed with caution.

1.6 Objectives

Based on the review of previous Quaternary research in Newfoundland, it was considered that the objectives of the present study would be:

1. To map and describe the surficial deposits at a scale of 1:50,000 (final compilation at a scale of 1:100,000), with a view of determining the various modes of expression of specific deposits as they relate to an overall pattern of deglaciation.

2. To determine the sequence of Quaternary events to take account of multi-directional opposing striae, reports of buried organics (Newfoundland and Labrador Corporation, Lot IV Exploration Project, unpub. rept., 1972) and sections containing beds of massive sand and gravel overlain by till (Grant, 1975c).

3. To analyse the series of wave-cut benches and terraces with a view to resolving their geneses and succession.

4. To study all accessible periglacial and weathering phenomena in an attempt to delimit specific zones of intensive weathering in the manner of Løken (1962a,b), Ives (1960a,b), Brookes (1977a) and Grant (1977a).

To these ends, a total of 26 weeks were spent on the Burin Peninsula during the summers of 1976 and 1977 as well as one week in the winter of 1978. During the 1976 field season, which followed a preliminary air photo analysis of the area, a comprehensive record of glacial striae was obtained from the northeast corner of N.T.S. sheet 1M/16 to 1M/15 and south to 1L/13 and 1L/14. General stratigraphic records were noted for all accessible coastal sections, road cuts and specific points of interest visible on the air photos. All raised bench and terrace remnants were levelled in an attempt to organize patterns of isostatic rebound.

After a detailed air photo analysis, generally following the style of Fulton *et al.* (1975), the 1977 field season was concerned with field checking the morphogenetic map units and obtaining specific information from important stratigraphic sections. Fabric analyses of particular till units were completed and samples were collected for later analyses of texture, clast lithology and marine fauna. Tasks also included: detailed profiling of selected raised glaciomarine features, gathering weathering data from various physiographic and lithologic zones, and recording data on both active and fossil periglacial features.

One week during each of the 1976 and 1977 field seasons was spent on the French islands of St. Pierre et Miquelon to investigate coastal sections visible on the air photos and considered relevant to the glacial history of the Burin Peninsula. Data obtained from these excursions are discussed separately in Chapter 6. Field work in February, 1978 was concerned with coring a water-filled kettle hole to obtain an organic record for palynological analyses and C^{14} dating.

1.7 The Field Area

The Burin Peninsula field area (Fig. 1.9, See map pocket) lies on the southeast coast of Newfoundland between Fortune and Placentia Bays, extends 170 km southwest from the main island and contains over 5,200 km^2 of territory. This area also includes Sound Island, Woody

Island, Bar Haven Island, Long Island, Merasheen Island and Red Island in Placentia Bay. Part of the main landmass of Newfoundland, extending as far west as Long Harbour, Fortune Bay and 16 km north of Gisborne Lake was taken into the study area since it is considered critical to deciphering Quaternary events on the peninsula. Specifically, the area encompasses the 1L/13 and 1L/14, 1:50,000 N.T.S. sheets of the St. Lawrence, 1L, 1:250,000 N.T.S. sheet, and 1M/3, 1M/4, 1M/6, 1M/7, 1M/8, 1M/9, 1M/10, 1M/15 and 1M/16 of the Belleoram, 1M, 1:250,000 N.T.S. sheet. It is bounded by the following co-ordinates: Lat. 48° 00'N. Long. 55° 00'W; Lat. 48° 00'N; Long. 54° 00'W; Lat. 46° 50'N, Long. 56° 00'W; Lat. 46° 50'N, Long. 54° 10'W.

1.7.1 Physiography

The topography of the Burin Peninsula may be divided into three sections (Fig. 1.10); the lower peninsula or St. Lawrence plateau, the Marystown-Garnish lowland and the upper Burin Peninsula. Mean surface elevations range from 90-120 m a.s.l. on the southwest corner of the lower peninsula to 150-180 m a.s.l. in the Terrenceville area of the upper peninsula. The terrain slopes from west to east with elevations of 60-90 m a.s.l. in the southeast corner and 90-120 m a.s.l. in the northeast corner being common. The Marystown-Garnish lowland ranges from 30-75 m a.s.l. in elevation and is hummocky to planar in nature. Except for this area, which is covered by expansive areas of outwash and ice stagnation material, the peninsula is generally rugged and barren with a minimum of unconsolidated deposits and vegetation. Highest peaks on the lower south coast of the peninsula are the 230-245 m a.s.l. volcanic

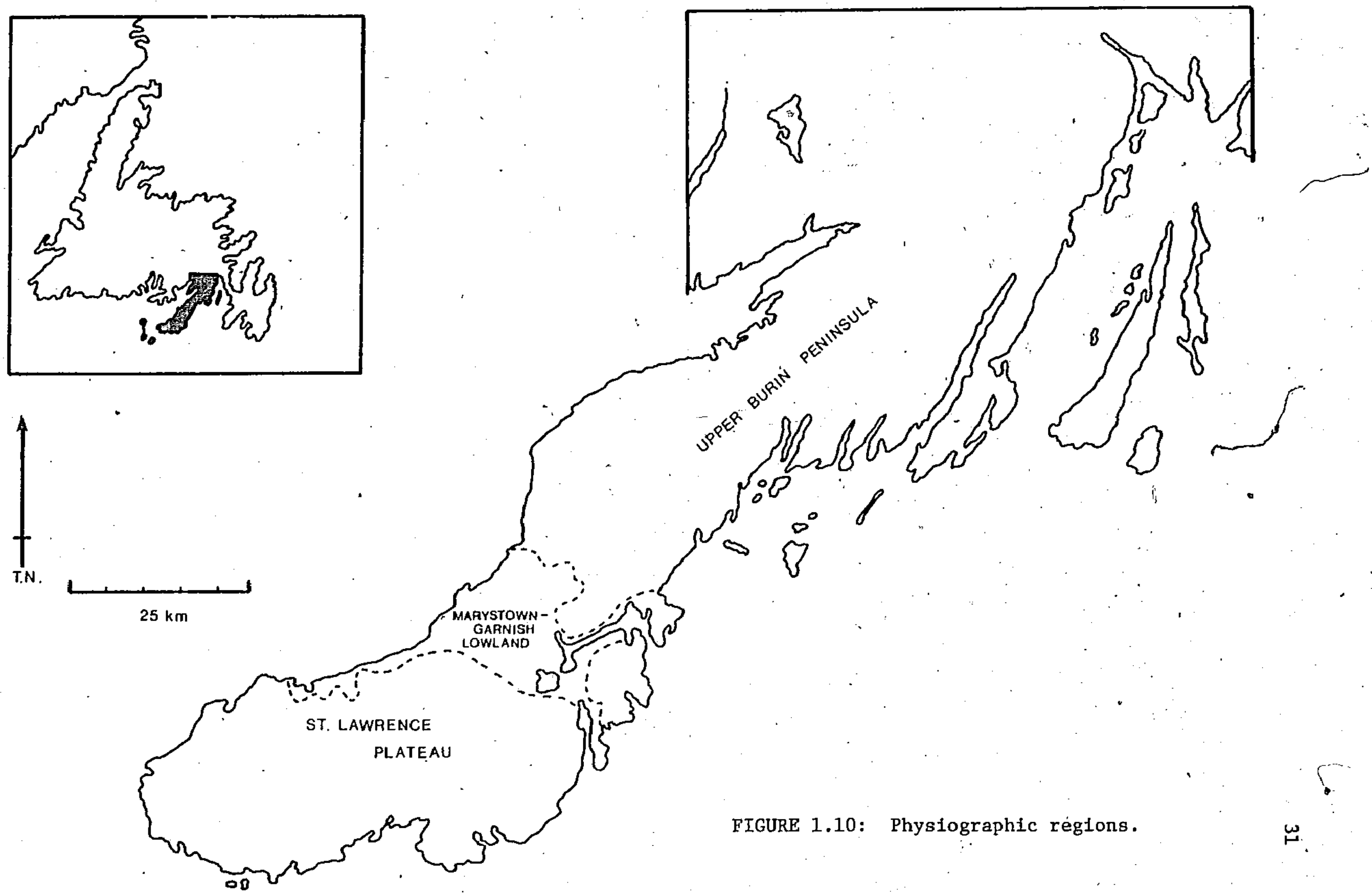


FIGURE 1.10: Physiographic regions.

plugs of Mt. St. Margaret, Mt. St. Anne, Mt. Lucy Anne and the Hare Hills. In the northeast, the White Hills reach 335-365 m a.s.l.

The structure of the peninsula, which is dominantly underlain by Hadrynian or earlier acidic to mafic volcanics and Devonian or earlier granites (Williams, 1967), trends southwest to northeast. A general section across the terrain near the mid-point of the peninsula, shows an agonizing 25-45 m vertical seesaw in elevation for every 500-700 m in plan view, the bane of foot traverses.

In addition to the Burin Peninsula, the field area includes a large zone around Gisborne Lake that is underlain almost exclusively by Devonian or earlier granite. Bradley (1962) states that the topography of the Gisborne Lake area is controlled to some extent by rock type and structure. For example, the granite that outcrops over much of the north half of the area breaks down readily to form lowlands and, consequently, contact zones and roof pendant areas of volcanics and sedimentary rocks project above the granite as resistant ridges. In the southern half, volcanics and older granite form ridges whereas meta-volcanics and meta-sediments form lowlands.

The physiography of the area has been discussed in terms of denudation chronology by Twenhofel and MacClintock (1940) and Van Alstine (1948). The authors correlated two erosion surfaces at 200-245 m a.s.l. and 100-120 m a.s.l. on the Avalon Peninsula with the High Valley and Lawrence peneplains of Newfoundland. Chiefly because similar surface elevations were observed on the Burin Peninsula, MacClintock (1947) and Van Alstine (1948) suggested that the higher level in the St. Lawrence area constituted part of the High Valley peneplain and the lower surface part of the Lawrence peneplain. Brookes (1977a) has questioned the validity of assigning these supposed Tertiary erosional surfaces to the island and suggested that the problem of the tectonic framework of upland surface development requires further study because it appeared to him that complete base levelling has never been achieved since initiation of drainage towards the Atlantic continental margin.

The coast of the Burin Peninsula is steep and jagged, especially along Placentia Bay, which is bordered by vertical cliffs up to 60 m a.s.l. in elevation. Only in the Garnish-Grand Bank and Point Crewe-Point au Gaul areas on the south and west coasts is the coastal relief subdued; here cliffs under 15 m a.s.l., cobbly barrier beaches and lagoons prevail.

Patches of scrub spruce and fir occur in bands along narrow topographic lows and the Marystown-Garnish lowland, but elsewhere the research area is almost devoid of timber; peat bogs and rugged barren rock predominate.

1.7.2 Drainage and tides

Generally, the area is poorly drained by small brooks that head in swamps and ponds. The uplands are dotted with countless small ponds which lie in rock basins and are elongated parallel to structure; others are randomly located on drift covered surfaces and are connected by brooks having aimless drainage. Many ponds are rimmed with bogs while others are bordered by boulders pushed up along the edges by expanding pond-ice. The largest ponds are: Freshwater Pond, southwest of Marystown, which covers nearly 6 km^2 and lies 3 m a.s.l., Garnish Pond, northwest of Marystown and Gisborne Lake, located in the northwest corner of the field area. The latter has an area of 32 km^2 and is contained in a shallow morainal dammed basin behind Silurian/Ordovician volcanics, 6 km north of Grand le Pierre.

The longest stream in the field area, with headwaters >50 km from tidewater, is Long Harbour River (Bradley, 1962). Long Harbour, the continuation of this river valley is a spectacular fjord formed where ice movement coincided with preglacial drainage. Several smaller, less spectacular fjords such as Jacques Fontaine and Grand John Point, are located along the upper east coast of Fortune Bay. Other major rivers in the northern section of the field area include Piper's Hole River, Sandy Harbour River and Paradise River, all of which flow southeast across bedrock structure and parallel to what is considered as being the oldest known glacial trend. Bay de l'Eau River has its headwaters 17-20 km from Placentia Bay and flows parallel to structure. Garnish River (16 km), Main Brook (20 km), and Shearstick Brook (8 km) are located on the southern half of the peninsula. They all flow through thick, unconsolidated deposits in their lower reaches and are more sluggish. The latter two meander their way into Freshwater Pond and flow north, then east from the St. Lawrence plateau. Garnish River, which has its source in Garnish Pond, flows directly west across an area of ablation till and outwash to empty into a shallow lagoon on the Fortune Bay coast.

On the lower portion of the peninsula, a drainage divide runs roughly east-west bisecting the plateau from which smaller 7-10 km long streams empty to the south, northwest into Fortune Bay and north onto the Marystown-Garnish lowland. On the upper peninsula, streams flow radial to Fortune and Placentia Bays except in the Boat Harbour-Davis Cove area in which they move parallel to structure.

Along the south coast of Newfoundland the tide is semi-diurnal and high water occurs almost simultaneously along all coastal points. The tidal range is not very great, the difference between high and low water seldom exceeding 1.8 m (Stevenson, 1977).

1.7.3 Bedrock geology

The geology of the Burin Peninsula (Figs. 1.11 and 1.12) has received considerable attention through both private and public research. Aside from the corporate studies that involve the Alcan Fluorspar mine at St. Lawrence, maps and reports (predominantly government), cover the peninsula at various scales. These include; Dale (1927), Twenhofel (1947), Van Alstine (1948), Walthier (1948), Potter (1949), Bradley (1962), Anderson (1965), Williams (1967), Bell and Blenkinsop (1975), Strong *et al.* (1976, in press), O'Brien *et al.* (1977, 1978) and O'Driscoll (1976).

The peninsula is considered part of the Avalon Platform (Poole *et al.*, 1970), and is dominated by over 10,500 m of Precambian volcanic and sedimentary rocks, as well as Devonian or earlier granite (Bradley, 1962). The field area contains rocks of two structural provenances separated by the Terrenceville fault which trends northeast from the head of Fortune Bay. To the southeast of this fault, lie mainly the Precambrian volcanics with infolded or infaulted remnants of Cambrian shales and limestones. West of the Terrenceville fault, most of the rocks are Cambrian to Devonian in age and consist of clastic sediments

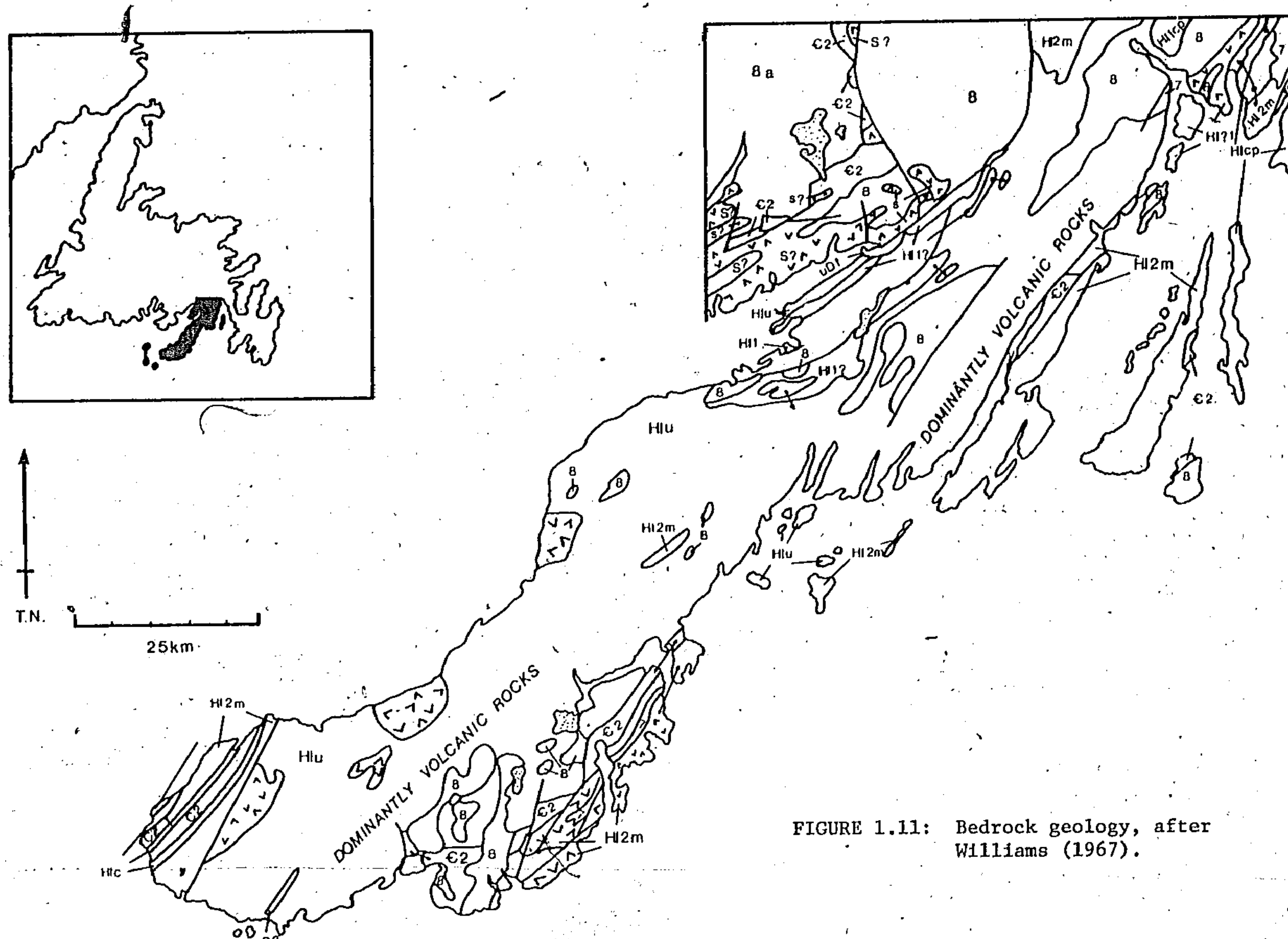


FIGURE 1.11: Bedrock geology, after Williams (1967).

SEDIMENTARY AND VOLCANIC ROCKS

(volcanic symbol)	mainly volcanic rocks, porphyries and shallow intrusives
(line)	geological boundary
(line)	fault

UPPER DEVONIAN

uDt Comglomerate, arkose, acidic volcanic rocks Terrenceville Formation.

SILURIAN

S Sandstone conglomerate, acidic to mafic volcanic rocks, greywake, shale, limestone.

LATE HADRYNIAN AND/OR CAMBRIAN

€2 Dominantly shales with limestone, conglomerate, siltstone, sandstone, minor volcanic rocks and manganese beds (comprising lower to upper Cambrian shale facies.) Faunas dominated by trilobites of European or Atlantic faunal remains. Unsup. Bonavista, Smith Pt., Brigus, Manuals River, Chamberlains Brook Formations and Elliot Cv. Group and equivalents.

H C Quartzite, conglomerate siltstone arkose: Random Formation and equivalents.

H 2M Siltstone, arkose conglomerate slate acidic to intermediate volcanic rocks: Musgrave Group or equivalents.

H 1 Slate, siltstone, greywake, conglomerate, minor volcanic rocks

HADRYNIAN OR EARLIER (undivided)

H u Acidic to mafic volcanic rocks, slate, siltstone, greywake, conglomerate: (probably equivalent in large part to Hbr. Main and Love Cove Groups.)

(cont'd)

FIGURE 1.12: General geology legend.

(Figure 1.12 cont'd)

PLUTONIC ROCKS

DEVONIAN AND EARLIER

8 granite, granodiorite syenite, monzonite, quartz diorite and related rocks (mainly Devonian).
8a, coarse grained porphyritic biotite granite.

7 Gabbro, diorite, pyroxene, quartz diorite, granodiorite, mafic syenite and related rocks.

and acidic to mafic volcanics (Anderson, 1965). Acidic-mafic volcanic and associated pyroclastic rocks and clastic sedimentary rocks immediately north of Fortune Bay have been assigned to the Ordovician (Bradley, 1962) because of a possible unconformity with known Cambrian sediments.

There were several periods of granitic intrusion in the Burin Peninsula. The larger bodies of massive granite, north of Terrenceville, are considered Devonian in age, while the foliated, hornblende-biotite granites located near Bay l'Argent may be Silurian. The granitic bodies on the lower Burin Peninsula are unfoliated and considered to be Devonian by Anderson (1965), however, Bell and Blenkinsop (1975) determined their ages to be Carboniferous.

Most of the rock units in the area have a pronounced northeasterly trend except in limited areas along the north shore of Fortune Bay and west of the south end of Paradise Sound where the trends are easterly. The northeasterly grain of the country has been emparted by schistosity and thrust faulting (Strong *et al.*, 1976). These faults which are near vertical to oblique and extend over tens of kilometres, occasionally have slices of Cambrian rocks occurring along their length.

1.7.4 Climate

The climate of the Burin Peninsula has been described by Stevenson (1977). It is, on the whole, temperate but is less equable than Vancouver Island lying on the same latitude. The influence of the sea is modified by the cold Labrador Current which flows along the east and west coasts of Newfoundland. These ice-laden waters chill the atmosphere above them and set up a barrier against warm air masses from the south. Spring is late and summers are cool. Winters are cold, but less severe on the Burin than further inland and on the Northern Peninsula.

The region lies in the southwest quadrant of the Icelandic low pressure area and to the north of the mid-Atlantic high pressure belt. Hence, the most prevalent winds are from westerly directions. In cold seasons, the region is one of considerable storminess since it lies within the core of a belt traversed by intense extratropical depressions. In summer, the Burin Peninsula, which lies near the Grand Banks of Newfoundland is subject to very heavy and prolonged fogs.

Table 1.1 summarizes relevant meteorological data for the town of Grand Bank in 1976 and is considered representative of the Burin Peninsula climate.

TABLE 1.1

Meteorological Data, Grand Bank, Nfld., 47°06'N, 55°46'W.

(Stevenson, 1977)

Month	Mean Sea Level Pressure	Temperature: Average	Temperature: Mean Daily Max.	Temperature: Mean Daily Min.	Temperature: Extreme Max.	Temperature: Extreme Min.	Relative Humidity	Cloud Amount Scale 0-10	Precipitation: Total	Precipitation: Max. in 24 Hours	Days with: Rain	Days with: Snow	Days with: Precipitation	Days with: Fog	Days with: Thunder
	kPa	°C	°C	°C	°C	°C	%		mm	mm					
January	100.9	-2.3	0.6	-5.3	11.1	-20.0	81	8.6	130.0	77.0	7	11	17	2	0.0
February	100.9	-2.9	0.1	-6.1	11.1	-18.9	80	7.7	123.4	77.5	6	10	15	2	0.0
March	100.9	-1.3	1.5	-4.0	15.0	-18.3	81	7.3	102.4	54.1	7	8	13	2	0.1
April	101.2	2.1	5.1	-0.9	16.7	-9.4	83	7.2	84.8	63.0	9	4	12	4	0.1
May	101.5	6.0	9.7	2.2	22.2	-5.6	81	7.3	97.3	55.6	11		12	6	0.2
June	101.4	9.9	13.9	5.9	25.0	-1.7	82	7.1	88.9	62.2	12	0	12	6	0.4
July	101.5	14.7	18.7	10.8	28.9	3.3	87	6.7	82.0	52.6	11	0	11	9	0.8
August	101.4	15.8	19.3	12.3	30.0	1.7	85	6.5	84.1	93.0	11	0	11	5	0.8
September	101.6	12.7	16.3	9.2	25.0	0.6	82	5.2	93.2	61.7	11	0	11	4	0.4
October	101.5	8.2	11.5	4.7	21.7	-3.9	82	6.5	121.4	99.1	13		13	3	0.1
November	101.4	4.4	7.2	1.6	18.3	-8.9	83	7.3	156.2	106.7	14	2	16	2	0.1
December	101.0	-0.2	2.4	-2.9	12.8	-15.0	81	8.3	141.2	64.8	9	10	16	2	0.0
Means	101.3	5.6	8.9	2.3				7.1							
Totals									1304.9		121	45	159	47	3.0

CHAPTER 2

GLACIAL PATTERNS DERIVED FROM REGIONAL TERRAIN ANALYSES

2.1 Glacial Deposits as Macroindicators of Ice Movement

2.1.1 Introduction

Because of the rugged terrain and low density of transportation routes, access to natural exposures and other sites of specific interest was limited. It is considered by the writer that in such circumstances, remotely sensed morphogenetic mapping used in conjunction with geotechnical analyses, is the most useful tool available to provide an inventory of surficial deposits and overview of glacial events. The level of detail at which such mapping should be carried out depends, to a large extent, on what is required as an end product. Lacate (1969) discussed classification, mapping units and levels of generalization for terrain evaluation, the results of which are summarized in Table 2.1. For surveys of the type being carried out on the Burin Peninsula, he recommended that the Land System be the working level for providing an initial overview and inventory of surficial deposits. Lacate defined the Land System as an area throughout which there is a recurring pattern of landforms soils and vegetation.

Fulton *et al.* (1975) add that terrain analysis should include:

1. a complete description of the form and character of the static land surface,

2. an analysis of the processes currently acting on or within the surface materials and

3. an interpretation of the Quaternary history (in addition to providing a key to the strategraphic or third dimension, this supplies information on previous processes and their rates).

For the purposes of this chapter, we will only be concerned with the first of these points, and in a very general way, the third.

Table 2.1

Surficial Mapping Hierarchy (Lacate, 1969)

Level	Unit of Classification	Practicable Scale of Mapping
Level 1	Land Region	1:1,000,000 - 1:3,000,000 or smaller
Level 2	Land District	1:500,000 - 1:1,000,000
Level 3	Land System	1:125,000 (on occasion up to 1:250,000 if landscape pattern permits)
Level 4	Land Type	1:10,000 - 1:20,000

The availability of complete air photo coverage at a scale of 1:50,000, and 1:50,000 N.T.S. sheets, was an overriding factor in the decision to map at this scale. There were several reasons for choosing 1:100,000 as the scale for final presentation. The most important was that 1:100,000 is large enough to allow one to adequately describe important surficial units, yet small enough to yield a comprehensible surface picture of past events. Secondly, 1:100,000 has become the standard scale at which surficial maps are produced by the Geological Survey of Canada and other institutes. Therefore, the Burin Peninsula maps should be compatible with others that might follow from adjoining areas.

Air photo mapping is as much an art as a science. A large part of the interpretation is subjective or intuitive. The ability to map accurately is gained largely with practise, and by becoming familiar with various types of terrain. Whether one is looking at, for example, a rock ridge, a rock-cored moraine, or a true recessional moraine will probably be determined, on the first occasion, by ground-truthing. With experience, the technique becomes less arduous, and an ability to distinguish not only geomorphic features, but also surficial deposits is developed. Because of past experience in mapping Newfoundland surficial deposits (Tucker, 1971, 1973, 1974a,b; Hornbrook *et al.*, 1975; Grant, 1975c; Grant and Tucker, 1976), it was decided to utilize a mapping scheme similar to that used on previous occasions. A detailed legend was developed, with modifications, from Fulton *et al.* (1975) and Grant (1972d). It and the surficial maps are presented in Appendix 1.

2.1.2 Definitions of Terms

i. Genetic categories

A series of general working definitions of genetic categories, modified after Fulton *et al.* (1975), is here catalogued so that the reader is aware of the parameters used in following sections.

1. Till deposits - these deposits are considered to be direct deposits of ice without intervening transportation by water but some of the *in situ* material may have had fines removed by meltwater. Till is generally unsorted to poorly sorted, unstratified to partly stratified clay, silt, sand, pebble and boulder-sized material. The uppermost till on the Burin Peninsula is sandy with minimal clay and contains subrounded to subangular cobbles and boulders. Lower till units are more variable and will be discussed in greater detail in later chapters.

2. Lacustrine deposits - silt, fine grained sand and clay, generally well washed and well stratified. They are defined as materials that have been deposited in quiet, fresh water.

3. Marine deposits - silt, sand, clay and gravel, well stratified to moderately stratified and in some places containing marine fauna. Marine deposits are laid down in salt or brackish water or are located in an area that might reasonably be considered to have contained salt water at the time of deposition formation. The division between fluvial and marine deposits presents a problem at delta fronts as deltas are built into brackish water. Therefore, the term fluvial is restricted to areas apparently cut or planed by running water; unmodified slopes and areas obviously modified by wave action are referred to as marine. Marine deposits mapped on the Burin Peninsula, are sand-gravel textured and the term generally refers to relict deposits.

4. Fluvial deposits - sand, gravel, silt and clay, well stratified and sorted to moderately stratified and sorted; detrital material laid down by running water. Fluvial deposits consist of sand and gravel and locally include washed bedrock, bouldery channel deposits and channel fillings of silt and clay.

5. Colluvial deposits - texture ranging from clay and silt to rubble and boulders, generally poorly sorted and massive to crudely stratified. They are defined as loose materials accumulated on and at the foot of slopes by various processes of mass movement other than by frost and may be derived from various parent materials, especially till and weathered rock.

6. Aeolian - is applied to all deposits arranged by wind, such as sands and other loose materials along shores, etc. Burin Peninsula aeolian deposits are confined to limited zones of reworked beach material along the south coast and several of the larger lakes.

7. Rock - is used to denote bare or moss covered bedrock and areas where near surface rock severely restricts the growth of trees.

8. Organic deposits - peat, muck and marl generally unstratified and locally containing inorganic detritus. Organic deposits are materials of organic origin which commonly accumulate in and around closed basins or on gentle slopes. Burin Peninsula bogs consist of *Sphagnum* and sedge deposits, commonly 1-4 m deep which in many places contain and interfinger with open water.

ii. Symbols

1. Drumlinoid trends - long axis orientation of drumlinoid ridges, stoss-and-lee hills, flutings and other macro features (direction of ice movement known, unknown).

2. Moraine ridge generally transverse to ice flow direction.

3. Minor moraine ridge – washboard moraine, ribbed moraine and other till ridges transverse to ice flow direction.

4. Esker ridge of glaciofluvial material (direction of flow known, unknown).

5. Kettle hole – depression formed by the melting of ice buried in glaciofluvial or glaciolacustrine material (generally not used for depressions, possibly of similar origins, in till).

6. Abandoned strandlines.

7. Escarpments in unconsolidated material, both ice contact and erosional (fluvial and marine).

2.1.3 Pattern description

Figures 2.1 is an overall synthesis of glacial patterns. It is based solely on air photo interpretation for the 1:100,000 surficial geology maps and does not attempt to depict features in great detail.

For convenience in presentation, the Burin Peninsula is best subdivided into more workable physiographic units than those discussed in Section 1.7.1. The subdivisions consist of:

1. the lower peninsula or St. Lawrence plateau, as previously described.

2. the Marystown-Garnish lowland, as previously described.

3. the upland extending roughly from Devil Brook Head to Point Enragée on the west coast and Jean de Baie to Parkers Cove on the east coast, here called the Bluff Head upland.

4. the upper Burin Peninsula stretching from Terrenceville, south to Point Enragée, northeast to the Swift Current area, east to the Placentia Bay islands and southwest along the western perimeter of Fortune Bay, here named the Terrenceville highland.

5. the northwest corner of the study area which includes the region north of the English Harbour East – Grand

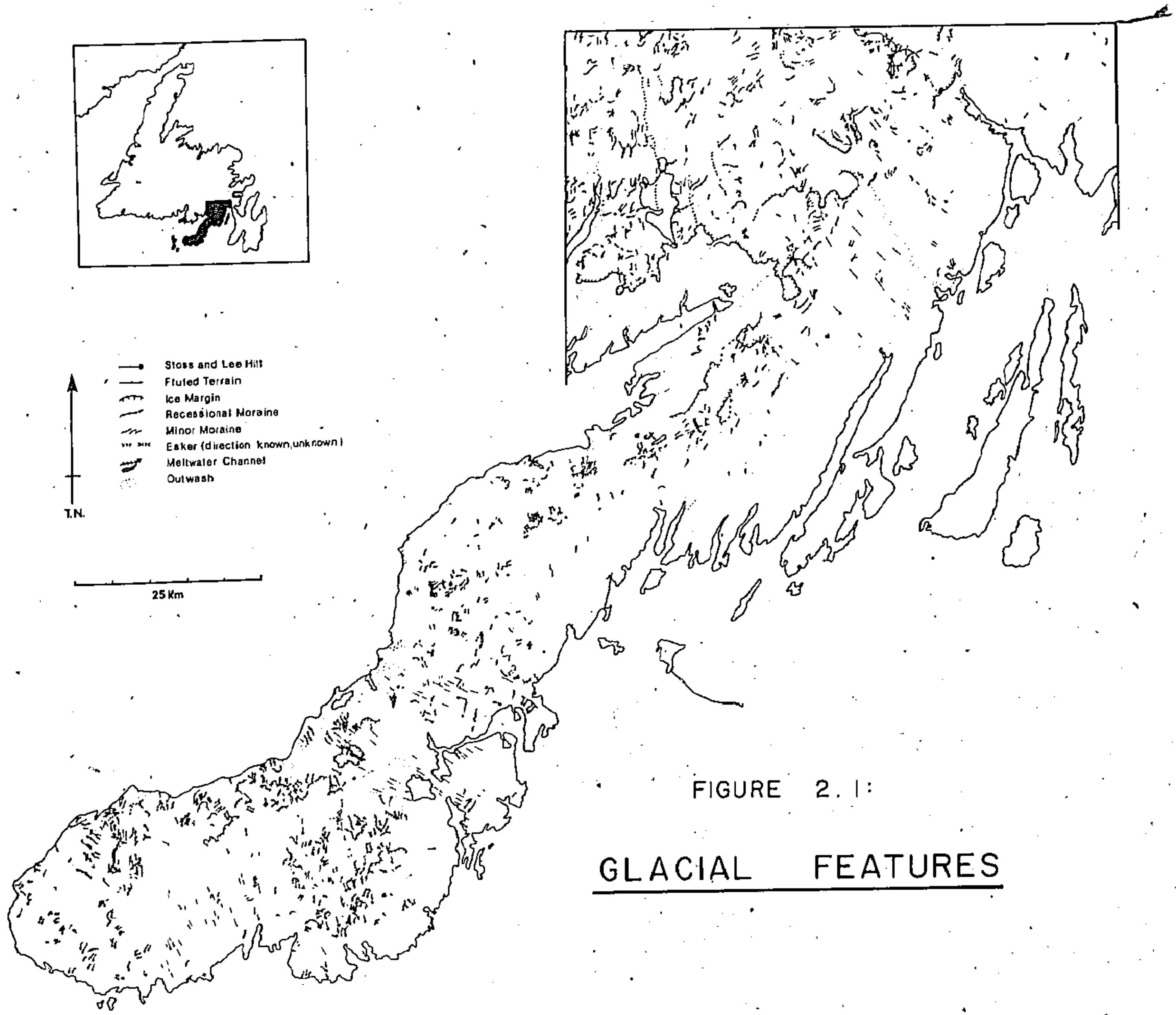


FIGURE 2.1:

GLACIAL FEATURES

le Pierre ridge, the Gisborne Lake - Long Harbour plateau and that area of land extending northwest behind an imaginary line which roughly parallels Burin Peninsula Highway 210 between the Terrenceville turn-off and the northeastern limit of the field area. The area is herein referred to as the Gisborne basin.

2.1.3.1 The St. Lawrence plateau

Former glacial flow patterns to the south and southeast are visible in the form of roches moutonnées and bedrock flutings. Peaks such as Wet Tilt Hill, Mt. St. Margaret (Fig. 2.2), Mt. St. Anne, Ryans Hill and Flaherty Hill further to the east, are major stoss-and-lee hills with streamlined, northwest oriented ramps and south to southeast facing, jagged faces. Much of the south sloping highland area above 195 m, such as the Eastern Hare Hills and Fortune Tolt, as well as the eastern perimeter between Highway 210 and Corbin, and a zone southeast of St. Lawrence, is devoid of any quantity of surficial material and has a rugged weathered appearance.

The southeast coast of the St. Lawrence plateau is characterized by substantial thicknesses of drift on its lower margins, especially at Allan's Island, Little Dantzic Cove, Dantzic Cove and along the coast southwest of Fortune. The St. Lawrence-Lawn area has a general, southerly fluting to its barren ridges and the smoothed valleys appear to be deeply infilled.

Following initial glacial flow, the dominant pattern which is superimposed on the fluted terrain, is one of ice stagnation. From a point just north of Eastern Hare Hills, north to Fortune Tolt then northeast to the Grand Beach area and southeast to Brown Ridge Pond (Fig. 2.3),

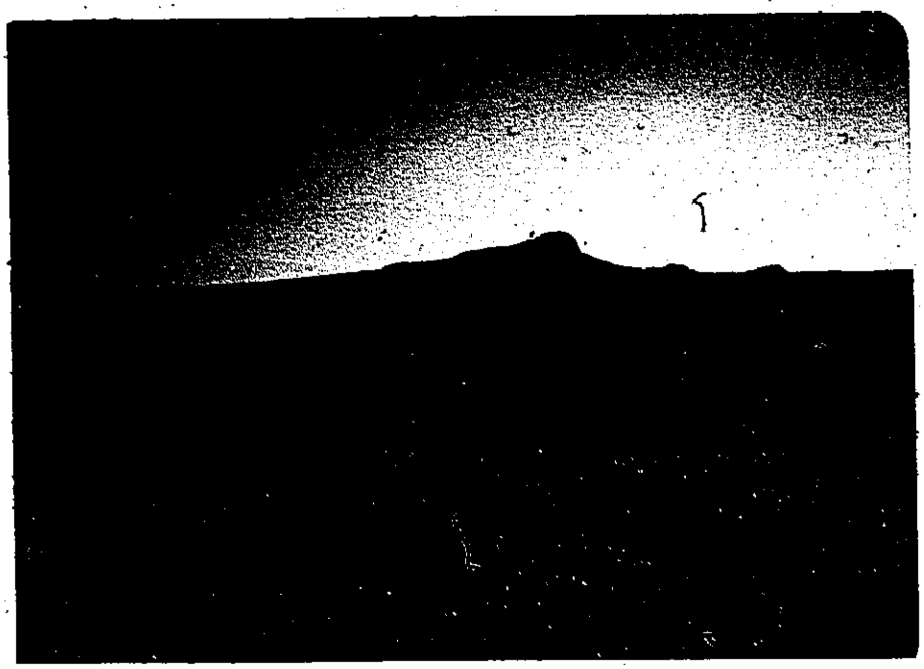


FIGURE 2.2: Mt. St. Margaret stoss-and-lee form located north of Little St. Lawrence. The 213 m a.s.l. hill was streamlined in a 175 direction by the last major ice flow to cross the Burin Peninsula from Newfoundland.

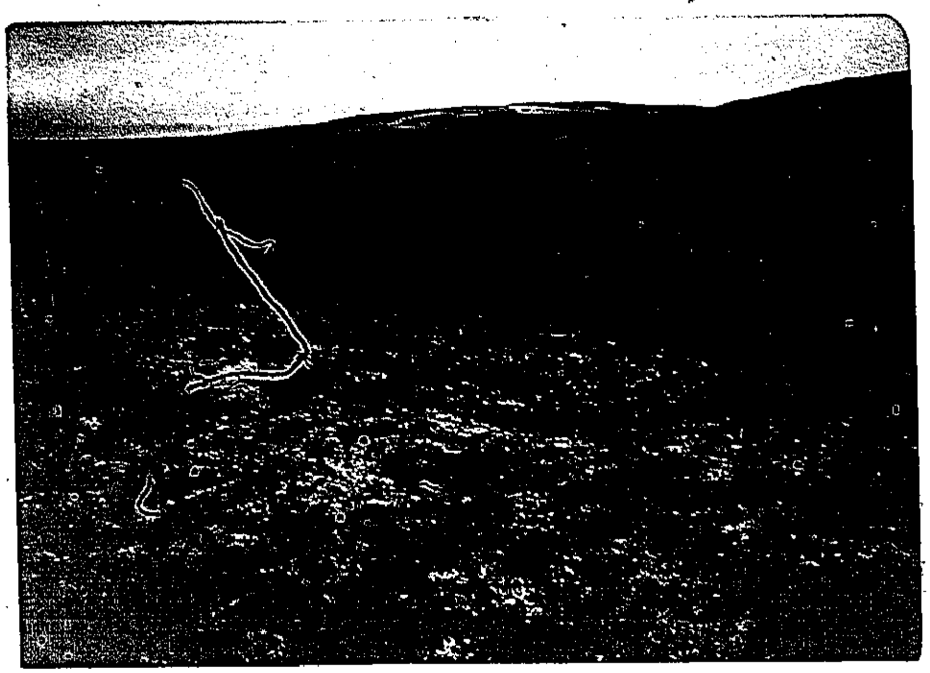


FIGURE 2.3: Dead ice terrain east of Brown Ridge Pond. Surficial deposits are washed, and highly dissected by meltwater channels. Stunted black spruce in the central foreground mark a 2 m deep channel.

the terrain is characterized by a series of recessional moraines, dissected kame terraces and ice contact drift, ablation till, and evidence of proglacial ponding. Many of the kame terraces and ice contact, proximal slopes surround weathered rocky peaks to elevations of 200-230 m in the east near Stroud's Pond and 30-135 m in the western Grand Bank-Grand Beach area. Practically without exception, the ice contact positions and kame terraces are open to the south and southeast and have an association of proglacial meltwater channels radiating away and downslope to the northwest. Many of the meltwater channels are eroded back and truncated at the coast. Separate series of meltwater channels along steeper slopes laterally mark the marginal downwasting of ice. None of these channels are above 260 m in elevation.

Several major glacial spillways were mapped on the eastern portion of the St. Lawrence plateau at points 3.5 km south and 1.5 km west of Fortune Tolt, 3 km north of Eastern Hare Hills, and also in the town of Fortune. All are about 2 km in extent and up to 180 m at their widest points. Except for the proglacial channel which flows north away from Eastern Hare Hills parallel to present drainage, the other major spillways cut across present drainage and topography to flow generally west into Fortune Bay via Fortune valley.

In the west-central and southern portion of the St. Lawrence plateau, minor recessional and terminal moraines in south facing cirques and niches mark later ice positions. Within these cirques and in positions behind the ice contact margins, there appears to have been minor proglacial ponding, however, much of the terrain is covered by thick, organic deposits and clear-cut evidence is lacking.

Glaciofluvial deposits in the form of eskers and kames are most prevalent in Fortune valley (Fig. 2.4) and north to Bennett Hill, near Grand Bank. In the Fortune area, eskers are aligned north to northeast and are present on both valley-walls. They are superimposed across valley-side kame terraces and outwash that extends ~5 km from the coast southwest in Fortune valley. Smaller, less extensive esker ridges are located in the topographic low between Wet Tilt Hill and east of Loughlin's Hill, on the south coast at Lord's Cove, and plastered on the eastern valley-wall of the upper course of Main Brook.

2.1.3.2 The Marystown-Garnish lowland

The Marystown-Garnish lowland is characterized by a south south-east fluting that extends from the barren highland east of Salt Pond and Creston Inlet, west to the Fortune Bay coast and north to Black River Pond. The northeast-trending Fox Hills-Cashel Lookout area is nearly devoid of fluted material; in fact, all drumlinoid forms on the lowland are confined to elevations of less than 100 m with the majority being located near sea level. They average 1.2 km in length, 300-400 m in width and are normally less than 20 m in height. A major rock-cored, morainal ridge is located on the isthmus northeast of Spanish Room (Fig. 2.5). It is over 2.3 km in extent, ~45 m in elevation and appears to have had ice located behind it in Jean de Baie since meltwater channels are directed southwest into Mortier Bay. The Rock Harbour Peninsula is similar to the Salt Pond-Creston Inlet highland in that it lacks any quantity of surficial cover.

The only ice contact material of significance is located in a

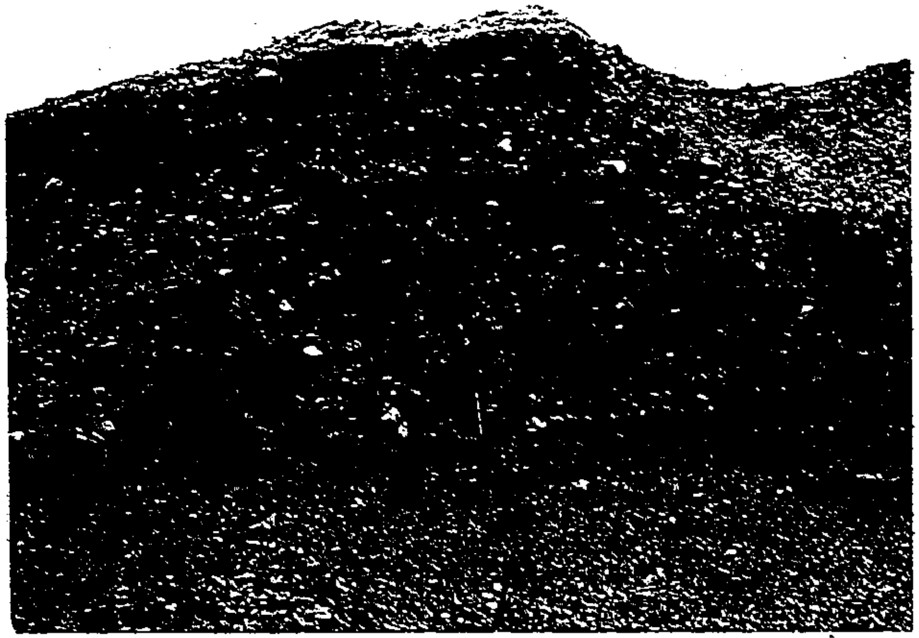


FIGURE 2.4: Fortune valley glaciofluvial deposit. Poorly sorted kame, located 2 km south of Fortune, contains a high proportion of local chlorite schist and iron stained, thinly bedded siltstone clasts. Spade is 45 cm long.

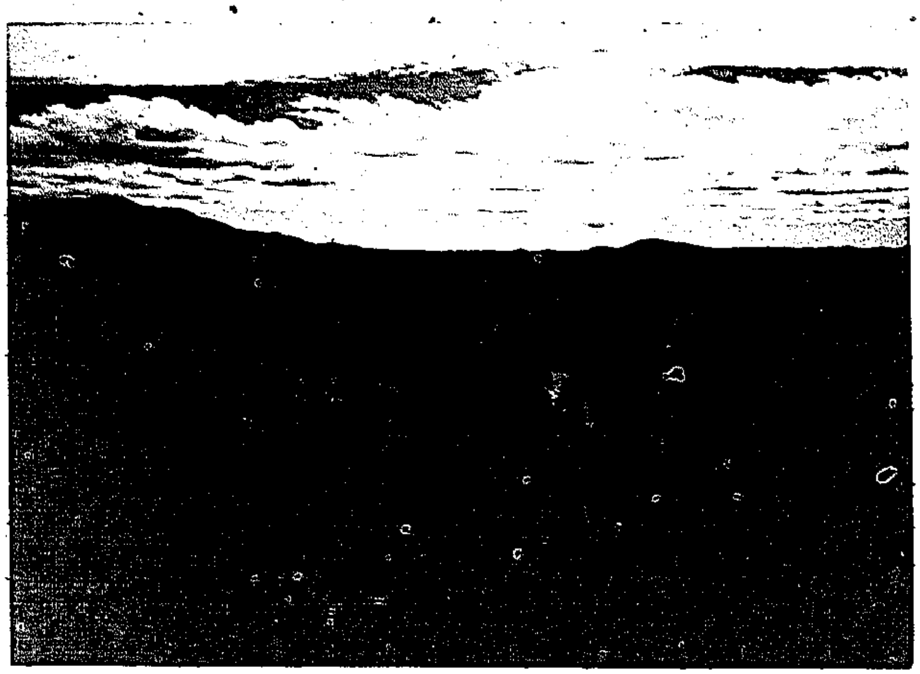


FIGURE 2.5: Spanish Room-Creephole Point rock-cored moraine, 35 m a.s.l. Photographed from the proximal side looking southeast.

zone 4-5 km southeast of Frenchman's Cove. The pattern is similar to that described for the Grand Beach to Brown Ridge Pond area. Again, ice margins are open to the southeast and meltwater channels radiate to the Fortune Bay coast. Since the features are located on the lower western perimeter of the Marystown-Garnish lowland, they can be considered as an extension of the St. Lawrence plateau ice stagnation deposits.

The majority of the terrain is below 75 m and drift cover is thick and extensive. In the west Freshwater Pond and Garnish River areas, outwash plains that appear to grade to lower sea levels extend east and west respectively. In the case of Freshwater Pond, dead-ice located east of Frenchman's Cove and on the St. Lawrence plateau was the source, while for the Garnish outwash train, ice was located in the Black Pond-Garnish Pond basin as well as to the north. Both of these ice margins are marked by small scale transverse recessional moraines, ice contact deposits and meltwater channels. The Freshwater Pond outwash train (Fig. 2.6) is very planar and is covered with extensive organic deposits. Along the lower reaches of Main Brook and on the northwest shore of Freshwater Pond, aeolian deposits are visible. These are considered to be relict and stable features. On the Fortune Bay coast, outwash has been truncated and forms a low escarpment (<10 m) between White Point and Doughball Cove.

There are few eskers or similar glaciofluvial features in the Marystown-Garnish lowland. Several small esker remnants are located near West Brook and southwest of Garnish Pond; the largest esker which trends northwest, is ~1.8 km in length and is located on the northwestern perimeter of the lowland.

FIGURE 2.6: Freshwater Pond outwash plain. Photographed from the top of ice contact material on the Winterland road looking southeast to Freshwater Pond and the St. Lawrence Plateau.

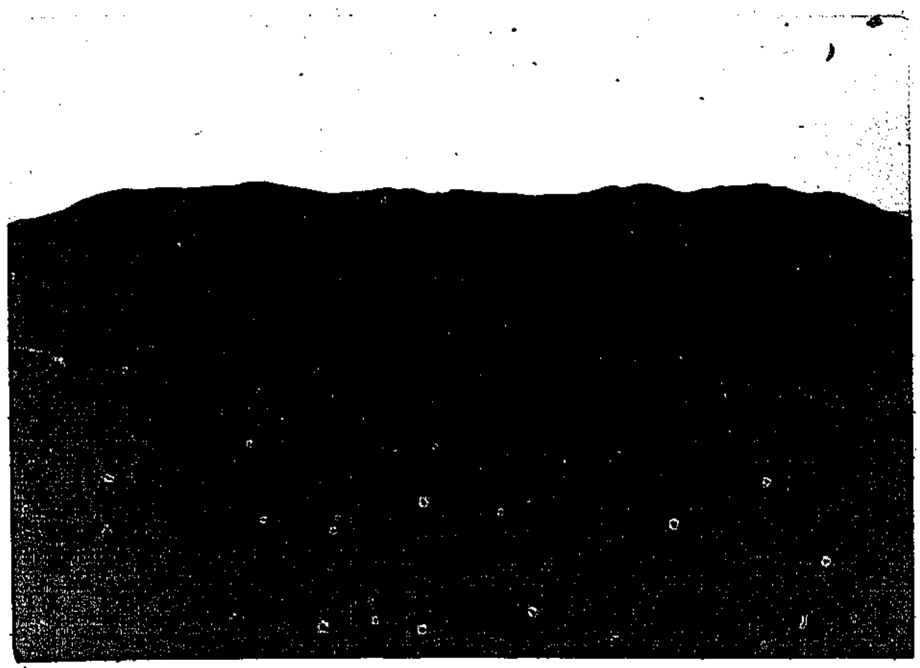


FIGURE 2.7: Broad Cove Head and till plug. Ice flow is considered to have been from the northwest. Till exposed on the southeast coast (right middleground) is compact, silty, and crenulated from overriding ice.

2.1.3.3 Bluff Head upland

This subdivision of the study area contains a minimum of glacial deposits, these being confined to the lowlands and high valleys. There is no macroexpression of ice movement across the peninsula in surficial material except at Broad Cove Head, Placentia Bay which is connected to the main peninsula by a southeast oriented plug of till that is <15 m in height and has been terraced by marine action (Fig. 2[illegible] Northeasterly trending bedrock ridges show a slight oversteepening on their south to southeast faces and an increased thickness of till veneer on the stoss or north to northeast slope. Most of the rock above 230 m is devoid of any surficial material and has a weathered, fractured appearance.

There is evidence of ice stagnation in very localized areas on the higher western portion of the Bluff Head upland, specifically near Grandfather Lookout, Pin Hill and Hare Hill. It is marked by small cirque-like ice contact kame terraces, short esker remnants following local valley trends, and meltwater channels which radiate away from the ice areas in a random pattern. Most of the channels are short, <1 km, and do not grade to any particular elevation. Surficial deposits are more extensive along the Placentia and Fortune Bay coasts. Between Jean de Baie and Baine Harbour, deeper valleys such as Red Harbour contain significant quantities of fill that has been deeply incised and ends as outwash terraces at the coast. On the Fortune Bay coast, the terrain is characterized by short outwash trains that extend <2 km inland and cover most of the lowland from Garnish to Point Enragee. The remaining higher ground is marked by a thin veneer of till that shows evidence of upward isostatic adjustment in the form of raised beaches ~15 m a.s.l. at Bluff Head, and erosional terraces in unconsolidated material at similar elevations to the north and south.

2.1.3.4 Terrenceville highland

The Terrenceville highland is marked by two significant glacial features that separate it from the Bluff Head upland and the Gisborne basin. The first is a dominant, southeast drumlinoid trend in the Paradise River and lower White Hills area. The larger drumlinoids are over 2 km in length and greater than 400 wide at their midpoints. Although the flutings exist as far south as the headwaters of Cape Roger's Brook, they are mainly concentrated in the Paradise River-Sandy Harbour River basins. The Placentia Bay islands do not have significant quantities of surficial cover; they are, for the most part, weathered, lineated rock with thin till veneer and organics caught in the depressions. Placentia Bay islands coastal zones contain thicker plugs of till that have been planed and terraced by marine action.

The second set of glacial phenomena that characterize the Terrenceville highland is a series of fjords located at Grand John Cove, Lange de Cerf Cove, Jacques Fontaine, Bay l'Argent, Terrenceville, Grand le Pierre, Pays Cove and English Harbour East (Fig. 2.8). The fjords situated on the east coast of Fortune Bay differ from those at Terrenceville and along the west coast of Fortune Bay in that they appear to have contained later ice, and as a result have ice contact material at their mouths. The Terrenceville fjord, like those at Grand le Pierre, Pays Cove and English Harbour East, was fed glaciofluvial material from upland ice. All the fjords have baymouth, erosional terraces at about 15-20 m a.s.l. At Harbour Mille, the rocky headland is connected to the main peninsula by

FIGURE 2.8: English Harbour East fjord looking south from the Terrenceville highland, 183 m a.s.l. The 18.8 m a.s.l. raised glaciomarine delta at its mouth was fed from upland sources.

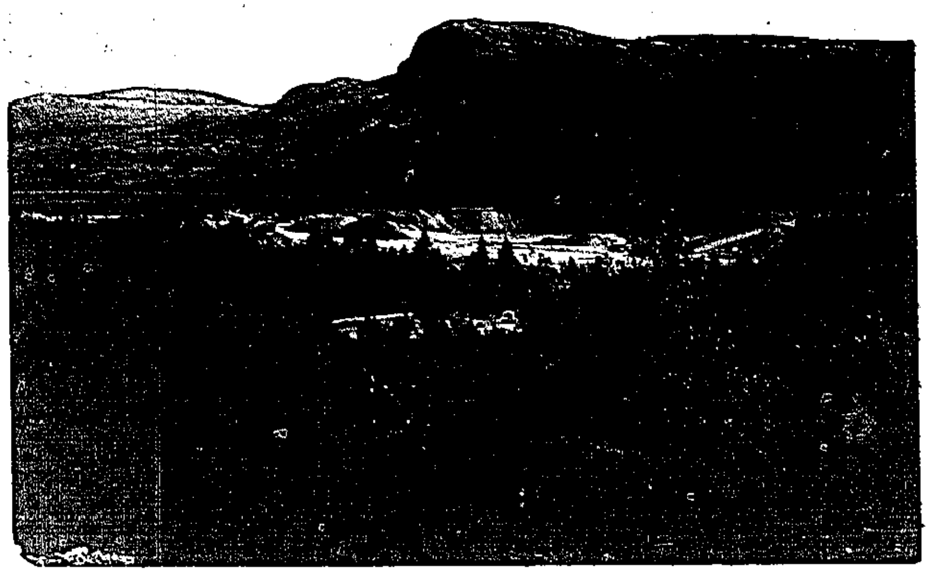


FIGURE 2.9: Swift Current outwash plain and Bears Folly. At this point, the well sorted cobble gravels are 16.7 m a.s.l., however, they grade to 8.5 m a.s.l. at the coast.

a raised tombolo of similar elevation. Along the Placentia Bay coast, all raised glaciofluvial/glaciomarine features have been derived from distant meltwater sources. This is especially visible at locations such as Bay de l'Eau, Paradise Sound, Sandy Harbour and along the north coast of Sound Island. The same holds true for the Swift Current outwash plain (Fig. 2.9), and the raised deposits at North Harbour, though in both of these instances ice was more "proximal".

About 5.6 km directly east of Bay l'Argent and Terrenceville, there is a central spine of stagnant ice material caught between two northeasterly trending bedrock ridges at elevations of <180 m. It contains a series of generally northwest-southeast trending recessional moraines, esker segments and a profusion of meltwater channels that are followed by present drainage. Two, large recessional moraines, >2 km in length and oriented northeast-southwest, are located 7 km south of the Paradise River-Dunn's Brook intersection. These appear older than the higher ice contact deposits because they are heavily masked by organic deposits, have a subdued relief, and do not have the expected, complimentary pattern of meltwater channels.

South of the Jacques Fontaine highway, the same pattern of dead ice material exists as that further north except that meltwater channels radiate north and northwest to the Grand John Point and Jacques Fontaine fjords. As in the area north of the Jacques Fontaine highway, all rock above ~180 m is weathered and devoid of surficial cover.

At Terrenceville, a postglacial bay-head bar >1.5 km long has developed to within 15 m of the opposite shore. A similar feature occurs at Grand le Pierre. Smaller bars and spits have developed locally along the upper coast of Fortune Bay and sand beaches connect rocky promontories to the mainland at Bay l'Argent and Little Bay East.

2.1.3.5 Gisborne basin

Gisborne basin contains the greatest variety and concentration of glacial features in the field area. In its centre-northernmost parts, flutings, drumlinoids and stoss-and-lee hills have a southeasterly trend while further west, north and west of Gisborne Lake, the dominant direction of glacial moulding is south.

North of the 170-300 m English Harbour East-Terrenceville range (Fig. 2.10), and northeast of Swift Current, there is a distinct boundary that marks a significant ice still-stand. It is more-or-less paralleled by Highway 210, perhaps because of the local abundance of building material. Behind the ice margin, nonsynchronous, lobate to arcuate recessional moraines up to 5 km in circumference fall back to the northwest. They are generally confined to broad, shallow valleys where ice would have been thickest. While hummocky, washed drift is almost continuous across the Gisborne basin (Fig. 2.11), it is thin and poorly vegetated; rock knobs and ridges appear regularly through the cover.

Glaciofluvial deposits in the form of eskers are frequent. They all occur northwest of the Highway 210 ice margin. The most prominent, >25 km long, forms a peninsula and two islands in Gisborne Lake and continues north to Long Harbour River. Another well preserved esker, >11 km in length, is located in Mary Ann Pond-Terrenceville Brook valley. Smaller remnants occur south of Dunn's Pond, near Paradise River and 2 km west of Bears Folly.

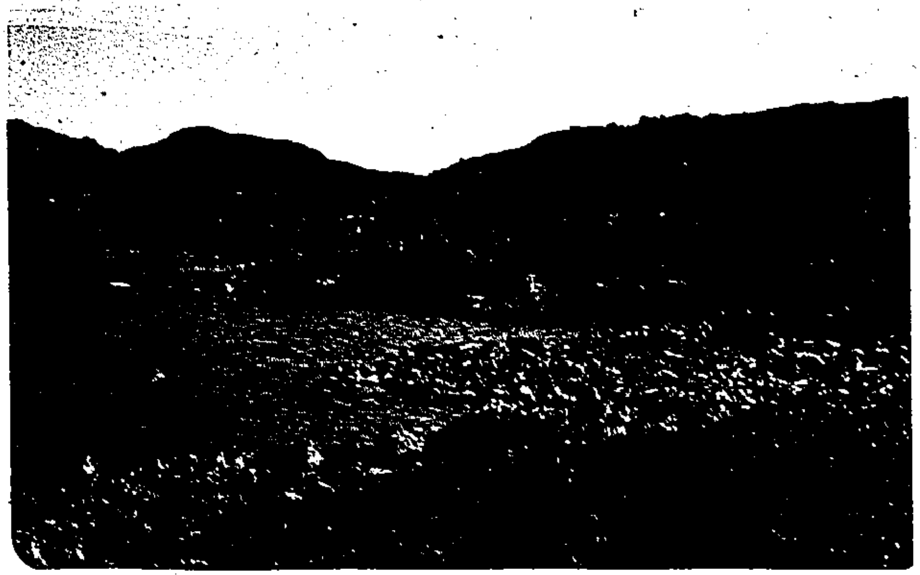


FIGURE 2.10: Grand le Pierre area, limited drift terrain. Blockfields, felsenmeer, perched erratics and organic covered basins dominate the landscape.

FIGURE 2.11: Gisborne basin, northwest of Bears Folly. The esker is within the zone of thicker drift and glaciofluvial deposits shown on the surficial maps. It is oriented ~090, with flow towards Swift Current.

Meltwater channels litter the Gisborne basin. In the western half of the area, they flow from the highlands towards Long Harbour where they have deposited glaciofluvial/glaciomarine material at the coast. Many of the channels are lateral and mark shrinking ice margins. In the centre of the area, meltwater channels follow existing and preglacial drainage and are thus oriented towards the Paradise and Sandy Harbour River basins. In the northeast, meltwater channels pour off the highlands into Piper's Hole River basin. Near Dunn's Pond at the junction of Paradise River and the Terrenceville highway intersection, as well as in the area west of Piper's Hole and Highway 210, there is distinct morphological evidence of proglacial ponding around esker ridges, hummocky moraine and ice marginal positions.

2.1.4 Discussion

The glacial patterns described above contain several significant points that bear discussion. In brief, an initial ice flow across the peninsula from Newfoundland has, to a certain extent, been verified. The southeasterly pattern of fluted till and drumlinoid forms is, however, confined to the Marystown-Garnish lowland and the Paradise River-White Hills area on the Terrenceville upland. This may be taken as evidence that ice flow was strongest through the depressions or, perhaps, that the earlier ice continued to flow here after it had cleared the highlands. The former suggestion is more in agreement with the ideas put forward by Shaw (1975), who stated that a relationship between topography and fluting trend illustrates that, at the time of fluting formation, the ice was relatively thin so that its flow direction was controlled by topography. In the northwest Gisborne Lake area, drumlinoids have a more southerly orientation. This suggests that they are not contemporaneous with the flutings just mentioned but instead relate to the Gisborne basin ice stand when flow would have been directed more towards Fortune Bay than across the Burin Peninsula.

The second feature of note is the position of major stagnant ice margins or still-stands on the St. Lawrence plateau, the Terrenceville highland and the Gisborne basin. On the St. Lawrence plateau, the perimeter of the ice margin is open to the south and southeast indicating that at some point ice was centred offshore in Placentia Bay. This is in general agreement with the findings of Grant (1975c), though at this stage, its chronological position (late-Wisconsinan, Grant (1975c) or earlier Wisconsinan, Grant (1977b)) is not clear. The ice margin identified along the central depression of the Terrenceville upland and in the Gisborne basin is similar to that described by Widmer (1950), Jenness (1960, 1963), and Grant (1977b), though its position varies in extent and refinement from that shown by previous studies. It is superimposed atop southeasterly directed flow features and represents a major stillstand. Its complete significance will be discussed at a later point.

Glaciofluvial/glaciomarine deposits along the upper coasts of Placentia and Fortune Bays appear to be contemporaneous with this Gisborne Lake-Terrenceville ice stand. Glaciofluvial material located on the Fortune Bay coast from Bluff Head to Point Enragée was emplaced prior to that around upper Fortune and Placentia Bays. This conclusion is drawn from the fact that series of raised beaches and terraces are cut in deposits which appear to grade to a lower sea level. This is similar to a situation that exists at Eastport, Bonavista Bay (Jenness, 1960, 1963; Dyke, 1972). The air photo analysis does not provide clear evidence of the time at which outwash was deposited on the Garnish or Freshwater Pond areas of the Marystown-Garnish lowland except that it was contemporaneous with stagnant ice deposits on the St. Lawrence plateau.

2.2 Glacial Striae as Microindicators of Ice Movement

2.2.1 Introduction

The most common and conspicuous unit of glacial abrasion is the striation (stria or scratch). Flint (1971) was of the opinion that as individual features, they are of very limited value as direction indicators of ice movement. He considered that most striae that have been mapped were made near glacier margins during deglaciation and, therefore, do not indicate the directions of flow that characterized glacial expansion. Nevertheless, comprehensive studies of large groups of striae, especially where combined with the measurement of other directional indicators, have proved successful in this regard. One of the more recent investigations to document the glacial history of an area by means of striae was carried out on the Shetland Islands by Hoppe (1974). He emphasized that in places like Shetland, where ice may have moved in one direction or the opposite, the determination of the sense of movement is of fundamental importance. Hoppe decided the sense of movement by observing the direction of plucking at joints and the orientation of crescentic marks and gouges. Flint (1971) has provided a comprehensive summary of the methodology by which the sense of direction of ice movement may be determined from striated outcrops and the reader is referred to relevant sections (pp.88-106) for more detail. In essence, the process involves determining the down-ice direction from miniature crag-and-tail or rat tail forms, crescentic gouges, lunate fractures, crescentic fractures, chatter marks, stoss-and-lee forms, and bevelled surfaces.

Previous studies on the Burin Peninsula have made use of striae patterns to detail glacial events. Both Van Alstine (1948) and Walthier (1948) mentioned northwest directed striae on the lower Burin Peninsula near the town of Burin, on the ridge east of Hamilton Brook, and near Fortune Brook. Jenness (1960) published one of the first compilations of striae for Newfoundland. He showed (after Bradley, 1954) two ice directions near Terrenceville; one southeast across the peninsula and another southwest down Terrenceville Brook valley. However, no chronological significance is attached to their orientations. Grant (1975c) described a bevelled, iron stained and weathered surface with striae and miniature crag-and-tail forms pointing south-southeast. It is truncated by a second west and north-stossed facet that is fresh and unstained. He used this evidence to hypothesize ice-free periods during the Wisconsinan stades.

Based on the above reports, a complete record of striae, amounting to some 300+ measurements, was obtained over the two field seasons. For convenience they are summarized in Fig. 2.12. In all cases, bevelled surfaces, crag-and-tail, crescentic marks, superposition, and weathering were used to determine the orientation and sense of direction. Only those for which the sense of direction could accurately be determined were recorded.

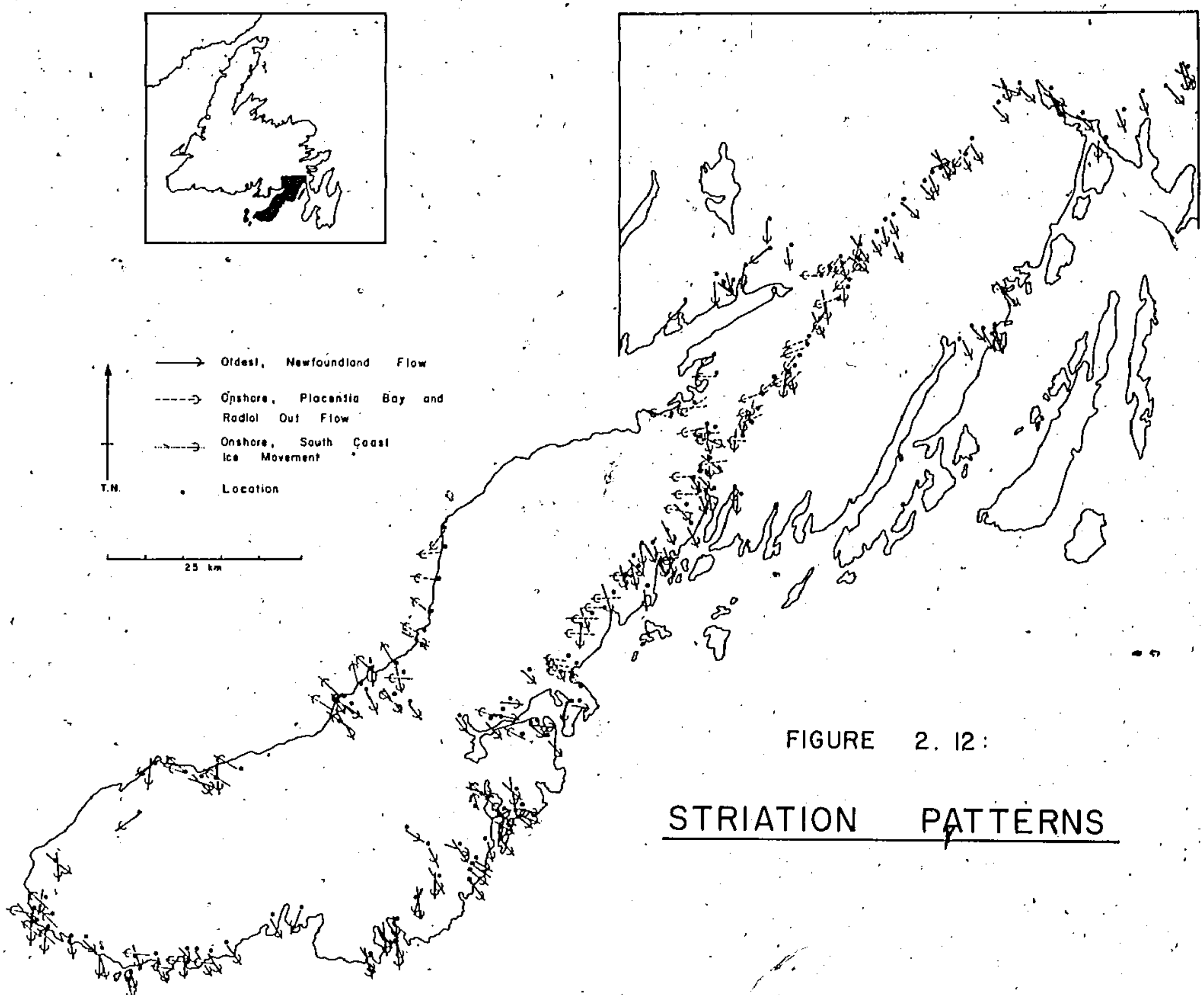


FIGURE 2.12:

STRIATION PATTERNS

2.2.2 Pattern discussion

On the northeastern corner of the Terrenceville upland, striae follow a 130-150 orientation and are not crossed by later flow directions. One anomalous exception occurs just south of Long Pond, 1M/16. Stained, deep 220 grooves are cut by dominant 145-directed striae; hence, the 200 direction represents an earlier flow. The situation may represent a late, thinner phase of an early flow that was modified by the White Hills barrier 4 km to the east. Less than 3.5 km north of this site, 145 striae are followed by a 070-oriented p-form which may have been cut during a late glacial stage when erratic changes in ice pressure and increased volumes of meltwater would have caused a more random and divergent orientation in ice flow forms. The geneses of various p-forms have been described in detail by Gjessing (1965) and Dahl (1965). Gjessing was of the opinion that variable ice pressure in conjunction with water-soaked ground moraine is the most important criterion in their formation while Dahl preferred meltwater. Both authors, however, considered the forms to be late glacial in origin.

In the Terrenceville junction area, 1M/10, a well documented series of striae record a different set of ice flow conditions; 130-145 striae, grooves and crag-and-tail are followed by a 205-250-oriented flow towards Terrenceville. Weathering and stain on both these bevelled surfaces is slight. Striae recorded south along Highway 210 repeat similar orientations. One of the most distinctive sets of striae was measured near the highway, 6.7 km southeast of Jacques Fontaine (Fig. 2.13). Profoundly stained and weathered facets with pitted grooves and striae oriented at 125 and 155 are cut by a fresh, highly polished facet on which

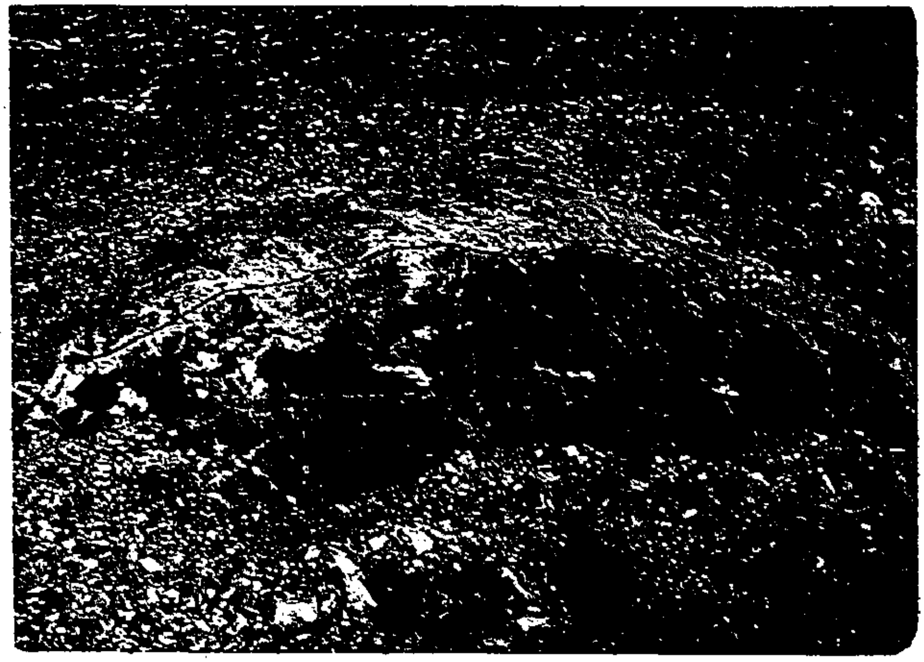


FIGURE 2.13: Bay l'Argent highway. Highly weathered and iron stained facet showing 125 and 155 striae which is cut by a later 270-directed flow.

FIGURE 2.14: Rushoon. Weathered and iron stained 150-oriented grooves and striae (indicated by pen) are cut by later, onshore - directed 290 striae (Brunton).

sharp, clean striae and miniature crag-and-tail directed 270 are found. These outcrops, more so than the Terrenceville examples, indicate that a period of intense subaerial weathering occurred between the two events. While it might be possible to suggest that the 270 striae were a result of late, upland ice pouring radially off the plateau towards Fortune Bay, slightly weathered 135-165 striae followed by 260-280 striae were continually recorded along the highway from the Bay l'Argent intersection to Jean de Baie and at coastal localities from Baine Harbour, south (Fig. 2.14). This suggests that an ice mass was centred somewhere east of the present Placentia Bay coast after the main south and southeast movement from Newfoundland. Whether the later, west and southwest flow represented an eastward shift in the ice dispersal centre or was a major push influenced by Avalon ice is not clear at this point. Striae recorded along the upper Fortune Bay coast are usually perpendicular to the coast line and record movement down valleys as Burin Peninsula ice collapsed and cleared highland areas. For the most part, it is impossible to put these striae in any chronological rank since they are not highly weathered. However, one outcrop located at Devil Brook Head, north of Garnish, 1M/6, shows weathered 120 striae followed by a clean 305 set. This indicates that a period of weathering intervened between the events.

The lower Burin Peninsula, which here includes the St. Lawrence plateau and the Marystown-Garnish lowland, shows an initial 120-170-directed flow. At Tumbling Head, west of Grand Bank, 1M/4, one set of striae oriented 230 were measured. The situation appears anomalous and may represent a localized deviation in the earliest onshore flow from Newfoundland. No similar striae were recorded in the vicinity. On the lower southwest coast as far east as Lord's Cove and as well in the Burin Inlet area, the 120-170 flow is followed by an onshore 310-320 push. Similar 310, cutting weathered 140-170 striae are found on the Fortune Bay coast from Grand Bank north to Frenchman's Cove (Fig. 2.15). Again, the exact extent and nature of the onshore-moving ice is not clear from the striae patterns. It may have been that the west coast Placentia Bay push and the offshore south coast push were contemporaneous and that flow was modified by topographic variations of the Burin Peninsula. But based on the high degree of weathering shown by some of the 120-170 facets on the lower peninsula, the 310-directed ice might have cleared this area prior to the 260-280 flow which affected the west Placentia Bay coast.

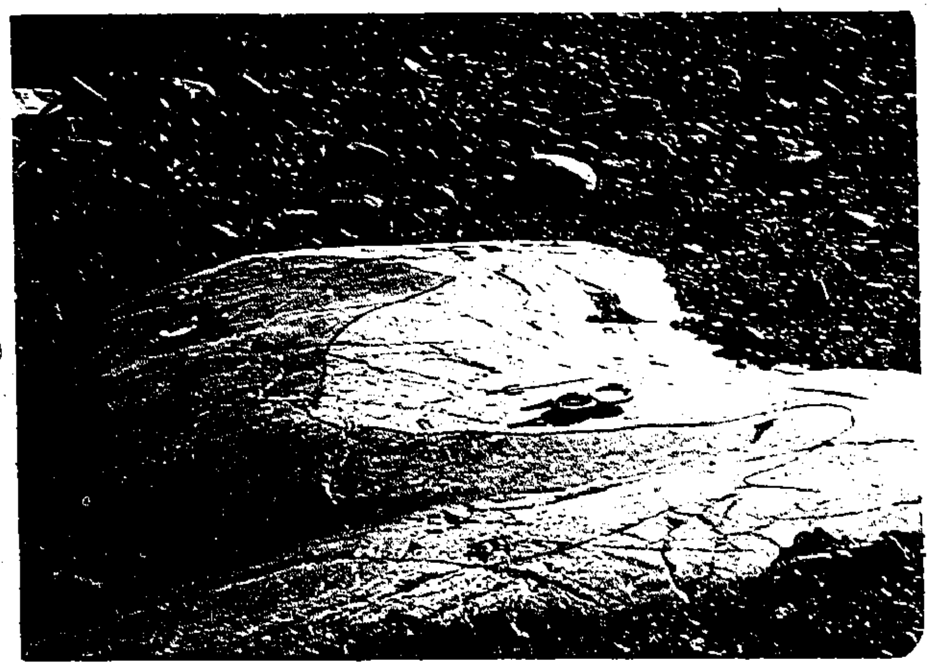


FIGURE 2.15: Near White Point on highway 210. Stained and weathered 125 directed striae and grooves are cut by fresher, 310 oriented striae. The differences in the degree of weathering between the two facets is taken to indicate that a significant period of ice free conditions existed between two separate glacial events.

CHAPTER 3

GLACIAL DEPOSITS AND EVENTS

3.1 Introduction

The purpose of this chapter is to describe and correlate the glacial deposits discovered at various coastal and inland sites throughout the field area. Some are mentioned in the literature, but most were discovered during the airphoto analysis and reconnaissance traverses carried out early in the first field season. Several analytical techniques were applied during these investigations and a considerable body of three dimensional (area x depth) data was collected. The analyses are divisible into field and laboratory components. On-site work consisted of obtaining detailed measurements from the various stratigraphic units, searching for datable material, and collecting 2 kg samples of each sediment type for later analyses. It also included the following:

1. Till fabric analyses - Each fabric consisted of orientation and dip measurements on 50 clasts with long and short axes in the approximate ratios of 2.5 to 1. Polar equidistant projection plots were completed in the field. Statistical calculations were applied to data from 20 sites and are catalogued in Appendix 4. The results are expressed in the text in terms of primary mode, moment mean, hereafter called mean, and standard deviation.

2. Gamma-ray detection study - A broadband (or total count) gamma ray scintillometer was used to measure background (thick overburden) radiation and point-specific radiation at certain sites. From a study of past research in the area and initial field investigations it became clear that some question existed as to whether certain deposits were "old"

till remnants or highly weathered bedrock. A comparison of the background radiation and that of the underlying bedrock with known bedrock sources that appear similar (i.e., weathered conglomerate) to the questionable surficial units, was able to provide some measure on the relative age of the material.

Laboratory analyses consisted of:

1. Till clast provenance study - Clasts up to 2.5-3.0 cm in diameter that were retained on a $-4\ \phi$ sieve were coded for bedrock source and based on percentages of a given bedrock type contained in the sample, general directions of transport were determined. Complete descriptions are contained in Appendix 2 and the reader is referred to it for details not contained in the text.

2. Grain size analyses - A total of 52 matrix samples from various environments were analyzed from $-4\ \phi$ to $9\ \phi$ following standard techniques. The results were tabulated and run through a computer program developed at the Atlantic Geoscience Centre, Dartmouth, N.S., which plotted cumulative frequency curves and calculated, where applicable, the mean, median, sorting, skewness and kurtosis following Inman (1952) and Folk (1968) methods (Appendix 3). Unless stated otherwise, statistical parameters used in the text are those of Folk (1968).

3. Trace element studies - These were completed on samples from three sites. Following a hot, two hour HNO_3-HCl mixed acid leach, the $<8\ \phi$ fractions were analyzed following atomic absorption fluorimetric methods at laboratories of the Geological Survey of Canada under the direction of Dr. W.W. Shilts. Results are tabulated and discussed herein.

4. Certain stratigraphic sections contained highly sorted, marine and/or fluvial material located below till units. Following preliminary separations and analysis by the writer, detailed identifications of foraminifera and diatoms were completed respectively by Dr. G. Vilks, Atlantic Geoscience Centre, Dartmouth, and Dr. S. Lichti-Federovich, Geological Survey of Canada, Ottawa.

Organization of information on glacial deposits might logically take any one of a number of approaches, but for the purposes of this dissertation, it has been decided to follow a locational organization, i.e., a methodical description and analysis of individual sites, starting on the southwest coast of the Burin Peninsula and following through to the northeast corner of the field area. To ease the task of locational correlation for the reader, site descriptions have been presented in three physiographic subdivisions; the lower Burin Peninsula, which may also be referred to as the St. Lawrence plateau, the Marystown-Garnish lowland, and the upper Burin Peninsula. This method is advantageous since it allows a relatively unbiased presentation of various data which may then be discussed and linked chronologically. While more than 260 site descriptions were obtained over the course of the field work, only those that were deemed significant in unravelling the Quaternary chronology of the Burin are presented in this chapter (Fig. 3.1). Random site analyses that were used as baseline data for the morphogenetic mapping are included in the various appendices.

3.2 Site Descriptions of the Lower Burin Peninsula

3.2.1 Dantzic Cove, 1L/13

Dantzic Cove (Fig. 3.2), which contains one of the most diagnostic stratigraphic sections on the Burin Peninsula, is located on the Fortune Bay coast 9 km north-northwest of Point May. On the basis of reconnaissance field work by the present writer, Grant (1975c) mentioned the existence of stratified sediment under till. Vanderveer (1977) identified the valley fill as a raised glaciofluvial delta. The stratigraphy is more complex than either of these reports suggest. The total section is about 37-45 m in height, 1.4 km in lateral extent and contains three units

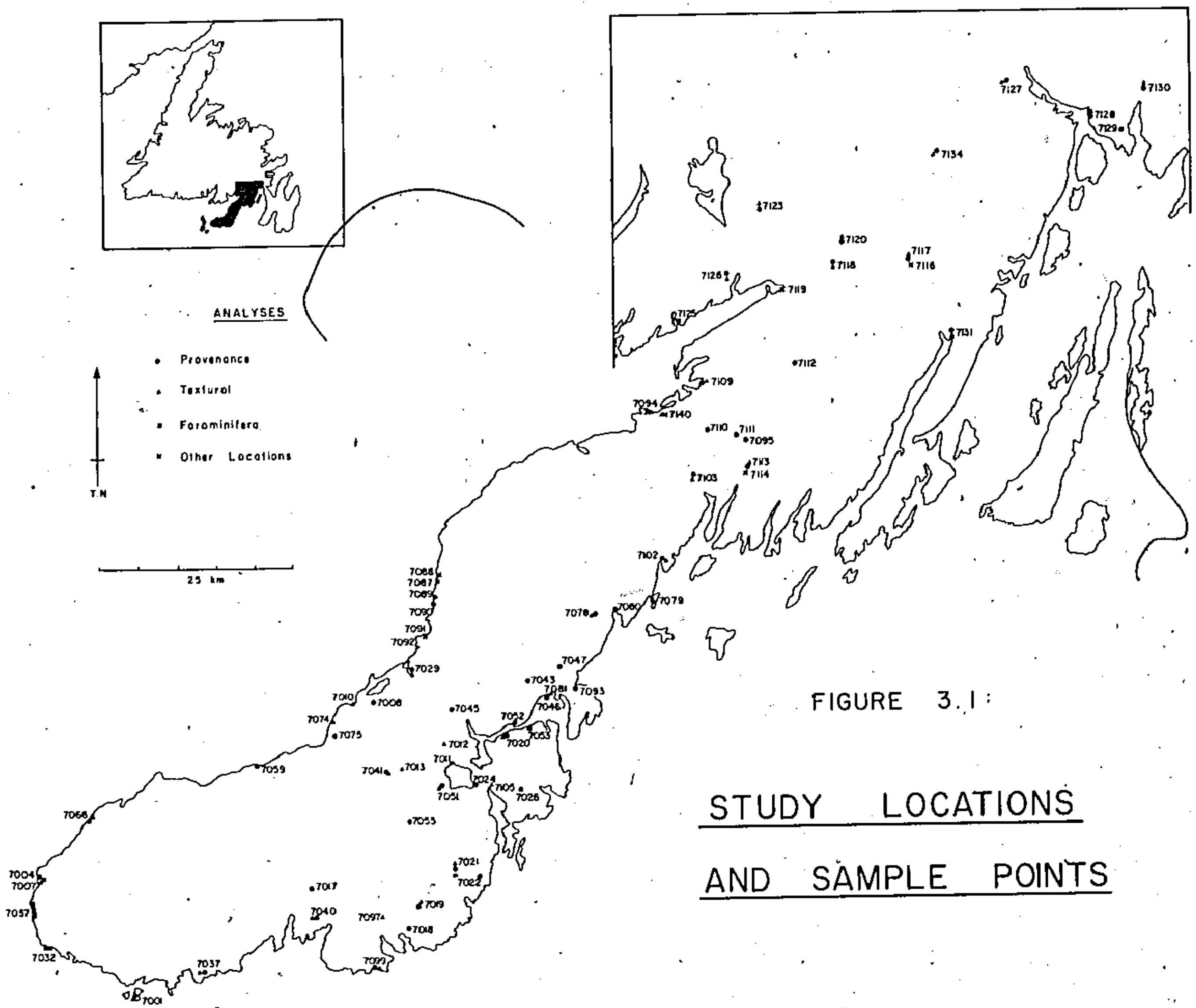


FIGURE 3.1:

STUDY LOCATIONS AND SAMPLE POINTS

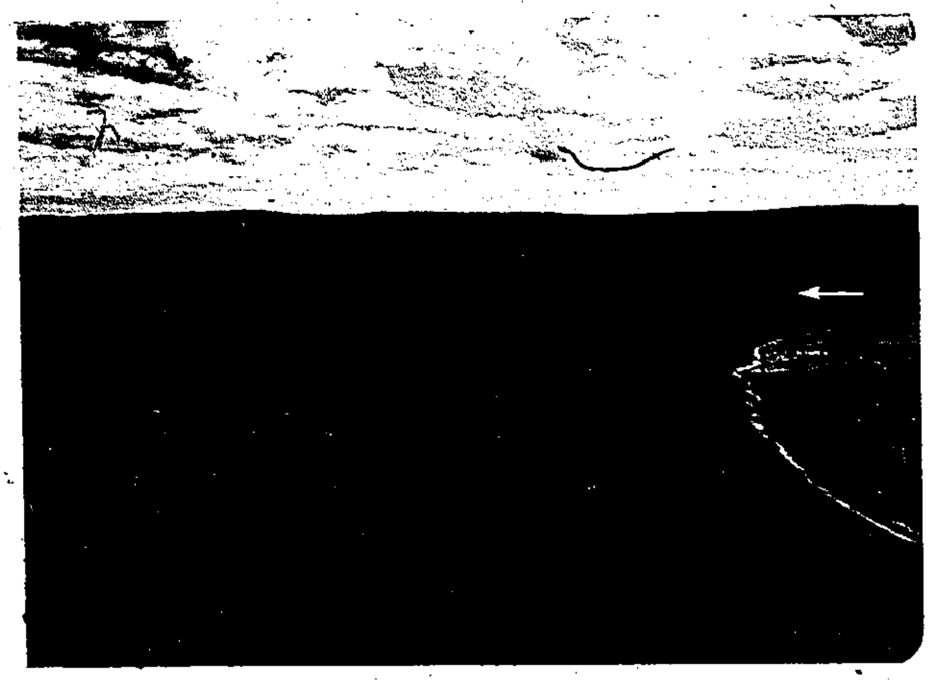


FIGURE 3.2: Dantzic Cove section. Contact between the lower, very compact, pink-grey, silty till and the upper, light brown, sandy till is shown by the arrow in the distant foreground.

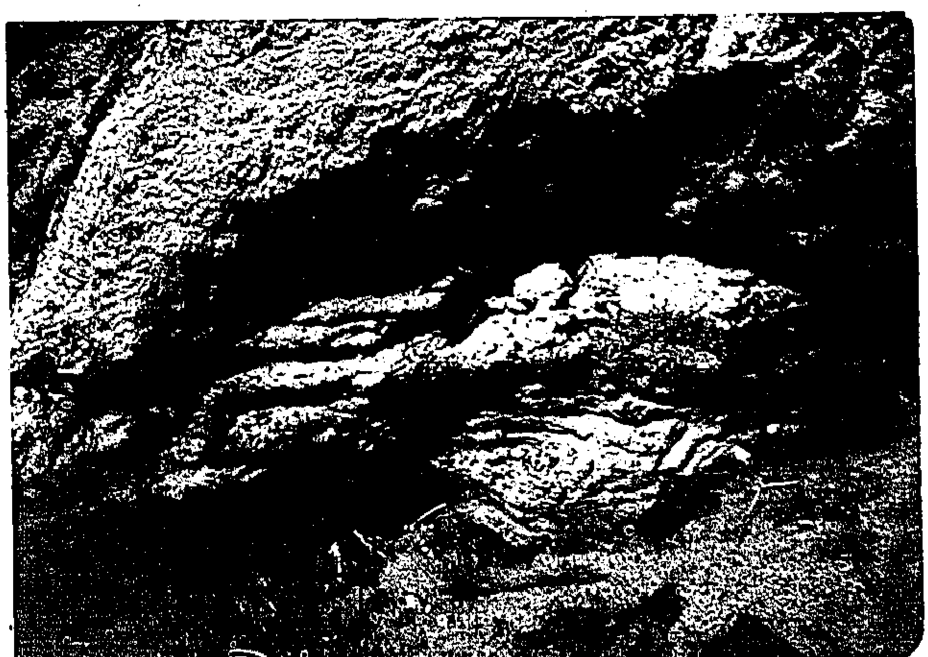


FIGURE 3.6: Allan's Island, cross-bedded marine sand. Located between a lower, silty, compact till and an upper pink-brown, sandy till. Similar to the marine sand unit at Dantzic Cove.

(Fig. 3.3); a lower, very compact, pink-grey till with a matrix primary mode in the fine sand class and a secondary mode in the coarse silt fraction, a unit of post-depositionally faulted, small scale planar, cross-bedded,very fine sand containing benthonic foraminifera (Table 3.1), and an upper, light brown, sub-stratified, sandy till. On the basis of their relative abundance, Vilks (pers. comm.) considered that the foraminifera indicate a paleoenvironment with inner shelf-marginal marine conditions, that is to say, an estuarine bay with a salt wedge. Estuarine circulation would explain the absence of planktonic foraminifera since the surface waters would have been brackish. Two forms, *Glabratella sp.* and *Bulimina sp.*, suggest sediments older than Holocene.

It is difficult to record elevations for the deposits since much of the material, especially the marine unit (Fig. 3.3), is exposed in a rotational slump. However, the boundary between the upper and lower tills is marked by a piezometric surface which occurs at ~37 m on the north edge of the exposure and slopes gently to the south. Provenance studies (Appendix 2) were completed on both tills. The lower unit (Sample 7004a) contains subrounded to subangular clasts 10-15 cm in diameter of which 7% are coarse grained, Carboniferous granite and 21% Carboniferous and earlier, brown to red sandstone. Both of these rock types, while occurring locally, may also be indicative of transport from the northwest coast of Fortune Bay. The upper, sandy till unit (Sample 7004c) contains Cambrian quartzite and Precambrian, grey and green siltstone as its major constituents. Clasts are more rounded in this unit and appear diagnostic of local transport from the east. Since the bedrock units trend northeast-southwest, it is difficult to suggest a northwest directed ice flow on the basis of

TABLE 3.1

Foraminifera Suites
Burin Peninsula, Newfoundland - St. Pierre et Miqueton
(Vilks, pers. comm.)

SPECIES	7-004B	7-121B	7129	M7002B	M7002E	Wagner (1977) 38 K.B.P.	PALEOENVIRONMENT*
Astrononion gallowayi	x	x		x	x	x	arctic, cold water
Bolivina pseudopunctata					x	x	silty, nearshore abyssal
Bolivina pseudoplicata		x				x	open water
Bolivina subaenariensis					x	x	open water
Bolivina spatulata	x	x	x			x	open water
Buccella frigida	x			x			nearshore, open bay
Bulimina sp.	x						ancient, nearshore - abyssal
Bulimina aculeata					x	x	ancient, nearshore - abyssal
Bulimina cf. gibba				x			ancient, nearshore - abyssal
Cassidella complanata		x			x		deep water, outer shelf
Cibicides concentricus						x	sandy nearshore - abyssal
Cibicides lobatulus	x	x		x	x	x	sandy nearshore
Elphidium barletti	x						low saline, shallow water
Elphidium clavatum	x	x	x	x	x	x	low saline, shallow water
Elphidium Subarcticum				x		x	low saline, shallow water
Elphidium oregonense				x			low saline, shallow water
Eoponidella pulchella					x	x	low saline, lagoonal
Epistominella takayanagii					x		bathyal zone, shelf edge
Eponides tenera			x				sandy, nearshore - abyssal
Eponides sp.		x					sandy, nearshore - abyssal
Fissurina marginata	x			x	x	x	bathyal - outer shelf

TABLE 3.1 (cont'd)

SPECIES	SAMPLE NUMBER 7-004B	7-121B	7129	M7002B	M7002E	Wagner (1977) 38 K.B.P.	PALEOENVIRONMENT*
Glabratella wrightii	x		x		x	x	ancient, nearshore
Globigerina quinqueloba		x					cold water, marine nearshore
Islandiella islandica	x	x	x	x	x	x	low saline, shallow water
Islandiella norcrossi				x	x	x	low saline, shallow water
Islandiella Teretis		x	x				low saline, shallow water
Lagena striata		x					clay, nearshore - abyssal
Neogloboboquadrina pachyderma		x	x		x	x	arctic
nonionello auriculata		x	x	x	x		sandy, nearshore - bathyal
Ooolina borealis	x			x		x	temperate, nearshore - bathyal
Protelphidium orbiculare	x	x		x	x	x	low saline
Rosalina sp.					x		sandy coastal
Trifarina fluens			x	x	x	x	nearshore - bathyal
Virgulina fusiformis		x			x	x	nearshore - abyssal
Virgulina schreibersiana					x		nearshore - abyssal

* Additional foraminifera paleoenvironments after Galloway (1933).

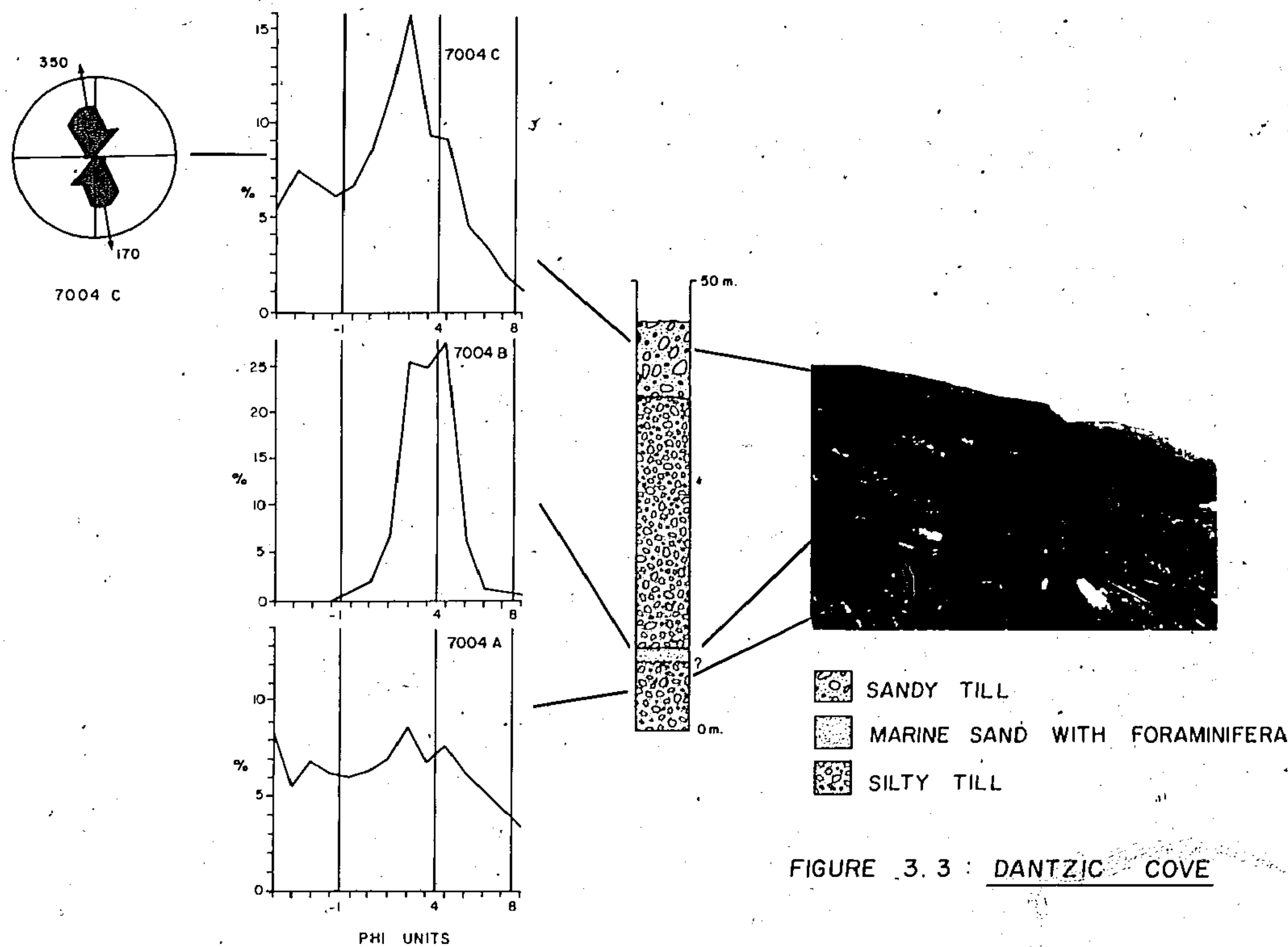


FIGURE 3.3 : DANTZIC COVE

clast provenance.

A till fabric obtained approximately 6 m from the top of the exposure exhibits a primary mode at 350 and a mean oriented 350-170 with a standard deviation of 34°. A weak secondary mode occurs at 040, transverse to the primary mode (Appendix 4).

3.2.2 Little Dantzic Cove, 1L/13

The coastal exposures at Little Dantzic Cove, which is located 3 km south of Dantzic Cove, exhibit two stratigraphic units (Fig. 3.4). A lower, compact, grey stoney till, 13.3 m thick, is overlain by 5.9 m of loose, light brown till of which the bottom 2 m is iron stained. The lower unit (Sample 7057a) has a mean matrix size of .56 ϕ while the upper unit (Sample 7057b) mean occurs at 3.55 ϕ. Till fabrics of the two units are not particularly diagnostic; the lower shows a primary mode at 020 with a secondary mode oriented 060 and a mean of 050-230. The fabric of the upper till has a mean orientation of 295-115 but it is not strongly directed. Clast identification of the lower unit reveals a high proportion of local material and a small amount of vesicular basalt that may indicate transport from the Hermitage Peninsula. The upper till unit, again, shows a predominance of local rock types. A source area to the east is indicated by Proterozoic conglomerates and breccias, however, the presence of 9% undifferentiated granite in the sample may be taken as indicating transport from either east or northwest.

3.2.3 Allan's Island, 1L/13

Allan's Island is located off the southeast tip of the Burin

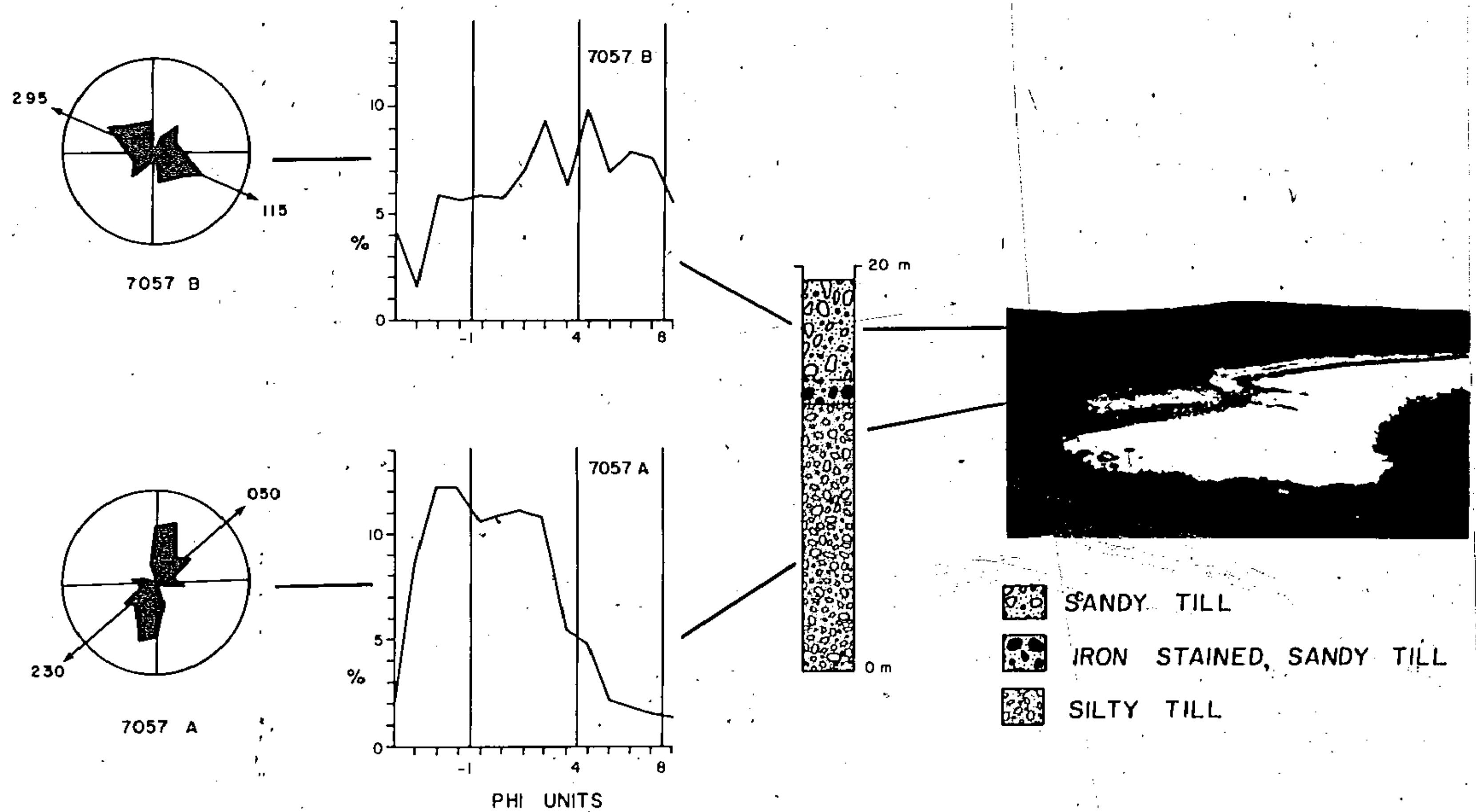


FIGURE 3.4 : LITTLE DANTZIC COVE

Peninsula and is connected to the mainland by a causeway. The east coast of the island would have been in the lee of an onshore-directed ice movement, as was discussed in Chapter 2, and it is here that the thickest surficial deposits are located. The section reveals a stratigraphy similar to that at Dantzic Cove, i.e., a lower, compact till separated from a loose,upper till by faulted and slumped sand. As at Dantzic Cove, the various units are not well exposed and recorded thicknesses are approximate. The deposits (Fig. 3.5) overly a marine bench 3.3 m a.s.l. The lower, grey-pink, sandy, silty till has a major portion of the matrix in the fine sand and coarse silt categories. At 14.1 m a.s.l. there is a block of faulted, cross-bedded, buff-yellow sand (Fig. 3.6) with sorting similar to that of the Dantzic Cove unit (Sample 7004b, Fig. 3.3). However, no marine fauna were discovered in the sample examined. Above the sand unit, from 18.2-21.5 m, is a pink-brown, coarse sand till which has a mean grain size of 0.88 ϕ.

Provenance study of this unit was generally inconclusive except for southward (and southeastward?) transport of Carboniferous granite and granodiorite. A sample of the lower till (Sample 7001a), obtained from a point 3.5 m a.s.l., showed dominant transport from the northwest of Eocambrian to Cambrian, red, micaceous sandstone and Late Protecozoic rhyolite flows. A fabric analysis conducted on the upper till revealed a primary mode oriented 080 with a mean direction of 075-265. Strong secondary modes occur at 040 and 140 indicating that the clasts are not well oriented; this is characteristic of loose, well sorted tills in the area.

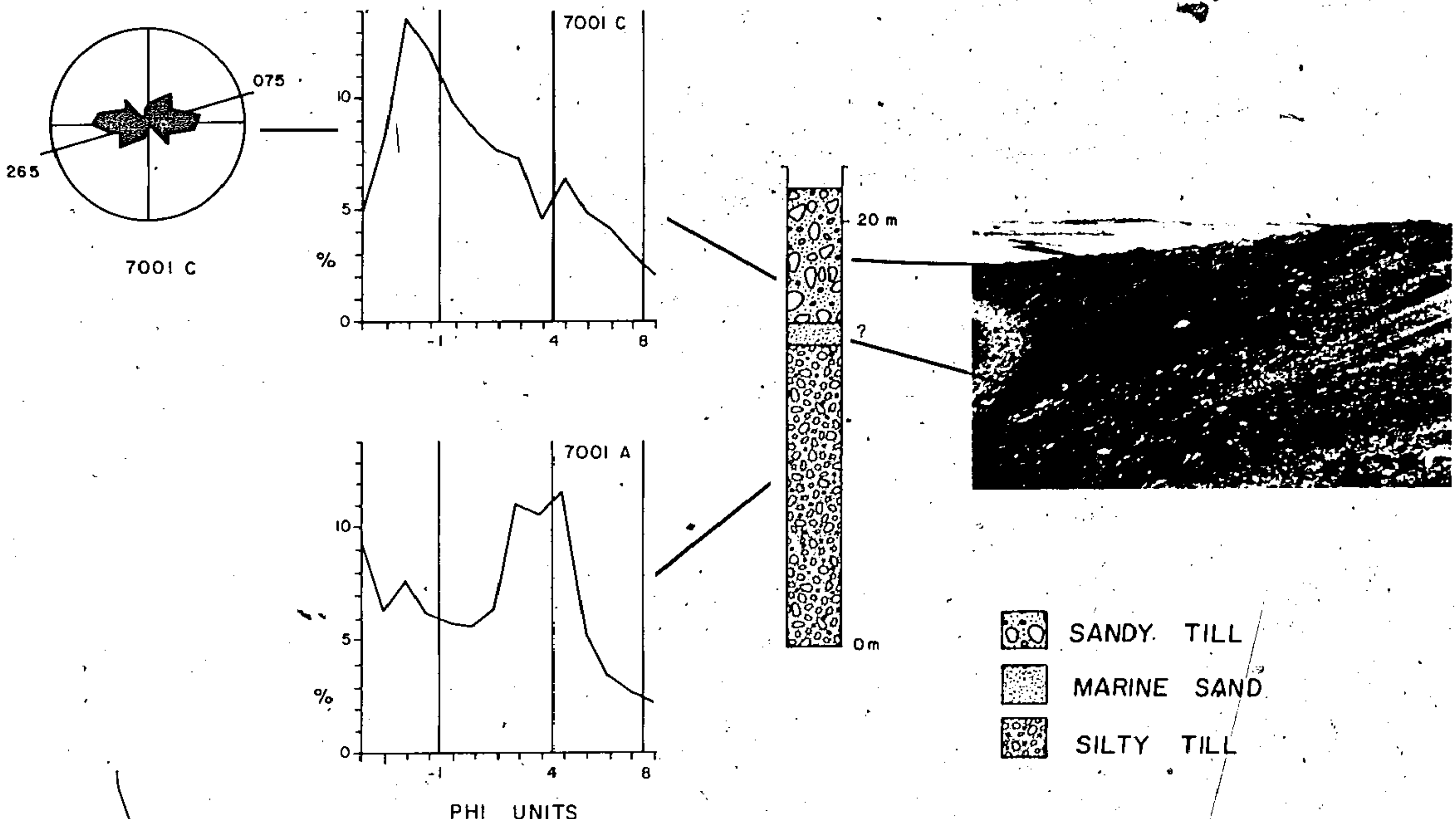


FIGURE 3.5 : ALLAN'S ISLAND

3.2.4 Salmonier Pond, 1L/14

The stratigraphic section at Salmonier Pond contains two till units separated by a stoney marine pelite and shaley colluvium (Fig. 3.7). The lower unit (7021a), is a compact, light to medium brown, silty till with minor sand lenses. Clasts are subrounded to subangular and average 5-8 cm in diameter. This is overlain by ~30 cm of very compact, laminated and crenulated, grey pelite containing rounded pebbles and granules. The silty unit contains benthonic foraminifera of species similar to those identified at Dantzic Cove (Table 3.1).

Covering the marine unit are 4.6 m of sandy colluvium containing >80% local, subangular to angular, Cambrian black shale shards. Other clasts in the unit are of local and western derivation. Many of the non-shale clasts in this unit may be contaminant from the overlying till. The upper, brown till (Sample 7021d) is very sandy with a mean grain size of 1.61 ϕ, subangular to angular clasts 7-10 cm in diameter, and subrounded cobbles and boulders up to 1.5 m in diameter. It contains a large proportion of Precambrian, acidic volcanics and Cambrian quartzite which identify transport from the west, however, Precambrian pillow lava situated to the east and contained in the till, may reflect either a late westward component to flow or ice movement to the southwest down Salmonier Valley.

3.2.5 Beaver Pond, 1L/14

A sample of very compact, brown, sandy, silty till with a mean grain size of 1.27 ϕ was obtained from a cliff section southwest of Beaver Pond. A provenance study (Sample 7019) showed some transport

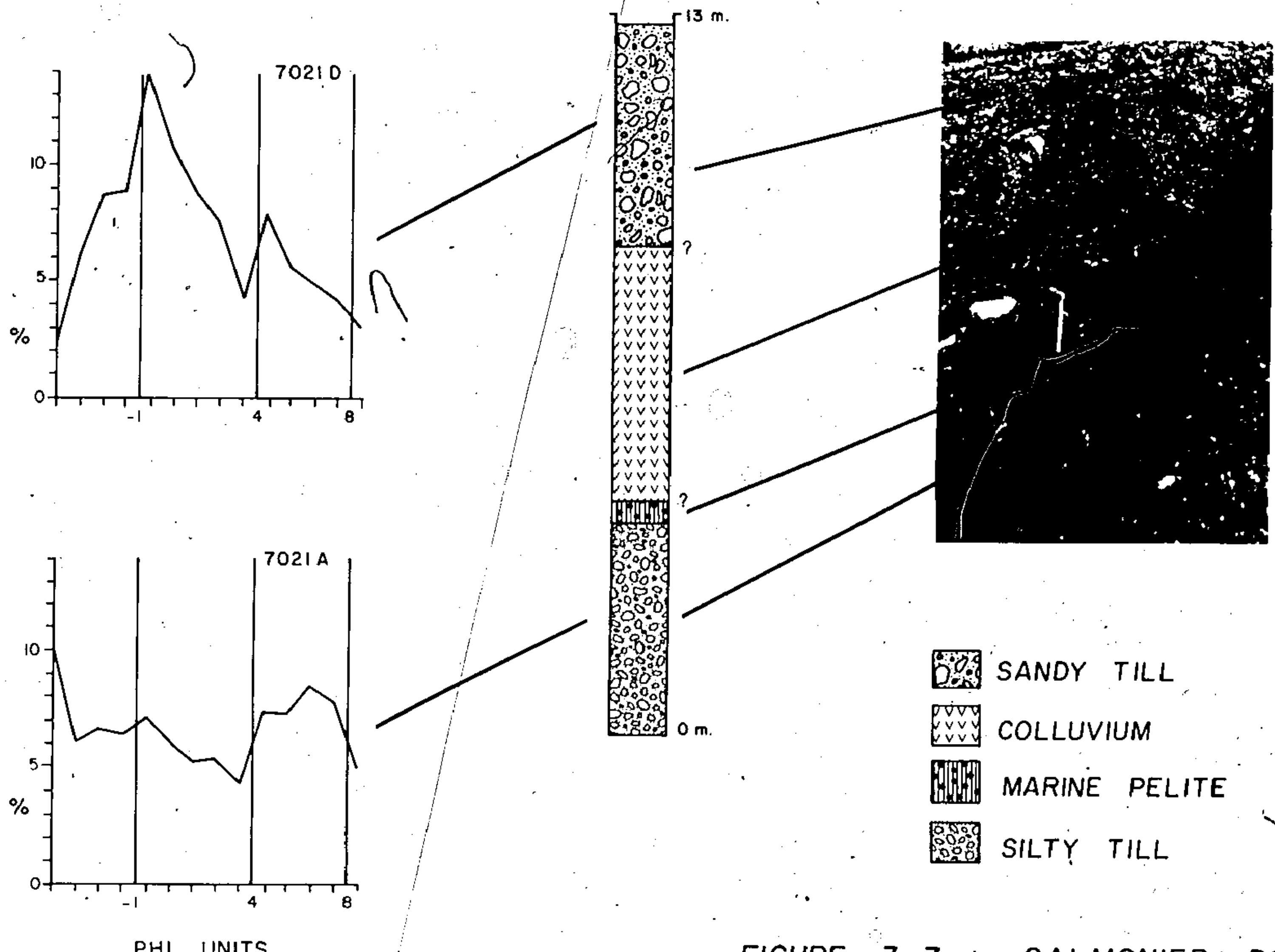


FIGURE 3.7 : SALMONIER POND

from the west but >53% of the clasts were local and, hence, the final direction of ice movement is uncertain. A fabric analysis of the deposit yielded a mean orientation of 270-090 with a secondary mode at 220. Because of its compact nature, and the fact that many clasts are slightly weathered and iron stained, the till is considered representative of a glaciation older than those previously described.

3.2.6 Fortune Coast to Clawbonny Brook, 1M/4

While there were several sampling points along the Fortune coast from Beach Cove, located 10 km southwest of Fortune, northeast to Clawbonny Brook, the area warrants discussion as a contiguous unit since the stratigraphy is laterally similar. At sample point 7066 (Figs. 3.1 and 3.8) there is a section which includes 13.8 m of poorly sorted, very compact, grey, sandy, silty till with a mean grain size of 2.23 ϕ, overlain by 1.7 m of crenulated and faulted, parallel laminated, fine sand and medium to very fine silt (Fig. 3.9). This in turn is capped by 12.1 m of loose, sandy till with a mean grain size of 0.70 ϕ.

Much of the material in both the basal and upper tills (7066a and 7066c) is from local sources, though, a higher percentage of Carboniferous granite and Ordovician pyroclastics in the lower unit indicates that the original source area was on the Hermitage Peninsula, to the northwest. Clasts in the basal till are well striated and subrounded while those in the upper unit appear a little rougher and more fractured. This is similar to the situation encountered in other multiple-till sections.

Fabric in the lower till shows a weakly oriented 320-140 flow

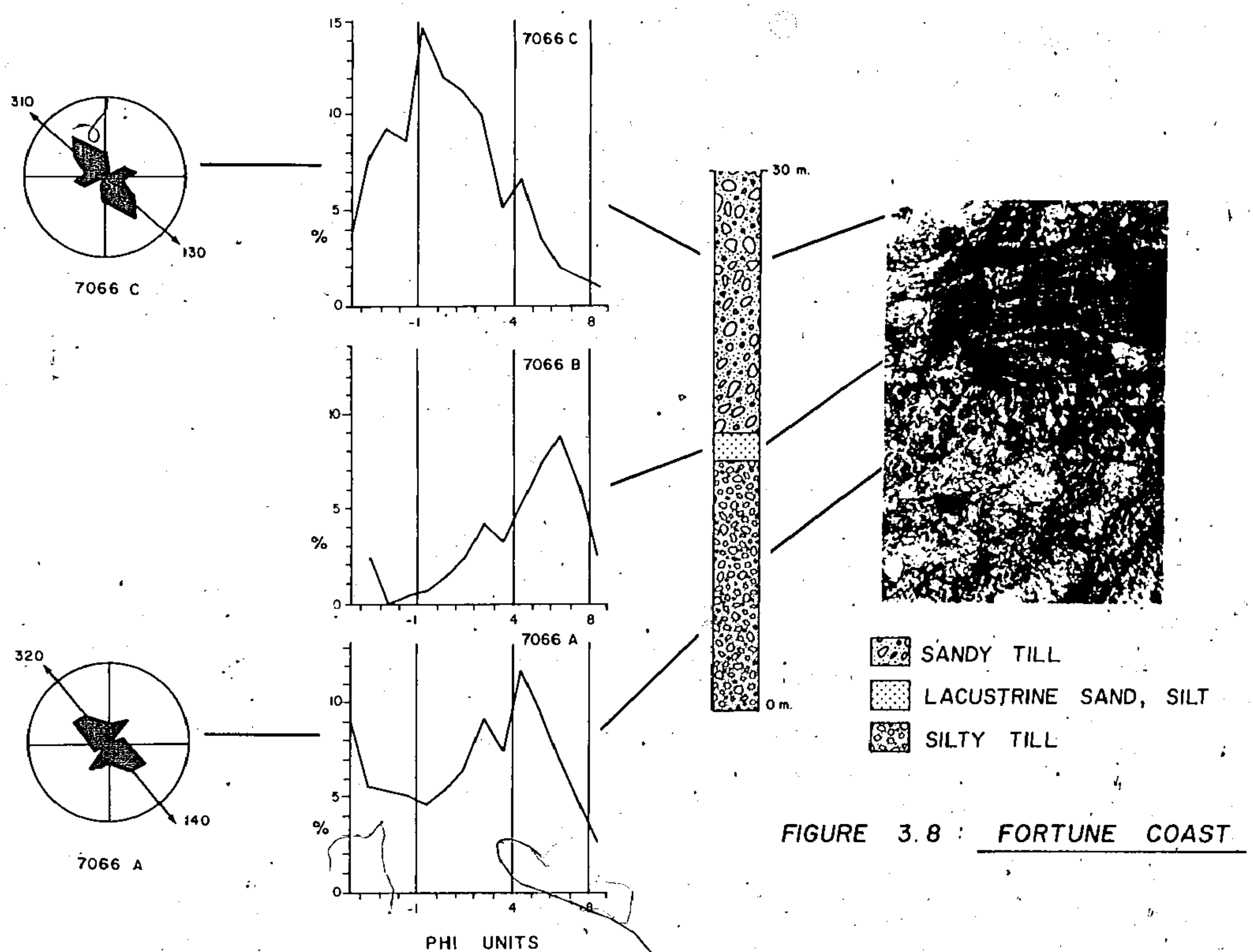


FIGURE 3.8 : FORTUNE COAST

FIGURE 3.9: Bedded, lacustrine fine sand and silt containing benthic-littoral diatoms. Located south of Fortune, 13.8 m a.s.l., between a lower, compact, silty till and an upper, loose, sandy till.

FIGURE 3.10: Kame terrace on the eastern flank of Fortune Head. Abrupt changes in grain size are a result of subsurface ice block melt.

with a secondary mode at 040, the upper till reflects a strongly directed 130-310 ice movement. The reason for the poor orientation in the lower till is not clear but both fabrics may be interpreted to indicate an ice source to the northwest or southeast.

A search for biota was made of the intermediate fine sand-silt unit. While no forams were discovered, fresh water diatoms were recorded (Table 3.2).

The environment of the dominant form *Gomphonema*, is benthic-littoral. It occurs in rivers and lakes but can also live in well oxygenated and slightly moist terrestrial habitats. The genus *Meridion* is a cold water form that prefers flowing fresh water. It travels with small streams into lakes where it is incorporated into the sediments. Hence, sample 7066b is probably lacustrine material that was subsequently overridden by ice.

A till fabric of deposits constituting a kame terrace, located along the west coast of Fortune Harbour (Sample 7077), showed a dominant orientation at 260-080 and a strong secondary mode at 020. Bedding and size sorting in the 17 m high terrace is chaotic and there is evidence of depositional faulting and collapse caused by subsurface ice block melt (Fig. 3.10). This feature is a record of the most prominent ice lobe on the southwest coast of the Burin Peninsula during the last glacial event.

At the mouth of Clawbonny Brook, 4.9 m of grey-pink, silty till, similar to that found at 7066a, is capped by 1.7 m of well sorted glacio-fluvial sand and gravel (Fig. 3.11) of which the upper 0.9 m is devoid of any significant quantities of fine matrix. It is noteworthy that only one glacial event is in evidence at this location.

TABLE 3.2

Diatom Report For Sample 7066b

(Lichti-Federovich, pers. comm.)

Material: Fine sand and silt

Sample depth:

Collection site: 6.4 km southwest of Fortune, Newfoundland

Location (Lat., Long.): 47°03'27"N 55°53'25"W

ANALYSIS: 8 slides examined. Diatomaceous flora poor in species.

1. *Gomphonema angustatum* (Kütz.) Rabh. Hal.: indifferent; pH: alkaliphilous
2. *G. angustatum* var. *sarcophagus* (Greg.) Grun. Hal.: ind.; pH: alkaliphilous
3. *G. intricatum* var. *vibrio* (Ehr.) Cleve Hal.: ind.; pH: alkaliphilous
4. *G. parvulum* var. *subellioticum* A. Cleve Hal.: ind.; pH: indifferent
5. *Meridion circulare* Ag. Hal.: indifferent; pH: alkaliphilous
6. *Surirella angustata* Kütz. Hal.: indifferent; pH: alkaliphilous

FIGURE 3.11: Clawbonny Brook coastal section. Reveals 4.9 m of compact, grey-pink, silty till capped by 1.7 m of well sorted, cobble gravel. Contact indicated by spade.

FIGURE 3.13: Main Brook multiple-till section. Lower, indurated, iron stained, brown-yellow till overlies bedrock and is capped by red, sandy, silty till. This in turn is overlain by glaciofluvial, cobble gravel. Contacts indicated by arrows.

3.2.7 Surface deposits on the lower Burin Peninsula

Figure 3.12 describes the matrix texture of several surface till samples from the lower Burin Peninsula. All are sandy with means in the granule to coarse sand fraction and fine skewed. This, along with their loose nature, indicates that they are an ablation facies of the final glaciation.

Provenance studies show general transport from the northwest with a high proportion of local material. However, east of Waterfall Pond near Little St. Lawrence, sample 7018 yields over 25% of late Precambrian, gabbroic sill clasts. While this is part of the locally undivided and larger Burin Group, it may be indicative of a westward component to flow since Strong *et al.* (1976) map a similar outcrop 3 km to the east. In the Taylor's Bay (Sample 7037) and Lannon Cove (Sample 7032) areas, onshore transport cannot be substantiated from clast identification.

Based on a report of inter-till organics (Nfld. and Lab. Corp., Lot IV Exploration Project, unpub. rept., 1972) at a depth of ~7 m, 400 m west of Mt. St. Margaret, 1L/14, an attempt was made to locate them with a Pionjar impact soil sampler. After repeated attempts to penetrate the bouldery granite till, the operation was abandoned at a depth of 11 m. Further searches for interstadial organic material on the Burin yielded nothing.

3.2.8 Discussion

Considered in isolation from the remainder of the Burin, the above site descriptions suggest a series of glacial events for the lower

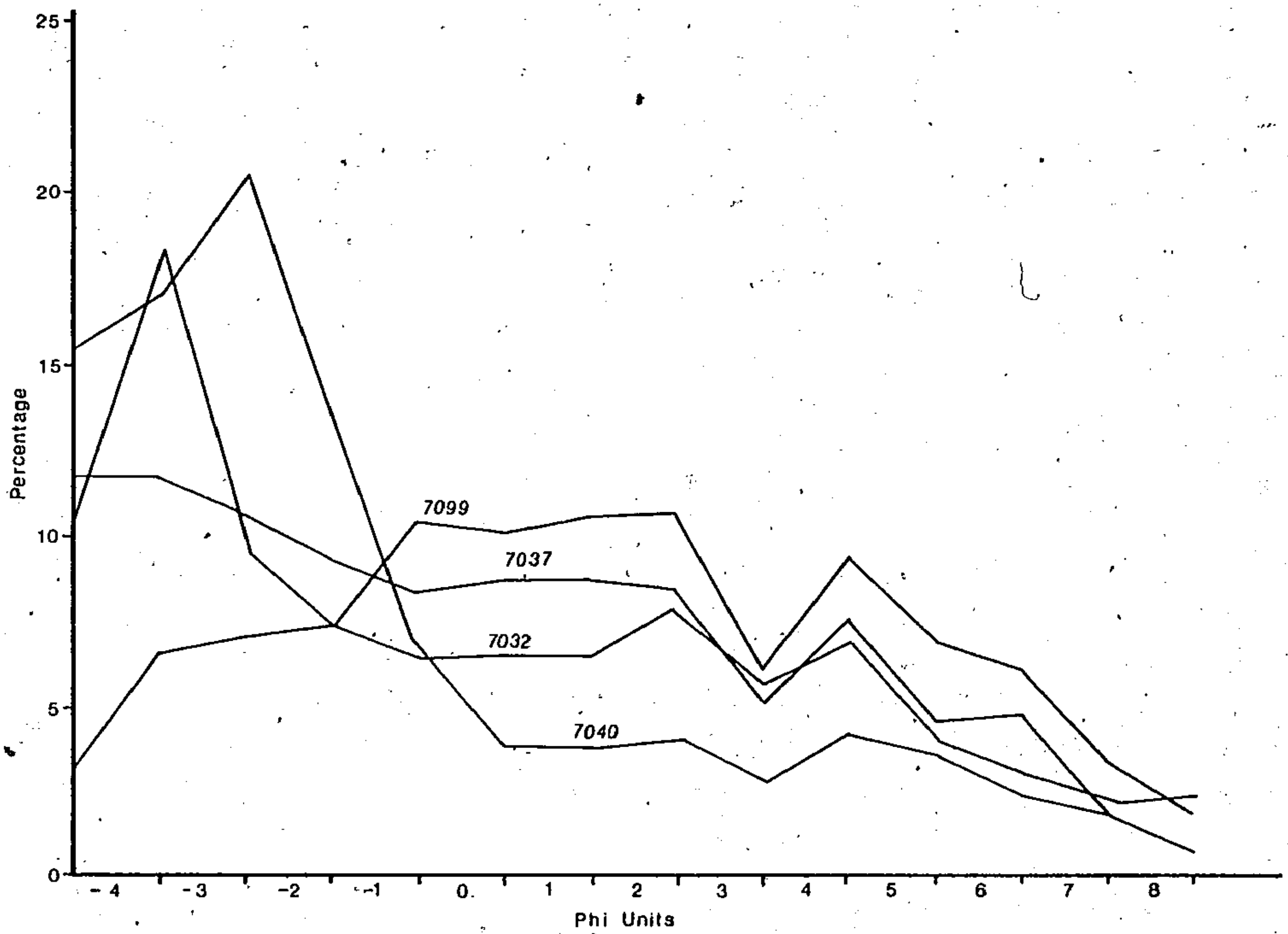


FIGURE 3.12: Lower Burin Peninsula, surface till matrix textures.

peninsula or St. Lawrence plateau. It would appear that the lower, grey to pink, silty till, located along the lower southwest coast of the peninsula, including Dantzic Cove and Allan's Island, is representative of a till sheet emplaced by ice movement from the mainland of Newfoundland, across Fortune Bay and southeast onto the continental shelf. This is indicated by; the silty matrix, probably derived from a marine sediment component, clasts that originated from the Hermitage Peninsula, and the general northwest-southeast trend to the till fabrics. Because this basal deposit is ubiquitous along the west coast of the Burin Peninsula, it will hereafter be referred to as the Fortune Bay till.

The foraminifera in marine sands at Dantzic Cove and freshwater diatoms near Fortune are open to several interpretations. It is considered that the marine sands represent overlap of the "Fortune Bay" till prior to deposition of the upper unit, with marine limit occurring somewhere north of Dantzic Cove but south of the Fortune coast and samples 7065-66. Both the marine and freshwater samples are located well above present sea level at 9-13 m. Because the samples at Dantzic Cove and Allan's Island are neither continuous nor *in situ*, it might be argued that the sands were emplaced as frozen blocks during the following stade, which appears to have had its source somewhere to the southeast of the Burin Peninsula (Section 2.2.2). This does not seem likely since; the sands occur too frequently, they are near horizontal in position, and they all occur at approximately the same elevation. Further evidence to substantiate this argument will be presented in Chapter 6.

Vilks (pers. comm.) is of the opinion that the suite of foraminifera from the Burin Peninsula is analogous to that discussed by

Wagner (1977) for the Salmon River sands, Bay of Fundy, Nova Scotia. These have been dated at 38,600 ± 1,300 B.P. and assigned to the mid-Wisconsinan. Unlike the Salmon River section, it is impossible to imply coeval ice at Dantzic Cove since the exposure is poor and the stratigraphic record incomplete. The evidence does suggest, however, that the "Fortune Bay" till is older than mid-Wisconsinan and that it should, as a minimum age, be assigned to the early-Wisconsinan, post-St. Pierre interstadial period. Therefore, the onshore, westward and northwestward ice movement must have followed at some point after an early, mid-Wisconsinan interstadial. Whether or not this event is exactly correlative with the continental Cherrytree stadial/Lennoxville till phase of Dreimanis and Goldthwait (1973) or the offshore unit B3, grey mud, mid-Wisconsinan stade of Alam and Piper (1977) is not clear. However, the idea of northward flowing ice during the early-Wisconsinan (Grant, pers. comm.) is not borne out by the evidence of mid-Wisconsinan marine sands overlain by one till sheet.

The sandy, loose texture of the upper till and the relatively undisturbed nature of the lacustrine unit (Sample 7066b) imply that the last glaciation was not strong and that the ice rotted in place. This is further evidenced by the glacial patterns and ice margins noted on the St. Lawrence plateau (Chapter 2). A till fabric analysis obtained on the kame terrace at Fortune indicates that ice advanced north down Fortune Valley and out into Fortune Bay. An offshore limit for ice is similarly postulated for the Allan's Island-Dantzic Cove area since there is no indication of landward ice stagnation in this area.

While tills south of Fortune are separated by units of nonglacial material, north of the town the silty basal unit and sandy upper are superimposed and, therefore, open to interpretation as being basal and ablation facies of a single glaciation. An analagous situation is described by Boulton (1972) for arctic glaciers. However, because of the overriding importance of the marine sands at Dantzic Cove, the higher percentage of Hermitage Peninsula clasts in the basal unit, and the glacial pattern described in Section 2.1.3, the explanation of two glacial events for the whole of the lower peninsula is preferred. The marine truncation of meltwater channels, located just north of Fortune, and the presence of coastal moraines further north, would suggest that later ice did move offshore, however, the well defined, inland, ice marginal position south of Grand Bank and Gull Pond (Section 2.1.4, Fig. 2.1) indicates that ice retreated somewhat before stagnating and melting virtually *in situ*.

The Salmonier Pond section is considered correlative with the Fortune coast deposits. The compact, basal till, though slightly more weathered than at Dantzic Cove, represents early-Wisconsinan ice movement southeast, across the peninsula. It is not clear from the limited exposure whether the marine pelite is transported, however, since it is located at ~100 m a.s.l. and sea level is unlikely to have reached this elevation during an interstadial, it more likely represents material moved onshore from the southeast in the final advance.

The Beaver Pond section, because of its induration, weathering and limited exposure, is considered to be ancient, and a remnant of a glaciation occurring prior to that which deposited the Fortune Bay till.

3.3 Site Descriptions of the Marystown-Garnish Lowland

3.3.1 Main Brook, 1M/3

Because of Van Alstine's (1948) report of multiple-till exposures near Main Brook, foot traverses were carried out along its length from the mouth to a point approximately 10 km inland. At a location where the Winterland road crosses Main Brook, a till section capped by glaciofluvial material was discovered at ~30 m a.s.l. The river-bank section (Fig. 3.13) was originally, poorly exposed and, therefore, was cleaned with a high pressure fire pump for further investigation.

The exposure (Fig. 3.14) revealed two superimposed till units overlying Precambrian volcanics. The brown-yellow, lowermost unit is ~5.2 m thick, highly indurated, crenulated, and contains several zones of ferruginous staining and manganese cementing. The coarse matrix which has a median diameter of $-3.79\ \phi$, is evenly distributed in the sand-silt-clay fractions. The possibility exists, however, that the size distribution shown for sample 7041a is not truly representative of the till in that it was difficult to properly disaggregate the cemented material for analysis. The matrix of the overlying 1.6 m of red, sandy, silty till has a mean grain size of 0.97ϕ, and contains modes in the granule, medium sand and coarse silt fractions. The material is indurated but only to the degree of the basal, silty till found at Dantzic Cove (Fig. 3.3).

Clasts in the lower unit, 7041a, are angular to subangular, 15-20 cm in diameter, heavily iron stained, and well striated. A provenance study showed dominant local transport from the northwest with

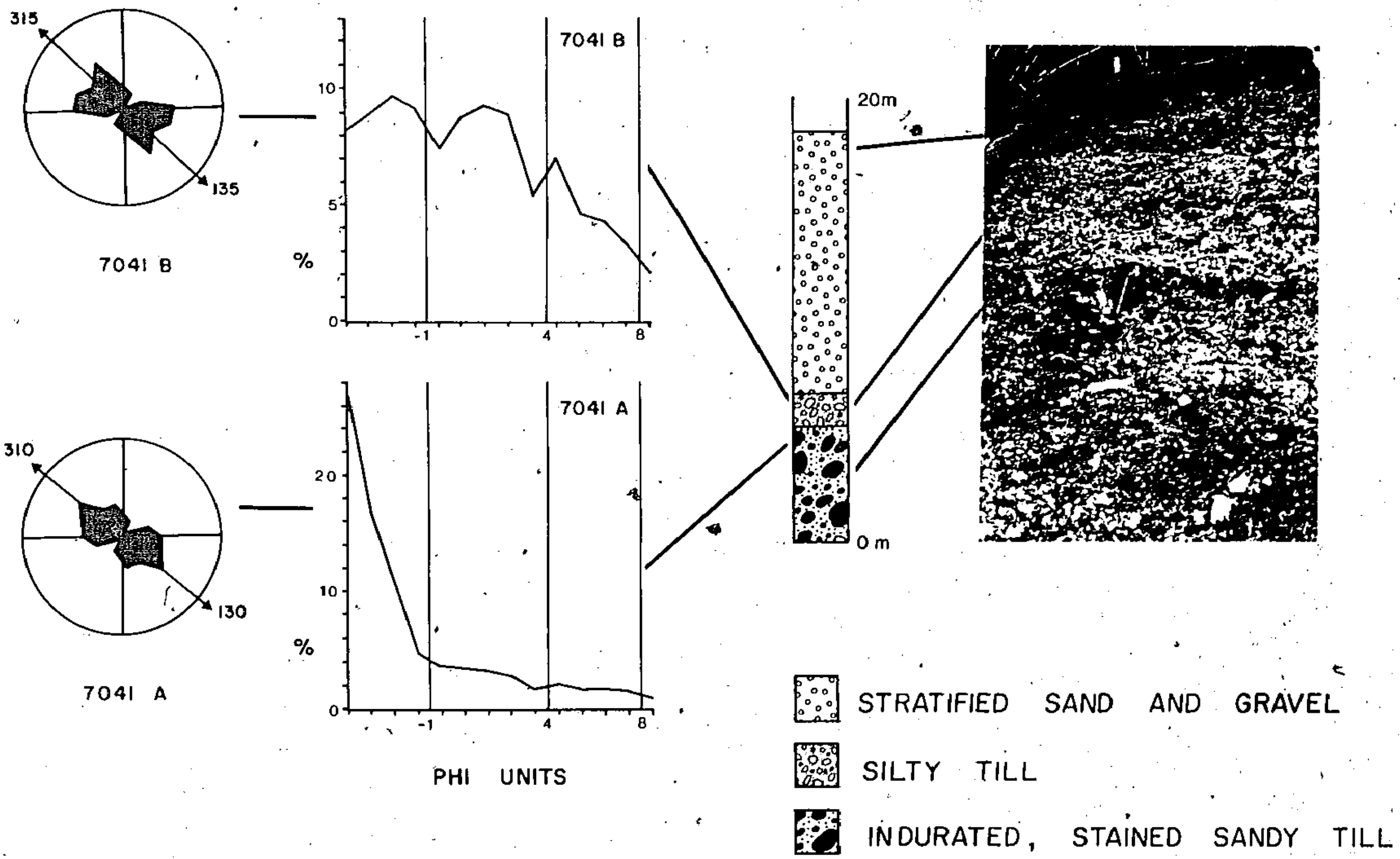


FIGURE 3. 14 : MAIN BROOK

granite being a possible indicator of a distant Hermitage Peninsula source. The high percentage (8%) of unidentified clasts is a function of iron stain and weathering. The upper till, 7041b, contains subangular to subrounded, striated clasts with a very high percentage 74%) of granitic rocks. As with 7041a, this might be an indicator of distant transport from the northwest but very local Cambrian sources are considered more important. Till fabric primary modes and means are not significantly different for the two tills and do not indicate major changes in ice flow directions. The fact that the analysis at 7041a is not well oriented may be a result of disturbance by the overriding ice. A similar conclusion was reached by MacClintock and Dreimanis (1964) in their study of fabrics from superimposed tills in the St. Lawrence Valley, New York.

Trace element analysis by atomic absorption spectroscopy was completed on a series of six matrix samples obtained from the two till units to determine if there is a difference in provenance of the two units and if the lower till is, quantitatively, more weathered than the upper unit. The latter question might be resolved by noting the quantities of manganese and iron present in both tills at increasing depth. The results (Table 3.3) show that sample 7041a4 which was obtained from an iron stained and manganese cemented zone 0.5 m below the top of the lower till, divides samples 7041a1-3 from 7041a5 and 7041b6. Both its manganese and iron values are significantly higher. Shilts (pers. comm.) interprets the high iron and manganese values in 7041a4 as being typical of old, weathered tills and the zinc enrichment as suggesting different provenance and perhaps, the inclusion of gossans from sulphide ore bodies. The till units are capped by >11 m of well stratified glacio-

TABLE 3.3

Trace Elements,
Atomic Absorption Spectroscopy, PPM
Main Brook

SAMPLE NO.	HEIGHT	Cu	Pb	Zn	Co	Ni	Ag	Cr	U	Mo	Mn	Fe%
7041 B6	6.7 m	00069	00069	00550	00009	00028	0002	0011	001.4	0005	1050	06.50%
7041 A5	4.7 m	00073	00039	00272	00014	00010	0000	0013	001.2	0004	1390	07.50%
7041 A4	4.2 m	00122	00052	00288	00033	00019	0001	0018	001.4	0008	8800	10.50%
7041 A3	4.0 m	00056	00070	00181	00016	00013	0001	0023	001.5	0006	1450	08.70%
7041 A2	2.0 m	00034	00064	00130	00008	00010	0001	0017	000.8	0004	0900	05.10%
7041 A1	20 cm	00077	00042	00182	00016	00020	0003	0030	000.7	0003	1305	05.90%
7041 B	Bulk	00074	00076	00495	00013	00013	0000	0009	001.4	0003	1400	07.60
7041 A	Bulk	00046	00153	00168	00015	00011	0002	0020	001.1	0004	1365	07.40

fluvial sand and cobble gravel that dip in an approximate 075 direction.

3.3.2 Shearstick Brook and Spanish Room Point, 1M/3

About 2.5 km from the mouth of Shearstick Brook, a section that was claimed by Van Alstine (1948) to contain "pre-Wisconsinan tills interbedded with sands and gravels and overlain by fresher non-calcareous grey-brown till" is visible. The lowermost unit of highly indurated, coarse sand and very weathered cobble gravel, which dips in a general 210 direction, is overlain by 3.2 m of brown-pink, silty, sandy till that grades into >8 m of a sandier facies of a similarly coloured till (Fig. 3.15). Preliminary investigations in 1976 led to the discovery of a similar, highly indurated, grey sand and red, fluvial conglomerate on the south coast of Spanish Room Point as well as immediately north of the tombolo on the northwest shore of Mortier Bay. The material, which has a strike and dip of 075, 16°R, contains well rounded and highly weathered clasts of which an overwhelming majority are derived from the Precambrian Marystown Group (Appendix 2). Although the Spanish Room Point deposits dip seawards, they appear intruded by a plug of limestone (Fig. 3.16), thus, a Quaternary interpretation for the formation becomes more tenuous. Despite the highly visible exposures, none of the more recent bedrock mapping projects (Anderson, 1965; Strong *et al.*, 1976) made any mention of the units. A formation with similar facies and induration that had been mapped in the Terrenceville area by Bradley (1962) and Anderson (1965) is classified as Upper Devonian (or Carboniferous, by Strong, pers. comm.) conglomerate and sandstone.

A method was devised by the writer to test whether or not the

FIGURE 3.15: Shearstick Brook section. Spanish Room Formation is overlain by >11 m of buff-pink, silty, sandy till.

FIGURE 3.16: Spanish Room Point. Spanish Room Formation conglomerate intruded by limestone. Bedrock is overlain by red, silty, sandy cobble till with clasts from local, northeastern sources.

materials at Shearstick Brook and Spanish Room Point could be termed very old surficial deposits in the manner of the Nova Scotian, Bridgewater conglomerate (Grant, 1977b). It involved the use of a BGS-ISL broadband gamma-ray scintillometer which was loaned by the Nfld. Dept. of Mines and Energy. A series of readings were taken on the Terrenceville formation and overlying surficial deposits, the Spanish Room Point conglomerate and overlying known till, the Shearstick Brook sandstone and conglomerate as well as the Main Brook section just described. The latter section was used as a baseline test for "old" tills. While it is recognized that the scintillation counter does not measure age, the test was intended to provide some rough indication of similarity between units if only from the amount of broadband radiation each emitted. It was expected that "background" surficial units would provide considerably weaker readings than those taken on a series of similar bedrock units. The results (Table 3.4) show that in all cases bedrock and suspected bedrock have readings 1.7-1.9 times greater than the background radiation, while known till samples range from 0.3-1.5 times greater.

During these field tests, the locations were visited by D.F. Strong who confirmed the writer's findings and classified the lower conglomerate found at sample point 7051 as the Spanish Room Formation. Strong (in press) included the Shearstick Brook rock in the formation, and on the basis of microfossil analysis, suggested an age (Tournaisian) similar to that determined for the Terrenceville Formation.

Having resolved the question of supposed multiple-tills at these locations, it remains to describe the overlying surficial units.

TABLE 3.4

Broad Band Gamma-Ray Scintillation Counts
(Recorded in Counts Per Second)

LOCATION	SAMPLE NO.	DESCRIPTION	BACKGROUND READING	SPOT READING	DIFFERENCE
Terrenceville	7119	-	80	-	-
	7119	Carboniferous Conglomerate	-	140	60
Spanish Room Pt.	7046	-	64	-	-
		Weathered Conglomerate	-	120	56
		Consolidated Conglomerate	-	100	40
		Sandy Till Cover	-	85	21
Shearstick Brook	7051	-	120	-	-
		Consolidated Conglomerate	-	180	60
		Carboniferous Granite	-	200	80
Main Brook	7041	-	80		
		Upper Till	-	110	30
		Lower Till	-	120	40
		Carboniferous Alkaline Rock	-	175	95

At Shearstick Brook, the buff-pink till (Fig. 3.15) has a mean grain size of 3 ϕ with a pronounced mode in the coarse silt fraction. Provenance studies of both samples indicate transport from the northwest and west, but of a local nature. The upper sample contained a higher percentage of Carboniferous granite, but it is not certain if this indicates local or distant bedrock sources since targets may be found to the south, west and northwest.

The Spanish Room Point section does not show clear contacts between the Carboniferous conglomerate and the overlying red, silt and medium sand, cobble till (Fig. 3.17). Provenance analysis of a sample (7046b) obtained from poorly consolidated material just above the Spanish Room Formation indicates that, although it appears to be glacial material, no significant foreign clasts could be found. Sample 7046c, taken from a point >4 m above the bedrock contact, suggests that because of the presence of quartzites and siltstones, agglomerates and gabbroic sill from the Burin Group, transport from the northeast or east is a distinct possibility.

3.3.3 Marystown-Creston, 1M/3

Opposite Wiscombe's Store in Creston there is a section exposed on a stream bank that contains two stratigraphic units. The lowermost consists of 4.5 m of red, very highly weathered, manganese stained and cemented conglomerate with a fine skewed, coarse and matrix (Fig. 3.18). The majority of the clasts are rounded, Precambrian Marystown Group pebbles and cobbles, but 11% are highly weathered, fine grained granite. The fabric of the material is oriented 095-275. This, and the granite

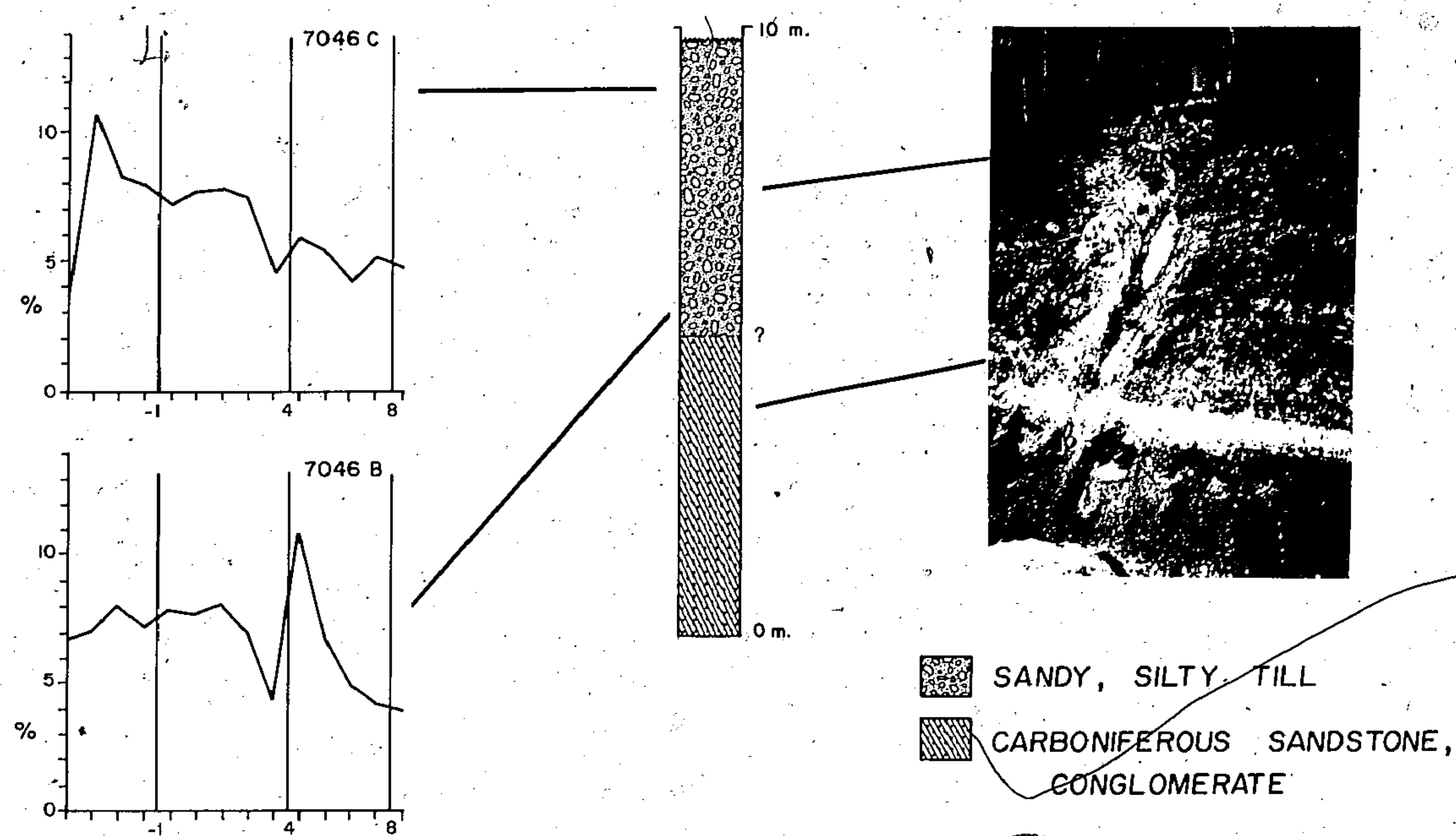


FIGURE 3. 17 : SPANISH ROOM POINT

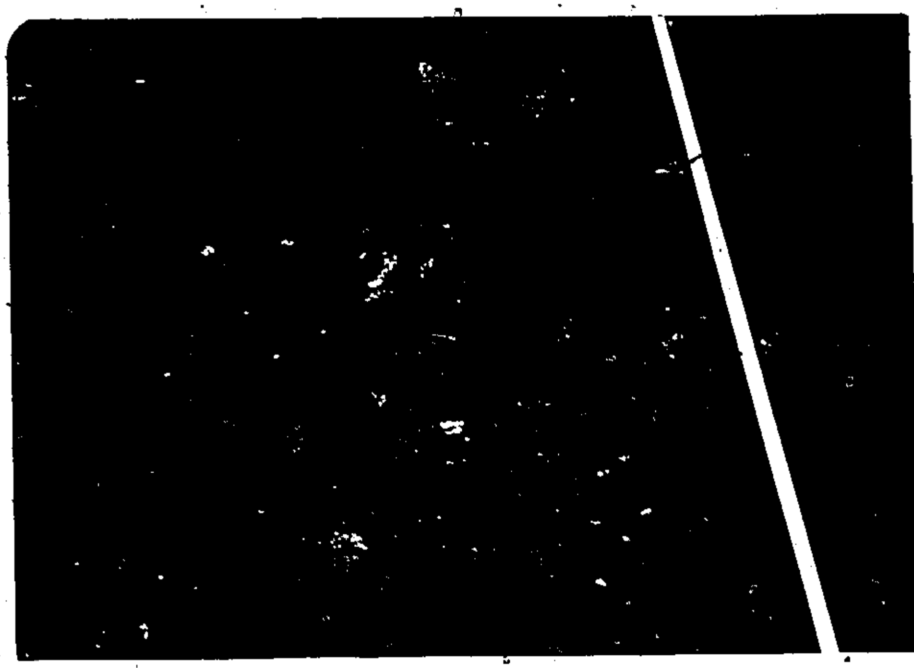


FIGURE 3.18: Spanish Room Formation at location 7020. Clasts are highly weathered and the unit grades into a loose, grey-brown, sandy till that contains local, eastern material

FIGURE 3.19: Cashel Cove multiple-till section. Very compact, crenulated, brown, sandy till is overlain by loose, brown, sandy till. Because of road construction, the contact is poorly exposed. Dominant transport in the lower till is from the west.

content, suggest a western source area. Although it was initially thought by the writer to be an old interglacial or interstadial sequence, it is now considered, based on the studies at Shearstick Brook and Mortier Bay, to be a weathered exposure of the Spanish Room Formation. It is overlain by a veneer of loose, grey-brown, sandy till containing subangular clasts which have a general size of 10 cm, and subrounded cobbles and boulders up to 40 cm in diameter. A till fabric analysis of this upper unit indicates a 280-110 direction of transport. Clast identification does not show distant transport from the west; in fact, the presence of Mt. Lucy Anne pyroclastics and rhyolite suggests that the material is locally derived from sources to the east.

3.3.4 Cashel Cove, 1M/3

On the northwest coast of Mortier Bay near Spanish Room Point, there is a small exposure of very compact, crenulated, brown, sandy till (Fig. 3.19) located 10 m a.s.l. The matrix (Sample 7081) has a mean grain size of 1.13 ϕ, and is very poorly sorted. Clast analysis yielded mostly local Mortier Bay Formation indicating transport from the west; no distant (Hermitage area) transport was proven. The compact, brown till is overlain by, though at this point, not in contact with, a loose, brown, sandy, ablation till that contains a majority of local, angular clasts that average 20-30 cm in diameter.

3.3.5 Creephole Point moraine, 1M/3

The Creephole Point moraine (Sample 7093) has been discussed previously both because of its morphology and because of its relationship with microindicators of ice movement (Sections 2.1.3 and 2.2.2). Because of its scale and vegetative cover little else was attempted by way of analysis. A provenance study of the clasts did reveal that while the larger proportion of the stones originated to the west and northwest, the presence of Inlet Group, micaceous siltstone and Burin Group, red sandstone may be taken as representative of an onshore ice movement from Placentia Bay. Outcrops of both these rock types are found <2 km to the east of the sample site, hence, onshore transport may be referred to only in a local sense.

3.3.6 Surface deposits on the Marystown-Garnish lowland

It is difficult to describe the surface tills of the Marystown-Garnish lowland explicitly. Much of the material is washed, sandy ablation till, mixed with ice contact, stratified drift and glaciofluvial material. Beyond the sites just described, there are few multiple till sections. Occasionally, as in the cliff face 300 m southwest of Salt Pond, one sees a compact, red-pink, silty, sandy, pebble till capped by a loose, brown, sandy, ablation facies. Generally, however, the cuts are so small and poorly exposed that it is impossible to obtain any meaningful stratigraphic information from them.

Along the Fortune Bay coast, from Grand Bank to Garnish, there are no exposures of the basal, "Fortune Bay" till which is ubiquitous south of Clawbonny Brook. A reddish, compact till is locally present in the area east of Freshwater Pond and west of the 168 m range of hills between Burin Bay Arm and Beau Bois. However, till cover in the town of Burin area is practically non-existant and where it does occur, it is usually a thin, locally derived veneer.

Clasts in other surface till samples record either local sources or transport from the west. For example, sample 7024, taken from the east coast of Freshwater Pond, shows a high percentage of Winterland porphyry and Garnish Formation conglomerate. The presence of Carboniferous, St. Lawrence granite is problematic and may be indicative of transport from the St. Lawrence plateau to the south or from the Hermitage Peninsula to the west. Similarly, a surface sample of weathered, subrounded pebbles, obtained at a point 3 km north northeast of the Winterland road intersection, contains a majority of local clasts, but Garnish Formation conglomerate and sandstone, and Mortier Bay mafic flow content suggest sources to the west and east.

Ice contact deposits located 6 km west of Freshwater Pond (Appendix 1) will be discussed in greater detail in the following chapter since they relate to a distinct phase of deglaciation and interfinger with prominant glaciofluvial ridges and outwash.

3.3.7 Discussion

From the stratigraphic information gathered on the Marystown-Garnish lowland, it is concluded that there are three separate phases of ice movement recorded, the last of which is represented by ablation facies.

The oldest Quaternary deposit on the Burin Peninsula is not Van Alstine's (1948) "pre-Wisconsin, washed hematitic drift", which has now been determined to be Carboniferous bedrock. Instead, it is represented by the lower tills at Main Brook (Sample 7041a) and at Cashel Cove (Sample

7081). It is also typified by the plug of weathered till located at Beaver Pond (Section 3.25). The age of this unit can now, more definitely, be assigned to an event occurring prior to the St. Pierre interstadial than it was in section 3.2.7. The total results of the trace element study and, in particular, the high Fe and Mn content mean that the compact brown till is considerably older than the overlying red, silty till and, therefore, may be as old as Illinoian. Shilts (1973) cautioned that some element concentrations are texture dependent but this should not be a factor in the present study since the fraction analyzed (<8 ϕ) was the same for all samples. Compared to a similar study of surface till samples from the centre of the province (Grant and Tucker, 1976), the Main Brook results show significantly higher trace element concentrations. This is indicative of pronounced weathering. Further evidence of a very old till is gained from the fissile induration and highly weathered nature of the Main Brook unit. This is also true of the Beaver Pond and Cashel Cove deposits.

The second oldest till on the lowland is represented by the middle unit at Main Brook (Sample 7041b), the red, silty till cap at Shearstick Brook and Spanish Room Point (Samples 7051 and 7046), and the reddish, silty tills described in the Marystown to Salt Pond area. These are correlated with the pink-grey, silty, basal units along the Fortune Bay coast near Grand Bank and south to Allan's Island. The possibility exists that the red, silty matrix of tills in the Marystown area was derived from previously, more extensive western occurrences of the Spanish Room Formation conglomerate. However, trenching operations in the area of thick drift between Winterland and Freshwater Pond have not revealed its presence (O'Brien, pers. comm.). Further, it would be reasonable that over such short transport distances the weathered pebbles of the Spanish Room Formation would not be entirely comminuted and that highly weathered clasts would be discovered in the provenance studies. This was not so and despite the compact nature of these tills, most of the clasts have a fresh appearance. A more logical source for the silty matrix, would be the marine sediment picked up as ice crossed Fortune Bay.

It was not immediately clear if the upper, brown, sandy till found at various locations in the Marystown basin reflected complete ice cover from the onshore, northwest directed ice documented for Allan's Island-Fortune-Brown Ridge Pond area, or if it represented separate, very limited, coeval ice. Since a well defined ice margin is located on the St. Lawrence plateau and in the Frenchman's Cove-Grand Bank area, it may be that the exact situation lies somewhere between these two conditions. Thus, most of the upper, brown till deposits are an ablation facies of the onshore ice movement which did not pour onto the lowland with any great force. Hence, is not represented by a basal or subglacial component. Speculatively, ice may have only been sloughed onto the southwest corner of lowland as an ice dome centred off to the southeast collapsed late in mid-Wisconsinan deglaciation.

3.4 Site Descriptions of the Upper Burin Peninsula

3.4.1 Red Harbour and Baine Harbour, 1M/7, and Jean de Baie, 1M/3

Each of the above locations are similar in that all are horseshoe-shaped coves with abrupt 100 m rock walls that open eastwards onto Placentia Bay, and are associated with 150-160 offshore striae followed by 280-290 onshore striae. The highland plateau surrounding the cirque-like harbours is virtually bare, devoid of either surficial cover or vegetation. For these reasons they are discussed as a unit.

The kame terrace at Red Harbour (Fig. 3.20) is typical of deposits along the Placentia Bay coast. It contains a compact, buff-light brown, silty, sandy lower zone with pockets of sandy, washed pebble and cobble gravel. The soil depth at sample point 7080 is 1.4 m and contained within a substratified facies. A provenance study of the till found no distant transport from the east (Avalon Peninsula) despite the presence of 270-oriented striae less than 1 km to the east at 100 m a.s.l. The fact that 42% of the clasts are Cambrian and earlier volcanic rocks cannot be taken as indicative of any single transportation direction since major outcrops are located to the northeast and east in Placentia Bay as well as immediately to the west.

A similar till sample was obtained from a road cut at Baine Harbour (Sample 7102). The till is a grey-brown, sandy material with a mean grain size of 2.44 ϕ and subrounded to subangular, well striated clasts. It is as compact as that at Red Harbour. Rock types show dominant southeastward transport from the upper Fortune Bay area by the presence of Ordovician tuffaceous slate and Silurian granite. Cambrian and earlier siltstone (7%) may reflect local transport from the northeast or east. Other local area samples, such as 7103 from near Rattle Creek, show similarly inconclusive directions of transport. Both southeastern and southwestern directions can be inferred but only the former with any certainty.

The till fabric at Red Harbour shows a weakly directed mean

FIGURE 3.20: Red Harbour kame terrace, location 7080. Section reveals zones of poorly sorted pebble and cobble gravel within a compact, buff-light brown, silty, sandy till. More than 42% of the clasts are Cambrian and earlier volcanic rocks which may be from western or eastern sources.

orientation of 195-015 with a strong secondary mode at 300-120. The dominant orientation is approximately transverse to flow, but since the fabric is not well oriented, it would be inappropriate to attach much significance to the results. A more strongly oriented fabric was measured at Jean de Baie (Sample 7050) on a coastal plug of loose, buff-brown, sandy till which contained subrounded to subangular, well striated clasts. Again, the dominant orientation (060-240) does not reflect southeastern ice flow. Rather, it indicates an onshore push from Placentia Bay or very local flow from the highland west of Baine Harbour. This assumes that the primary mode and mean orientation reflect the dominant flow direction which, in the case of a washed till, is not always the case (Harrison, 1957 and Harris, 1972).

3.4.2 Broad Cove Head, 1M/7

Broad Cove Head is located 3.9 km south of Rushoon and connected by a tombolo-like plug of till to the Burin Peninsula (Fig. 2.7). The reason for examining the unconsolidated deposits at this site was that from an air photo analysis, it was not clear whether the connecting materials were till, glaciomarine, or a combination of the two. A foot traverse was completed to the area and samples were collected from a site on the south corner of the deposit. The plug (Fig. 3.21) consists of buff-light brown, silty, sandy till with a mean grain size of 3.4 ϕ. It is very compact and shows crenulations from overriding ice. Clasts are slightly weathered, but well striated. Lithologic identification of pebbles and granules indicates that transport is exclusively from the west and northwest with undivided, Precambrian felsites and tuffs being

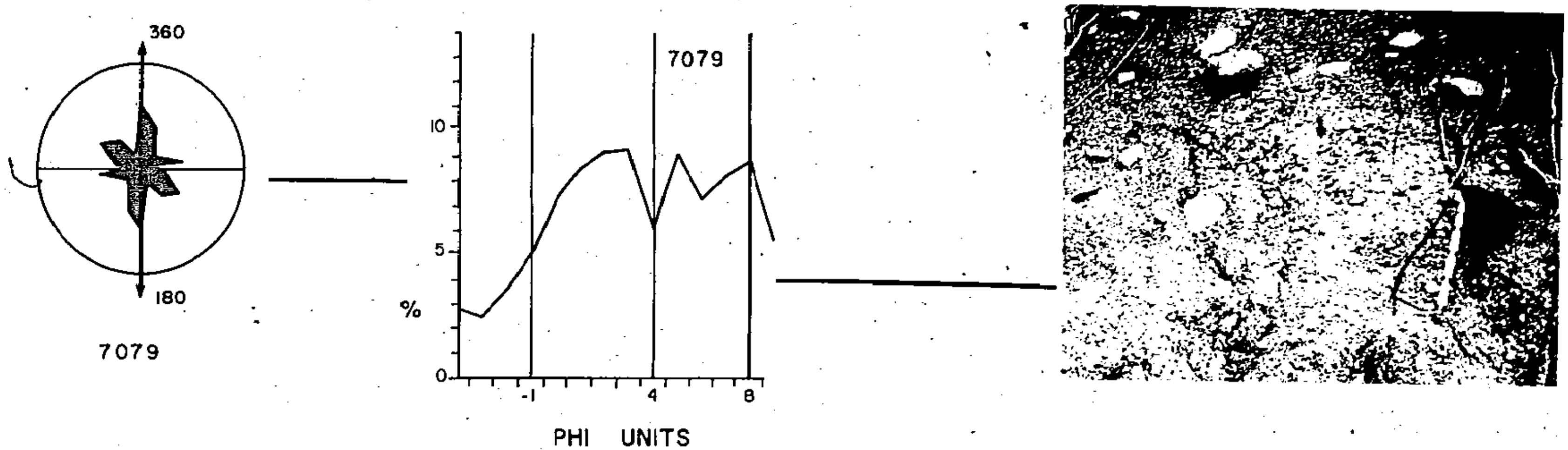


FIGURE 3.21 : BROAD COVE HEAD

the dominant rock type. Till fabric analysis of the coastal deposit is not conclusive. A mean orientation of 360-180 is blunted by a very strong secondary mode at 300 and a tertiary at 085. Flow is considered to have been from the northwest, but it is not unreasonable to assume that basal ice splayed as it came in contact with Broad Cove Head and that flow was modified to show a more southerly component.

3.4.3 Doughball Head to Point Enragée, 1M/6

The coastline from Doughball Head, 19 km north to Point Enragée is significantly different from the Placentia Bay coast. It is essentially a continuation of the area lying between Grand Bank and Garnish in that is rises gently from sea level. For example, in the Harbour My God Point area, the gradient is ~15 m/km. Yet, the coastal terrain is not particularly homogenous. It is made up of recurrent zones of outwash that meld with areas of washed till, and rocky headlands that jut into Fortune Bay. Striae are oriented 265-310, indicating ice flow into Fortune Bay and, significantly, there is evidence of marine overlap along the whole coast. A surface sample which was obtained at location 7089, north of Long Beach at a point ~15 m a.s.l., is considered typical of upper tills along the coast. It showed a very gravel-rich matrix with a median size at -2.47 ϕ and secondary mode at 0.5 ϕ. This is evidence of surface wash in the till. At a point 0.5 km further south, an 8 m section was exposed on the coast by marine erosion (Fig. 3.22). The location shows 2.8 m of compact, red-pink, very silty till with subrounded and subangular pebbles and cobbles. The matrix has a mean size of 0.5 ϕ, is symmetrically distributed, and very poorly sorted. It is overlain by

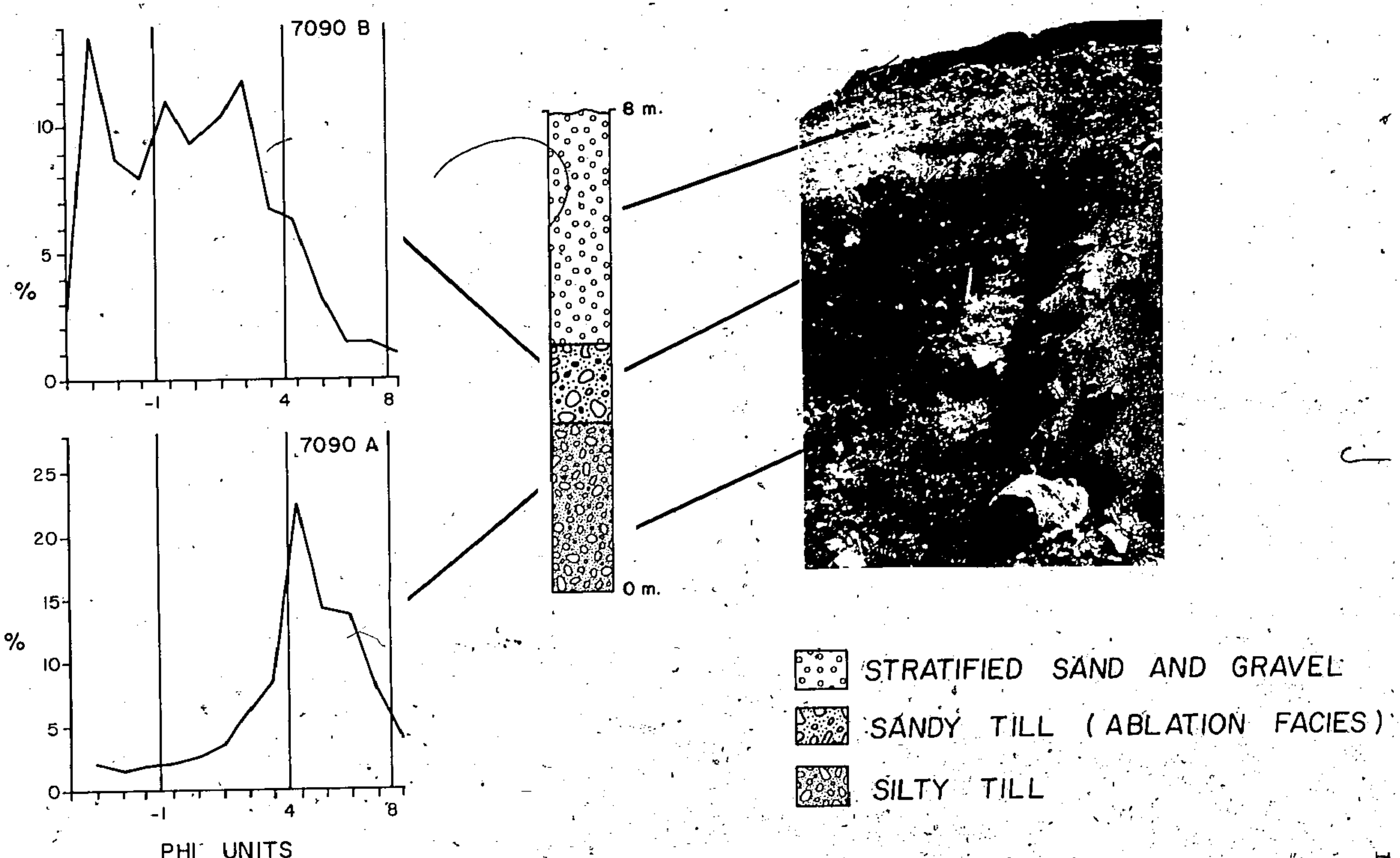


FIGURE 3. 22 : LONG BEACH

1.3 m of brown-pink, sandy till that incorporates lenses of pink, fine sand and silt similar in colour to the lower facies. A grain size analysis of the sandy till indicates that its mean is located in the very coarse sand fraction and that it is symmetrically distributed. The lower unit is just as poorly sorted as the upper, but it is siltier and more closely related to the basal tills further south (Samples 7001a, 7004a and 7066a).

Most of the clasts in the lower till were derived from local sources (Precambrian, intrusive, porphyritic rocks), but the upper Devonian, brown conglomerate and Cambrian and earlier, red sandstone content is from the Hermitage Peninsula. The upper till shows similar indicators of flow from the Hermitage Peninsula. In addition to those mentioned above, Cambrian siltstone, and Cambrian and earlier quartzite from the English Harbour East area were discovered. Both these tills are overlain by as much as 3.9 m of stratified, well rounded sand and cobble gravel that dips seaward.

No other well exposed sections of till are visible from this point south to Garnish. Occasionally, such as at Devil Brook Head, small pockets of pink-grey, silty till occur with slumped ablation material, but no stratigraphic information was obtainable.

3.4.4 Bay de l'Eau River and Western Feeder Pond, 1M/7

The till sections at Bay de l'Eau River (Samples 7113a,b and 7114) are significant in that they are very heavily iron stained and, hence, open to interpretation as old tills. Also, they are similar in lithology to other stained and weathered material in the general vicinity, specifically, deposits noted at sample point 7095, which is located 1.5

km southeast of Western Feeder Pond on a stream that flows east into Bay de l'Eau River, and just south of Western Feeder Pond at location 7111.

The till at Bay de l'Eau River (Fig. 3.23) contains two sections partly separated by a large block of very iron stained cemented conglomerate. These blocks litter the banks of the river for several kilometers downstream. The lower 1.4 m of the exposure consists of an iron stained, grey, coarse sand till with subrounded to subangular matrix clasts 2-5 cm in diameter and larger cobbles 15-20 cm in diameter. This is overlain by >8 m of iron stained, very coarse, granular till which has a mean grain size of $-1.39\ \phi$.

Provenance analysis of the lower unit indicates that most of the material is local, Precambrian, schistose tuff and felsite with Ordovician, green, varved, tuffaceous slate and Silurian granite marking transport from the northwest. The sourse of the upper, coarser facies is not significantly different; it is again to the northwest, but is a little more clearly defined in that the variety of rock is slightly greater.

The fabric was measured in a river cut located 1 km downstream from sample point 7113. It showed a mean orientation of 340-160 with minor secondary modes at 040 and 280. This is indicative of major ice flow to the south as ice cleared Bay de l'Eau River.

A collection of pebbles was taken from a highly indurated, iron stained outcrops at location 7095 because it appeared to be the source-type for the blocks of material contained in samples 7113 and 7114. A pebble count showed that 98% of the clasts were local, Precambrian, schistose, green tuff with grey-green sandstone making up the remainder of the

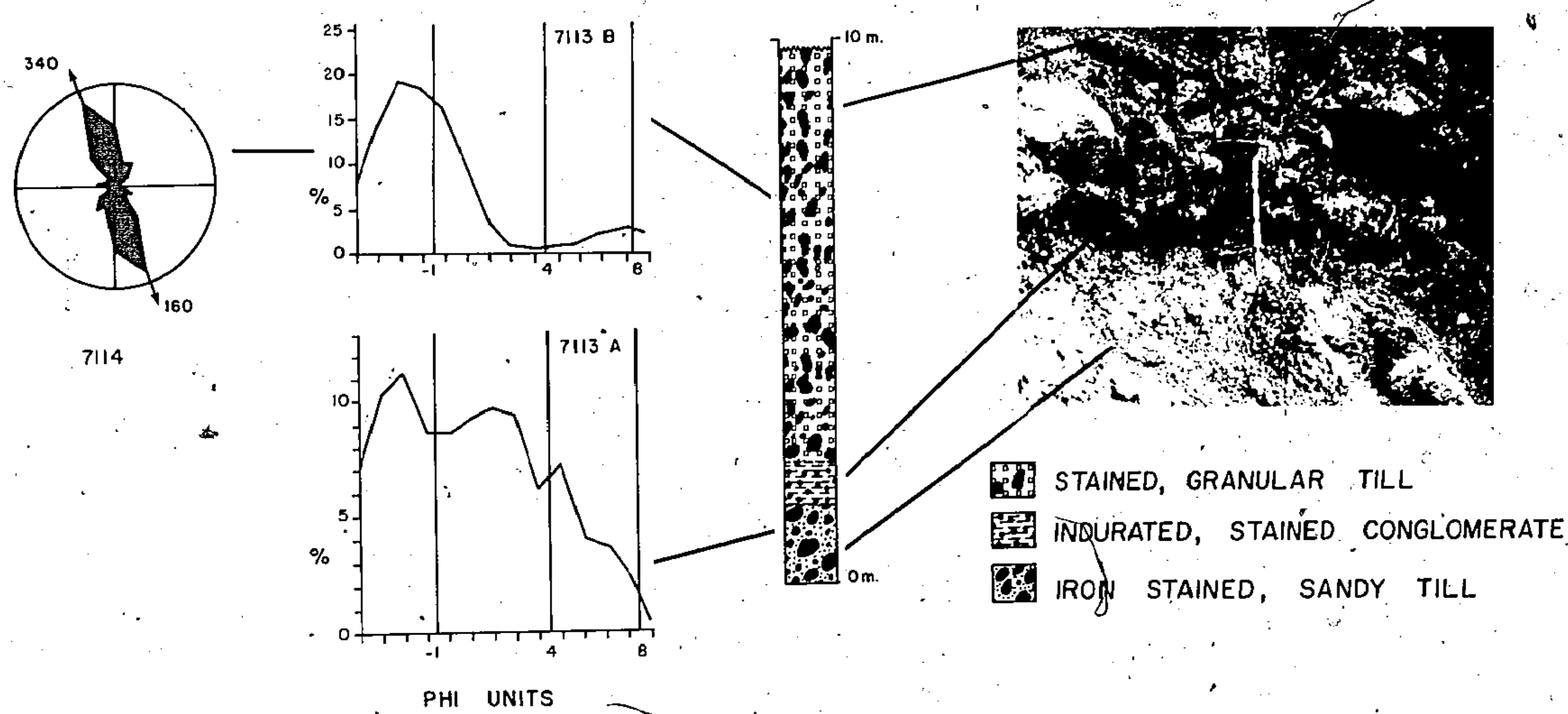


FIGURE 3.23 : BAY DE L' EAU RIVER

sample. Clearly, suggesting a Quaternary source for this material is tenuous.

At sample point 7111 on highway 210 near Western Feeder Pond, there is a borrow pit which shows outcrops of heavily iron stained, schistose tuff with 280 fresh striae cutting highly weathered and iron stained striae and grooves oriented 170. A yellow-brown, iron stained, silty till that contains angular, stained and cemented blocks similar to those found along Bay de l'Eau River is exposed in the walls of the pit. The section is inportant in that the surficial material overlies stained bedrock, one of the few locations on the peninsula where this occurs.

Lithologic identification of the clasts indicated that while most of the material was local, Precambrian, schistose tuff, the Devonian granite and Ordovician, tuffaceous slate content was from western sources. O'Brien (pers. comm.) states that schistose tuff in this area is rich in secondary iron. This is obviously a factor that needs consideration if iron content of the tills is being used as a criterion for weathering intensity. Therefore, a trace element analysis similar to that carried out at Main Brook (Section 3.3.1), was attempted on bulk samples from points 7095 and 7111. The results (Table 3.5) show high values for copper, lead, iron and molybdenum. (The latter is normally about 2-4 ppm. in Appalachian tills.) The values are significantly higher than those obtained from the Main Brook tills and as well as suggesting old tills, the inclusion of gossans from sulfide ore bodies in the matrix is considered highly likely.

Iron stained tills do not blanket the Bay de l'Eau River area, rather, they are confined to deeply incised river sections and road cuts.

TABLE 3.5

Trace Elements,
Atomic Absorption Spectroscopy, PPM
Main Brook, Bay de l'Eau River, and Western Feeder Pond

SAMPLE NO.	Cu	Pb	Zn	Co	Ni	Ag	Cr	U	Mo	Mn	Fe%
7041 B	00074	00076	00495	00013	00013	0000	0009	001.4	0003	1440	07.60
7041 A	00046	00153	00168	00015	00011	0002	0020	001.1	0004	1365	07.40
7095	00064	00452	00049	00003	00002	0020	0032	001.1	0028	0292	06.95
7111	00565	00708	00151	00011	00006	0028	0036	001.1	0082	0610	11.80

More abundant is the loose, grey, very sandy till veneer that is found in pockets over the highland. Good exposures of this till are found 0.5 km due west of Western Feeder Pond in a basin that contains rock knobs, eskers and hummocky moraine. The basin opens westward to Jacques Fontaine, and stretches southwest and northeast for 5-10 km. It is here that the diagnostic 125 and 155 weathered, iron stained striae, cut by fresh 270 striae which were described in Section 2.2.2 are located. Provenances of the sandy, grey tills (Samples 7110, 7112) are from the immediate west with high percentages of local rock material being present. Transport from the Hermitage Peninsula is not proven, although, rock types similar to those found locally are also present northwest of English Harbour East.

3.4.5 Paradise River Drumlinoids, 1M/9

One of three areas of drumlinoid concentration in the field area is the Paradise River-Sandy Harbour River basin. Others are located at the eastern end of the Marystown-Garnish lowland and in the Gisborne basin, north of Terrenceville. New road construction near Paradise River allowed an opportunity to obtain some reasonably accurate baseline data on what is considered to be an older drumlinoid, compared to those near Gisborne Lake. Sample point 7117 is situated on a road cut at the northeast distal end of a 150 x 1300 m southeast-northwest oriented, dissected drumlinoid located in an area essentially devoid of any quantity of till cover. The sample site (Fig. 3.24) contained a buff-yellow, very sandy till with an iron stained, weathered matrix in which the soil horizon is developed to a depth of 50 cm. The matrix has a mean grain size in the coarse sand fraction (1.2. ϕ) and is fine skewed. Sample 7116, which was obtained

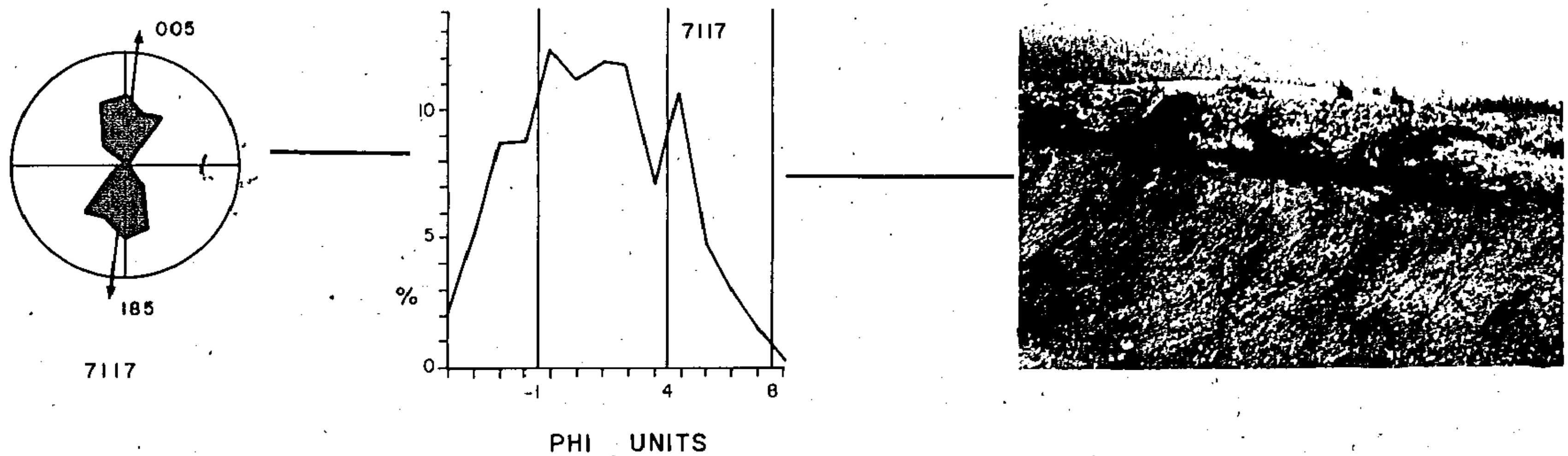


FIGURE 3.24 : PARADISE RIVER DRUMLINOID

from a borrow pit several hundred metres further down ice, has the same textural parameters.

Provenance of the material is to the northwest and west because high percentages of Devonian granite and Precambrian; schistose, porphyritic felsites are present in the sample. Two till fabric analyses were completed on the drumlinoid (Locations 7117 and 7116). Mean orientations of 185-005 and 155-335 and primary modes at 170-140 agree reasonably well with the local direction of ice flow obtained from striae.

3.4.6 Swift Current area, 1M/16

Detailed analyses were made in a road cut through a kame terrace located at the top of the valley feeding due east into the Mooring Rock Cove-Swift Current basin (Location 7127). The section is of interest because it occurs at a point that is considered to be on the late-Wisconsinan limit for the Burin Peninsula. East of this area, the terrain is devoid of extensive till cover while to the west, hummocky, sandy, granite till and ice disintegration features are abundant. Figure 3.25 depicts the Swift Current material, which consists of loose, buff, sandy till with a mean grain size of 2.90 ϕ. The kame terrace also includes discontinuous lenses of sand and substratified till, but the above parameters are considered representative for the deposit as a whole. Clasts are subrounded to subangular, and generally of the cobble to boulder size range. The source of the till is local and from the northwest with >85% of the identified clasts being Cambrian and earlier pyroclastic rocks and Precambrian, schistose felsite and tuff. This is similar to transport noted for most till samples in the immediate area (see samples 7120 and 7134).

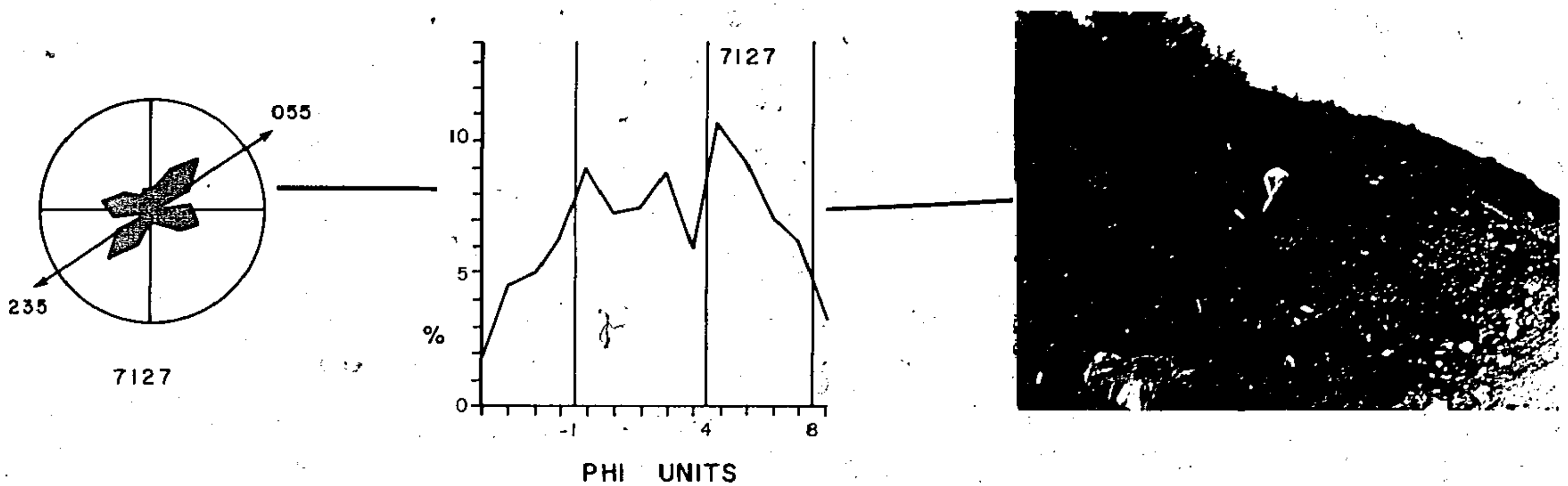


FIGURE 3.25 : SWIFT CURRENT

A till fabric analysis of the kame terrace deposits reveals ice flow to the northeast (mean orientations 055-235, dominant modes 040 and 280). These reflect topographic flow toward Swift Current, a situation that probably existed during the final throws of the late-Wisconsinan stade (see Fig. 2.1 and surficial maps, Appendix 2).

3.4.7 Surface deposits on the upper Burin Peninsula

Till deposits on the upper Burin Peninsula are variable in thickness, texture, and colour. In the area northeast of Swift Current, cover is thicker and less influenced by meltwater than further south and west but is, still, highly variable. Transport direction is from the north-northwest and west. Some of the patches of till exposed in borrow pits, especially that at the point where highway 210 crosses North Harbour River, have considerably iron stained matricies. Soil horizons are relatively well developed (40 cm at sample location 7128, Garden Cove road) and suggest that the exposed tills are older than the kame terrace and ice marginal deposits west of Mooring Rock Cove.

A surface till sample was retrieved from a road cut at the head of Paradise Sound (Sample 7131). The grey, sand matrix has a mean grain size of 0.91 ϕ and is fine skewed. Much of the Cambrian slate, red siltstone and sandstone which crops out in the area is iron stained so it is not clear whether the 45 cm deep soil horizon at this location is a result of weathering or leaching. Transport is dominantly from the west, indicated by lower and middle Devonian granite and granodiorite. However, a high percentage of local shale and sandstone is present.

In the area west and north of the highway 210-Terrenceville turn-off, till cover is fresh and within the area considered to have contained late-Wisconsinan ice. Along the upper western perimeter of Fortune Bay between Femme and Terrenceville, till cover is sparce. Just north of Grand le Pierre, a sample of pink-brown, sandy till with a mean in the coarse sand (0.03ϕ) fraction was analyzed for its clast-origins. All were from the immediate north. The sample was rich in Devonian granite and Ordovician, brown, crystal, lithic tuff, chert, basalt and pyroclastics. Sample 7123 is a surface material taken from a depth of 40 cm on the interior of the drift limit, 4.7 km east of Gisborne Lake. Again, transport of the sorted, very coarse sandy till is local as well as from the north and northwest.

3.4.8 Discussion

Fenton and Dreimanis (1976) emphasize that glacial correlations should be firmly based on lithostratigraphic or biostratigraphic units. Most of the interconnections developed in this thesis have been based on stratigraphic position or till properties such as; texture, composition-lithological or geochemical, fabric, colour, and weathering characteristics. However, because of the poor stratigraphy on the upper peninsula, the glacial deposits are not easily correlated with those of the St. Lawrence plateau or Marystown-Garnish lowland.

The oldest unit examined was the compact, basal till plug at Broad Cove Head. Because of its induration, iron stain, western clast provenance and fabric, it is considered to be part of the glacial phase that deposited the lower till at Cashel Cove, Main Brook, Salmonier Pond and Beaver Pond. Based simply on stratigraphic evidence, one might assign this unit to the early-Wisconsinan, pre-St. Pierre interstadial since it immediately underlies the "Fortune Bay" till at the Main Brook section. But since it does not crop out anywhere along the Fortune Bay coast, and because of the profound difference in weathering when it is compared with the "Fortune Bay" till, it may more logically be a preserved remnant of an older event (Illinoian).

The stained till patches at Bay de l'Eau River, Western Feeder Pond and along highway 210 from Black River to North Harbour River, 1M/16 are considered to be a generation younger. The high Cu, Pb and Mo content in samples 7095 and 7111, compared to the stratigraphically old till at Main Brook (Table 3.5), are anomalous and suggest conditions other than subaerial weathering. These deposits are thought to be correlative with the larger scale, southeast-oriented flutings in the Sandy Harbour River area and are representative of the last major ice flow across the peninsula, i.e., early-Wisconsinan, post-St. Pierre interstadial (Dreimanis and Goldthwait, 1973) and unit B5, grey mud, early-Wisconsinan stade (Alam and Piper, 1977). This is similar to the age determined for the drumlinoids on the Marystown-Garnish lowland. Recent work by Baranowski (1978) has shown that drumlins are formed when a flow regime changes from warm to cold based ice. Although no detailed studies were attempted on the Burin Peninsula flutings, the ideas of Shaw (1975) and Smalley and Unwin (1968) seem more acceptable locally. The drumlins are confined to southeast-northwest oriented basins and troughs and are likely to have been formed because of late glacial, strongly directed flow which caused the subglacial till to attain a critical boulder-content density and pack into stable obstructions.

The same event (early-Wisconsinan, post St. Pierre interstade) is suggested for the lower, pink-grey, silty till and its overlying ablation facies situated on the east, Fortune Bay coast from Doughball Head to Point Enragée. The coastal and inland units differ both in degree of weathering and texture, however, they have the same western to northwestern provenance and overall stratigraphic position. The texture and colour of the "Fortune Bay" till are probably a result of transport across marine sediment in Fortune Bay (Section 3.3.7), but the same till located north of Fortune Bay does not contain a silty marine component in its matrix and, hence, would be more susceptable to both subaerial weathering by leaching and periglacial action.

The washed surface tills on the upper peninsula near the Bay L'Argent and Terrenceville highway intersections are considered ablation facies of *in situ*, non-erosive ice from the late-Wisconsinan. They appear fresh and have no appreciable weathering. The clasts are dominantly local with no appreciable distant transport from either the east or west.

The onshore-directed striae and the related deposits along the Placentia Bay coast are problematical. It may be that the striae only reflect a shifting ice divide at some point in the deglacial phase of the early-Wisconsinan substage. Similar orientations recorded on the interior, upper part of the peninsula may even represent minor throws of local, late-Wisconsinan ice. However, if ice responsible for the striae was located further to the east on the Avalon Peninsula, then its effects should have been visible in the provenance studies. This was not so. In such a case, the various Placentia Bay coves would have acted as re-entrants in a manner similar to the valleys along the Niagara escarpment (Straw, 1968), but evidence of proglacial ponding similar to that described by Straw is lacking (since drowned, ?). Also, distant meltwater sources for the raised glaciofluvial terraces located on the Placentia Bay coast (Chapters 2 and 4), imply that ice responsible for the building of the kame terraces at Red Harbour and coves further to the northeast was not late-Wisconsinan. Therefore, a source older than late-Wisconsinan is suggested.

Figure 3.26 shows the textural differences of the various tills and generally, they fall into groups representing the Fortune Bay tills and sandy, ablation facies. The lower, oldest units such as that at Main Brook are not clearly distinguishable.

Taken on the whole, the till fabric analyses (Fig. 3.27) are of limited value in determining overall patterns of glaciation. The figure is included, however, so that there is ready reference for between-site comparisons. In many cases, fabrics were obtained from upper, ablation units and, hence, the mean orientations and primary modes reflect local topographic conditions. Strongest orientations are found in areas of well directed flow such as at the Paradise River drumlinoid (Locations 7116, 7117). For multiple-till units (Locations 7006, 7020, 7041, 7057, 7066), the fabrics are not well directed as is to be expected in reworked till sheets; stronger orientations would be expected in ice push features such as ribbed moraine (Cowan, 1968) or cross-valley moraines (Andrews, 1963a,b).

3.5 Conclusions

The various discussions on surficial deposits (Sections 3.2.7, 3.3.7 and 3.4.8) have tended to cover a variety of subjects. Therefore,

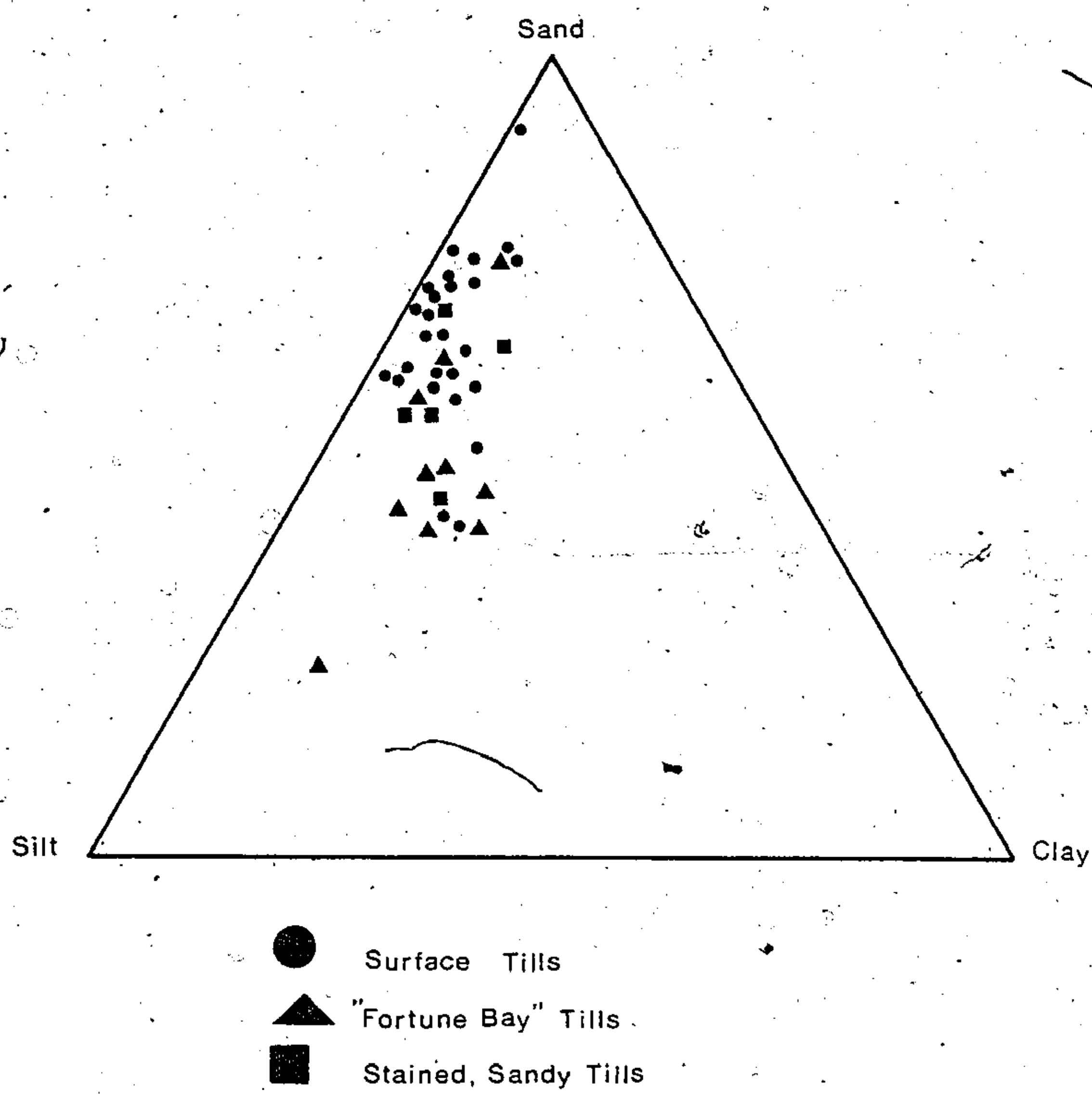


FIGURE 3.26: Textural ternary diagram of Burin Peninsula tills.

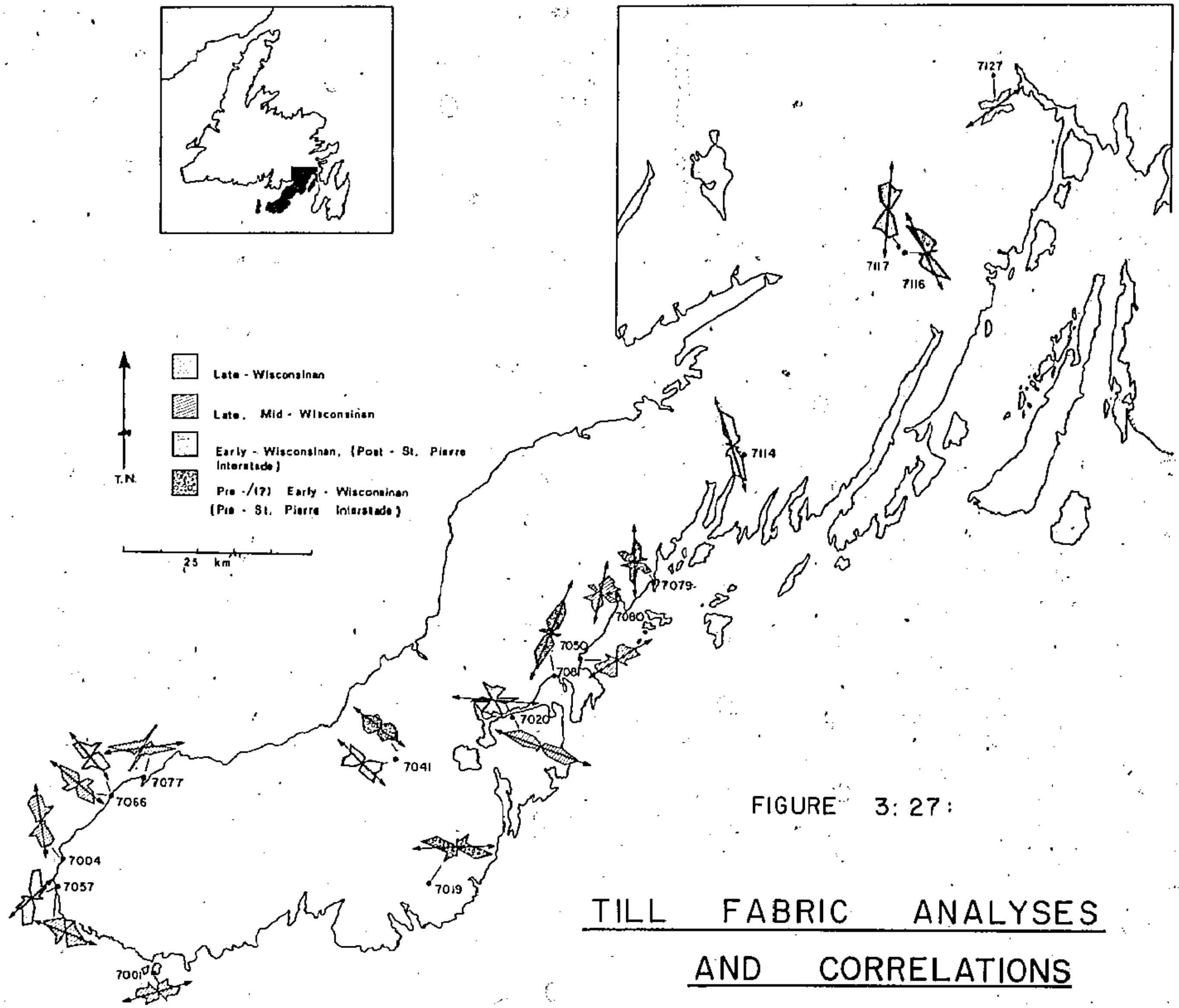


FIGURE 3: 27:

TILL FABRIC ANALYSES AND CORRELATIONS

a brief summary of glacial events is required to introduce the following chapters.

1. The oldest glacial event recorded on the peninsula is thought to be pre-Wisconsinan (Illinoian), or early-Wisconsinan, pre-St. Pierre interstadial in age, and to have originated with Newfoundland centred ice. Deposits are typified by a cemented and weathered, sandy till which is exposed as the lower unit at Main Brook. Stratigraphic evidence for the following nonglacial interval is absent, but if the stade was pre-Wisconsinan, then it was followed by the Sangamonian interglacial and a significant break exists between the upper and lower tills at Main Brook.

2. This was followed by the Fortune Bay event, which has been assigned to the early-Wisconsinan, post-St. Pierre interstadial. Ice was again centred on the mainland of Newfoundland, and it is considered to be the last to affect the whole of the Burin Peninsula. It deposited a grey-pink, marine derived, silty till along the west coast of the peninsula and a sandier, granite rich till on the area north and east of Fortune Bay.

3. Mid-Wisconsinan marine overlap is indicated by fossiliferous silts and sands located on the southwest coast of the peninsula. These have been the most important chronostratigraphic marker since it is from this point that the two preceding stades have been dated.

4. Following this, the lower Burin Peninsula was covered by ice centred to the south and east, which moved generally northwest at least as far as the Marystown-Garnish lowland, and probably into Fortune Bay. This is thought to have occurred during the late mid-Wisconsinan. The till generated during this event has a loose, slightly weathered, sandy matrix and contains a high percentage of locally derived material.

5. The final glacial event (late-Wisconsinan) had limited influence on the Burin Peninsula. Ice was essentially confined to that area north and northwest of the Terrenceville-Swift Current margin depicted in Figure 2.1. South of this margin, there was limited, highland ice contained in shallow, topographic basins. Late-Wisconsinan tills are very loose with a sandy matrix and fresh, angular clasts.

CHAPTER 4

DEGLACIAL, ISOSTATIC/EUSTATIC RESPONSES

4.1 Introduction

4.1.1 Preamble

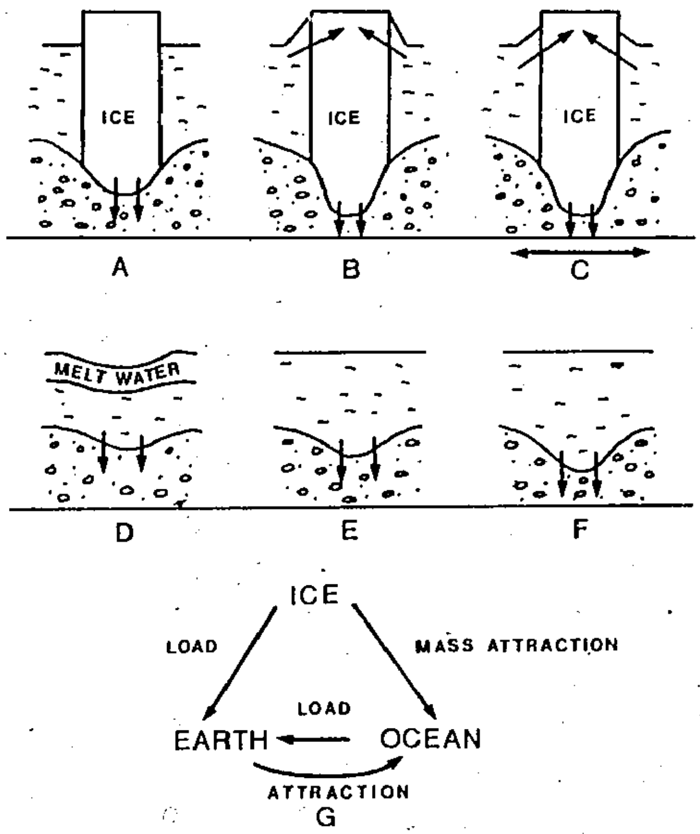
It became obvious early in the field component of this study that there are as many as four distinct types of marine and glaciomarine features on the Burin Peninsula that reflect isostatic and eustatic change. Unfortunately, it is generally unclear from the literature review which features pertain to the various events described in the previous chapter. Briefly listed, the features include raised marine benches capped by surficial deposits, raised benches devoid of surficial cover, uplifted terraces and beaches formed in glaciofluvial and glaciomarine material, and subaerial organics now located below sea level. By way of clarification, the term bench will refer only to the relatively flat surfaces cut by marine action in bedrock. Terraces are levels eroded in unconsolidated deposits.

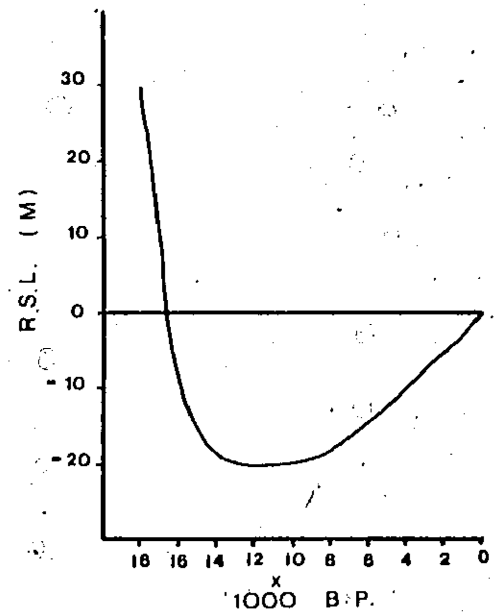
4.1.2 Previous research

Very little work has been done on the south coast of Newfoundland with respect to determining the geneses of raised glaciomarine features. Except for Widmer (1950), who described sets of lacustrine (sic) strandlines along the west coast of proglacial "Lake Fortune" as well as striated Sangamonian benches", and Grant (1975c), who also described an interglacial bench, all other work relegated the cutting of benches and terraces to late-Wisconsinan marine overlap (Flint, 1940; Van Alstine, 1948; Potter, 1949; Jenness, 1960; Wightman and Cooke, 1978). An exception is Walthier (1948) who indicated that non-marine sources (sic.) could be responsible for some of the raised benches. Flint (1940) and Jenness (1960) presented isobase maps for the area (Fig. 1.2) which varied in detail but not pattern. Both depicted the line of zero net postglacial emergence well north on the peninsula, but Potter (1949) put it south of both St. Pierre et Miquelon and the Burin Peninsula. Wightman and Cooke (1978) also place the zero isopleth south and east of the Burin Peninsula but show as much as 10 m of uplift on its southeast coast. They assume general deglaciation around 13,000 ± 500 B.P. and rely only on the minimal data provided by Grant (1975c) to update the pattern suggested by Jenness (1960). It becomes clear that a reappraisal of all strandlines with regard to the time and mode of formation is needed.

Adding further complication to the situation is the unknown position of sea level at given points during the Wisconsinan. Andrews (1975a) contended that since ice, during the mid-Wisconsinan interstade withdrew to a position approximately equal to that at 12,000 B.P., then we may logically expect sea level to have been ~55 m below present, a position it supposedly occupied 12,000 B.P. More recently, Farrell and Clark (1976; Clark and Farrell, 1978) have seriously examined conventional eustatic sea level theories (Fairbridge, 1969; Shepard, 1963; Emery and Garrison, 1967; Bloom, 1967). They built on the isostatic (elastic lithosphere-subcrustal material transfer) work of Walcott (1972a,b) who outlined three areas where sea level expressions should differ; rapid and large uplift under the melting ice, submergence peripheral to the ice sheets, and coastal tilting causing emergence on continental shorelines distant from the ice. Clark and Farrell added; limited areas of time-dependent emergence, a region of submergence on mid-oceanic islands, and a zone of emerged beaches up to 2 m in elevation that should be ca. 5000 years old. Without going into detail, their model (Fig. 4.1) is based on a spherical viscoelastic earth upon which the changes in separation between two dynamic surfaces - the ocean floor and ocean surfaces are considered. These processes are inextricably related since the water load is a function of both the changing ice load and the changing distance between the ocean floor and the geoid.

Clark and Farrell placed Newfoundland in a transition zone between the area covered by Laurentide ice and, hence, of continual emergence (Walcott's first area), and that subject to continual submergence because of a collapsing forebulge (Walcott's second area). At the ice margin transition zone, there is initial emergence followed by submergence. The amount of submergence and the height of the oldest emerged beach is dependent upon the distance from the ice sheet. Coasts close to the ice have greater emergence and less submergence than those slightly more distant. The authors suggested that a beach in Newfoundland formed 18,000 B.P. will have emerged 30 m, and that younger beaches will have submerged 22 m because of the migrating forebulge. However, they added that their sea level predictions for localities close to ice sheets are most in error and that slight modifications of the assumed melting history and/or the rheological model of the Earth's interior are





Transition zone between Zones I and II. Sea level in this region is controlled by the migration of the collapsing forebulge which causes initial emergence followed later in time by submergence. Newfoundland (47°N, 60°W).

FIGURE 4.1: Interactions among ice loads, water loads and the deformable Earth, after Clark and Farrell (1978): (A) The weight of the ice deforms the Earth and (B) the ice mass attracts the water. (C) The transfer of matter within the Earth distorts the geoid. Similarly, (D) the weight of meltwater depresses the Earth differentially and (E) more water flows into this depression increasing the water load and (F) causing added deformation of the ocean floor. These processes are interrelated as indicated in (G).

necessary. This is unfortunate since a most useful tool, considering the paucity of datable material relating to various marine stands, would be firm data on the position of sea level at a given point in time. But, ideas on relative sea level position are in as much of a state of flux as those on late Quaternary ice limits.

4.1.3 Methodology

With the above discussion in mind, an attempt was made to resolve the patterns of isostatic/eustatic change on the Burin as they relate to specific chronological and spatial events. For the sake of consistency, information will be presented in chronological order starting with what are thought to be the oldest features, despite the fact that they are not necessarily the most prominent or prolific.

The approach involved measuring the elevations of all accessible, suspected, raised marine features with a hand level or a Wallance and Tiernan barometric altimeter. In the case of significant suites of raised beaches or multi-terraced, raised, glaciomarine deposits, detailed profiles were constructed with the aid of a Wild level. When measuring benches capped with surficial material, heights were recorded at the mid-point of the exposed, horizontal surface (Fig. 4.2a), and when no surficial material was present, elevations were taken at the base of the wave-cut notch or break in slope immediately before the landward rise. For simple outwash terraces, the leading edge was considered to be a more accurate measure (Fig. 4.2b), while in the case of a continuous, vertical series of beaches or terraces, the break in slope below each ridge was used (Fig. 4.2c). If bedding was visible in any given terrace, then

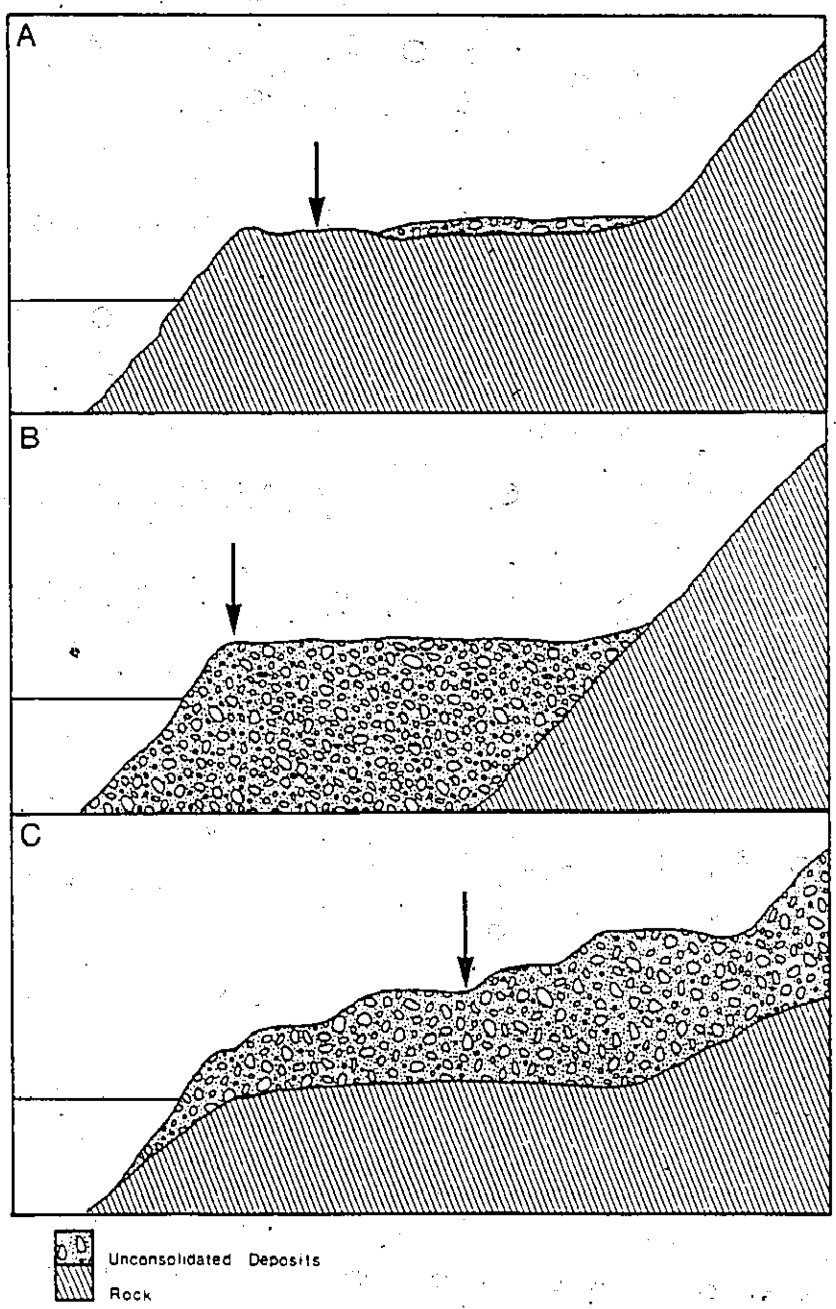


FIGURE 4.2: Raised marine bench and terrace heighting methodology modified after Gray (1975).

the contact between foreset and topset material was used as the height of marine limit. Unless there was a higher beach ridge atop the terrace to indicate further marine overlap, then this would have been the highest point at which marine deposition might be assured. Present sea level was always taken to be the nearest, well defined debris line above the immediate, local high tide mark. Therefore, the elevations of benches and terraces recorded in the text as above sea level (a.s.l.) are, in fact, above high, high tide level.

Interestingly, Gray (1975) did not consider these methods accurate enough. For work along the coasts of Scotland, he preferred closed traverses carried out with a surveyor's level tied to Ordnance Survey bench marks. Obviously, attempts at such accuracy are commendable, however, in remote areas such as the south coast of Newfoundland, where bench marks are few and access is limited, one cannot be expected to utilize such methods in anything but the most local and small scale studies. As has been shown by Blake (1975) in his detailed study of postglacial emergence at Cape Storm, Ellesmere Island, the use of barometric altimeters is still considered *derègle*.

Along with records of elevation, dips and strikes were taken from stratified deposits and a careful search was made for marine biota and other datable material which might help to determine marine limits.

4.2 Raised Marine Benches and Events

4.2.1 Correlations

Several levels of benches, which are cut in various types of bedrock, occur along the coasts of the Burin Peninsula. By means of the various types of instrumentation described the previous section, heights were obtained from most of the accessible remnants. The elevations were then correlated in sets and the results are shown in Table 4.1 and Figure 4.3. One well-defined, low-level bench was measured at 54 locations and forms a continuous 3.1-4.9 m a.s.l. ($\bar{x}$ = 4 ± 1 m), surface from English Harbour East and North Harbour to Allan's Island and Lawn. Except where exposed to coastal storms and marine wash, it is well striated, and covered with till deposits of varying thickness. Exposed bench widths are highly variable. For example, benches are less than 2 m wide at Taylor's Bay (Fig. 4.4) but reach several tens of metres at more exposed locations such as Salmonier, Burin Inlet (Fig. 4.5). Because this level is more-or-less horizontal, striated, and generally till covered, it is assigned to the Sangamonian interglacial. This is considered to be the only period during which world wide sea level would have attained long term stability allowing the cutting of so continuous a surface. Grant (1976b) has recognized a similar event on Cape Breton Island. There, the bench is capped by peat dated at more than 40,000 B.P. Till-cover on the Burin Peninsula 4 m bench is variable in texture and age; it can be a grey-pink "Fortune Bay" till or a sandier, ablation facies, depending on the location. Additional series of bench levels were determined from spot elevations (Table 4.1) and occur at 50, 40 ± 3, 26 ± 2, 20 ± 1, 17 ± 1, 11 ± 1 and 8.5 ± 1 m a.s.l. The age(s) of the first three groups in this series must remain conjectural since they are isolated in occurrence. However, the four lowermost series are very similar in elevation to those described by Widmer (1950) on the Hermitage Peninsula at 21.3, 17.7, 10.7 and 8.8 m a.s.l.,

TABLE 4.1

Raised Marine Benches, Locations and Elevations

LOCATION	MAP SHEET	BENCH ELEVATION	SET ELEVATION
Dantzic Cove	1L/13	8.5 m	8.5±1 m
Wreck Cove	1L/13	3.7 m	4 ±1 m
Lannon Cove	1L/13	3.4 m	4 ±1 m
Allan's Island	1L/13	3.1 m	4 ±1 m
	1L/13	10.1 m	11 ±1 m
Point au Gaul	1L/13	3.1 m	4 ±1 m
Taylor's Bay	1L/13	3.6 m	4 ±1 m
Lord's Cove	1L/13	4.8 m	4 ±1 m
	1L/13	42.3 m	40 ±3 m
Lansey Bank Cove	1L/13	4.6 m	4 ±1 m
	1L/13	7.6 m	8.5±1 m
Great Lawn Harbour	1L/13	3.1 m	4 ±1 m
Shoal Cove	1L/14	5.4 m	4 ±1 m
Great St. Lawrence Harbour	1L/14	4.9 m	4 ±1 m
Middle Head	1L/14	5.0 m	4 ±1 m
Corbin	1L/14	3.4 m	4 ±1 m
	1L/14	12.2 m	11 ±1 m
Epworth	1M/3	1.5 m	4 ±1 m
	1M/3	4.9 m	4 ±1 m
Burin Bay	1M/3	4.9 m	4 ±1 m
	1M/3	18.3 m	17 ±1 m
Burin	1M/3	4.9 m	4 ±1 m
	1M/3	12.2 m	11 ±1 m
	1M/3	14.3 m	17 ±1 m
Salmonier	1M/3	4.8 m	4 ±1 m
Bull's Cove	1M/3	7.0 m	8.5±1 m
	1M/3	17.1 m	17 ±1 m
Port au Bras	1M/3	7.6 m	8.5±1 m
Fox Cove	1M/3	3.5 m	4 ±1 m
	1M/3	12.0 m	11 ±1 m
Tides Cove Point	1M/3	41.0 m	40 ±3 m
Beau Bois	1M/3	4.8 m	4 ±1 m
Little Bay	1M/3	4.8 m	4 ±1 m
Mooring Cove	1M/3	4.6 m	4 ±1 m
	1M/3	7.6 m	8.5±1 m
Rock Harbour	1M/3	6.7 m	4 ±1 m
Jean de Baie	1M/3	1.5 m	4 ±1 m
	1M/3	3.1 m	4 ±1 m
White Point	1M/3	2.9 m	4 ±1 m
Garnish	1M/3	1.7 m	4 ±1 m
Beach Cove	1M/4	4.8 m	4 ±1 m
	1M/4	6.1 m	4 ±1 m

TABLE 4.1 (cont'd)

LOCATION	MAP SHEET	BENCH ELEVATION	SET ELEVATION
Fortune Head	1M/4	7.6 m	8.5±1 m
Grand Beach Point	1M/4	2.5 m	4 ±1 m
Brown Harbour	1M/6	16.8 m	17 ±1 m
	1M/6	24.7 m	26 ±2 m
Long Beach	1M/6	4.6 m	4 ±1 m
Point Enragée	1M/6	2.7 m	4 ±1 m
	1M/6	3.4 m	4 ±1 m
	1M/6	6.1 m	4 ±1 m
	1M/6	9.5 m	8.5±1 m
	1M/6	24.7 m	26 ±2 m
Wood Cove	1M/6	5.9 m	4 ±1 m
Red Harbour	1M/7	1.5 m	4 ±1 m
	1M/7	3.1 m	4 ±1 m
Rushoon	1M/7	6.4 m	4 ±1 m
	1M/7	13.0 m	11 ±1 m
	1M/7	18.3 m	17 ±1 m
Baine Harbour	1M/7	3.5 m	4 ±1 m
	1M/7	5.5 m	4 ±1 m
	1M/7	22.0 m	20 ±1 m
Parker's Cove	1M/7	3.0 m	4 ±1 m
	1M/7	5.5 m	4 ±1 m
	1M/7	6.4 m	4 ±1 m
Monkstown	1M/9	6.7 m	8.5±1 m
	1M/9	13.4 m	11 ±1 m
Davis Cove	1M/9	8.3 m	8.5±1 m
	1M/9	10.7 m	11 ±1 m
Great Sandy Habour	1M/9	7.6 m	8.5±1 m
	1M/9	11.6 m	11 ±1 m
	1M/9	15.8 m	17 ±1 m
Langue de Cerf Cove	1M/10	1.5 m	4 ±1 m
Jacques Fontaine	1M/10	18.5 m	20 ±1 m
	1M/10	50.3 m	50 m
Bay L'Argent	1M/10	28.9 m	26 ±2 m
Little Bay East	1M/10	1.5 m	4 ±1 m
	1M/10	4.9 m	4 ±1 m
	1M/10	50.3 m	50 m
East Bay	1M/10	4.8 m	4 ±1 m
	1M/10	6.7 m	8.5±1 m
Little Harbour East	1M/10	4.6 m	4 ±1 m
Harbour Mille	1M/10	6.7 m	8.5±1 m
	1M/10	9.4 m	11 ±1 m
	1M/10	18.3 m	17 ±1 m
	1M/10	42.6 m	40 ±3 m
Grand le Pierre	1M/10	4.6 m	4 ±1 m
	1M/10	23.2 m	26 ±2 m

TABLE 4.1 (cont'd)

LOCATION	MAP SHEET	BENCH ELEVATION	SET ELEVATION
English Harbour East	1M/10	4.6 m	4 ±1 m
	1M/10	28.0 m	26 ±2 m
Swift Current	1M/16	4.6 m	4 ±1 m
	1M/16	13.0 m	11 ±1 m
Garden Cove	1M/16	4.5 m	4 ±1 m
North Harbour	1M/16	4.5 m	4 ±1 m
	1M/16	4.8 m	4 ±1 m
	1M/16	22.0 m	26 ±2 m

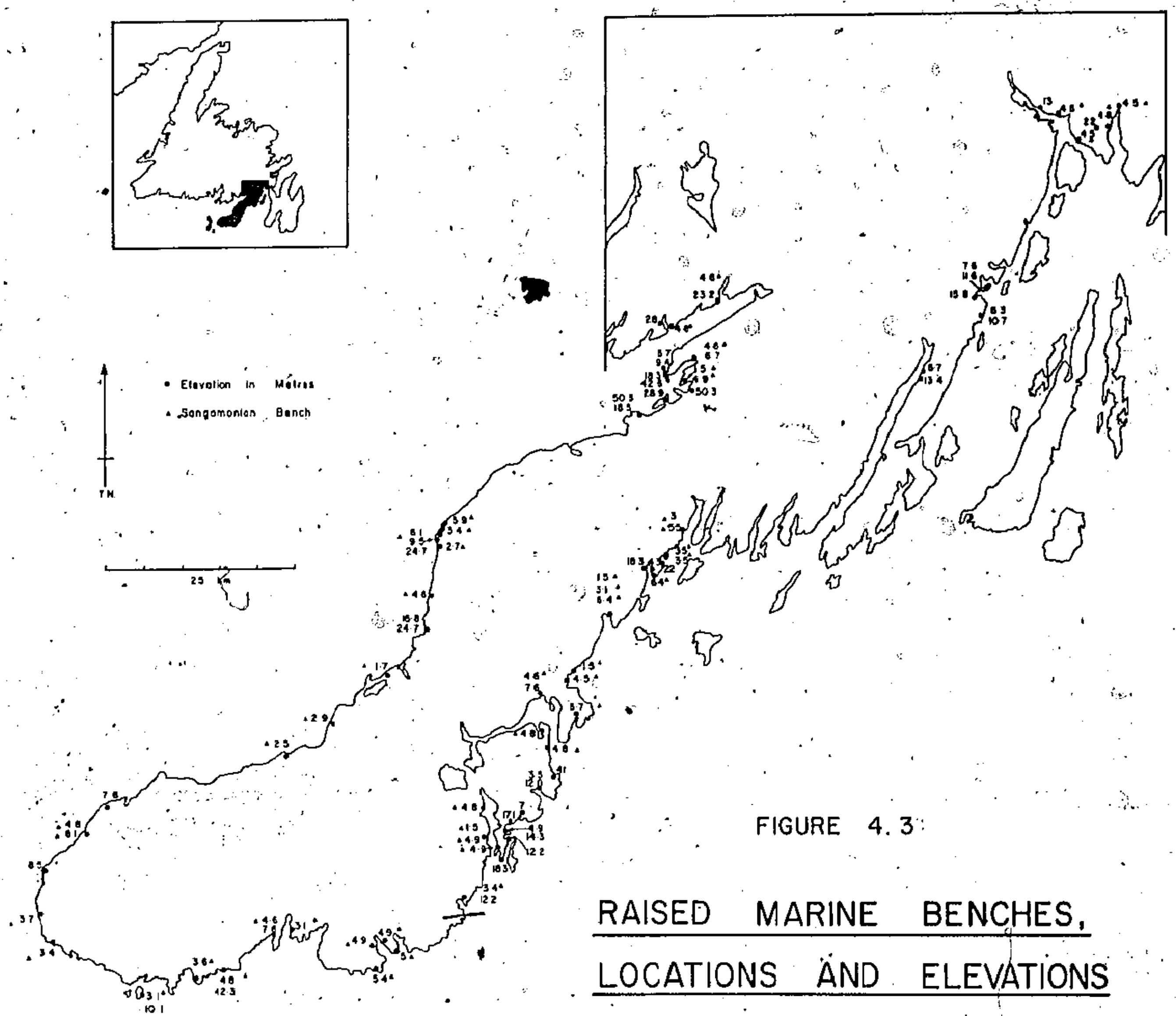


FIGURE 4.3

RAISED MARINE BENCHES, LOCATIONS AND ELEVATIONS

FIGURE 4.4: Taylor's Bay, raised marine bench. The 3.6 m a.s.l. Sangamonian bench is capped by a loose, sandy, rubbly till.

FIGURE 4.5: Salmonier, raised marine bench is 4.8 m a.s.l. and overlain by thin, silty, sandy till containing a high percentage of red and grey mudstone and shale. It is correlative with the bench shown in Figure 4.4.

and may be Wisconsinan in age.

4.2.2 Discussion

The argument as to the time required to cut a marine bench in resistant rock is difficult to resolve. For example, Flint (1940) used elevations obtained from wave-cut, bedrock benches to help define his late-Wisconsinan, Bay of Islands Surface, but Grant (1977b) ascribed the surface to the Sangamonian. In discussing the records of past sea levels in Britain, Synge (1977) stated:

> "Such is the effectiveness of glacial erosion that the survival of pre-existing marine features cut in bedrock, such as cliffs and shore platforms within the areas covered by the last glaciation is not usually expected. Yet in Scotland, in areas exhibiting signs of considerable glacial erosion, a marine cliff and platform with a notch at 25-40 m has survived in the inner Hebrides (Wright, 1937; McCann, 1968). In some cases, till overlies the platform. Recently, the very well developed platform associated with a cliff notch at 10 m at Oban in Scotland has been considered to belong to a late interglacial phase (and) the former correlation of this shoreline with the Main Postglacial Beach (Wright, 1937) cannot be upheld. The freshness of this feature and its accordance in level with a buried gravel beach in the Forth dated about 10,500 B.P. suggest that it may have formed during cold conditions prevailing during the last advances of the Scottish glaciers between 10,800 and 10,300 (Sissons, 1974). On the other hand the short time available for its formation and the presence of ice moulding and striae that predated the latest advance of the glaciers on the platform, argue for a much earlier age (Synge, 1966; Gray, 1974a,b)."

This agrees well with the situation encountered on the Burin Peninsula. Because the benches are till covered, at least to the degree of the surrounding terrain, and are developed on competant bedrock, the likelihood of their being cut during the relatively short postglacial period seems unlikely. A problem arises with the interpretation of several of the levels, specifically those at 20 ± 1 m and 17 ± 1 m, in that they are similar in elevation to contiguous terraces cut in unconsolidated deposits. Examples of this situation occur at Jacques Fontaine and Brown Harbour, Fortune Bay and will be discussed further.

4.3 Raised Terraces and Marine Overlap

4.3.1 Depositional events

Evidence gathered from air photo analysis and field investigations has revealed that the deposition of all stratified material was not synchronous, that more than one event occurred, and that the events are separated by considerable periods of time. To reiterate the glacial patterns and stratigraphy described in the previous chapters, it is known that outwash on the lower peninsula is limited to the north and west coast, including the Marystown-Garnish lowland, and that there is no evidence of uplifted surficial deposits along the south coast of the peninsula. Last ice to cover the lower peninsula predates the limited ice on the central highland of the upper peninsula and the well defined ice margin in the Terrenceville-Swift Current area. The following sections will attempt to separate marine overlap for these events both spatially and chronologically. To this end all elevations obtained from raised beaches, and outwash terraces have been tabulated (Table 4.2) and are discussed in greater detail below.

4.3.1.1 Lower peninsula and Marystown-Garnish lowland

It is proposed that the deposits on the Point Enragée-Doughball

TABLE 4.2

Raised Marine Beaches and Terraces;
Locations and Elevations

LOCATION	MAP SHEET	TERRACE ELEVATION	LATE-WISCONSINAN MARINE LIMIT
Dantzic Cove	1L/13	6.1 m	*
Little Dantzic Cove	1L/13	3.3 m	
	1L/13	6.2 m	*
Salt Pond	1M/3	12.0 m	
Mooring Cove	1M/3	4.6 m	*
Spanish Room	1M/3	13.2 m	
Jean de Baie	1M/3	5.3 m	*
Fox Hummocks	1M/3	6.4 m	*
Frenchman's Cove	1M/3	3.7 m	
	1M/3	6.4 m	*
Garnish	1M/3	7.0 m	*
	1M/3	8.4 m	
	1M/3	10.4 m	
Doughball Cove	1M/3	6.4 m	*
Beach Cove	1M/4	3.7 m	
	1M/4	6.5 m	*
Famine Point	1M/4	2.8 m	
Brown Harbour	1M/6	7.5 m	*
Long Beach	1M/6	9.5 m	
	1M/6	12.2 m	
	1M/6	14.5 m	*
Bluff Point	1M/6	4.6 m	
	1M/6	15.0 m	*
Harbour My God Point	1M/6	4.5 m	
	1M/6	16.4 m	*
Point Enragée	1M/6	14.9 m	*
Wood Cove	1M/6	11.2 m	
Red Harbour	1M/7	6.4 m	*
Broad Cove Head	1M/7	2.1 m	
Rushoon	1M/7	6.4 m	*
Parker's Cove	1M/7	6.4 m	*
Boat Harbour	1M/7	6.4 m	*
Bay de l'Eau River	1M/7	6.7 m	
	1M/7	7.7 m	*
Davis Cove	1M/7	7.9 m	*
Great Sandy Harbour	1M/7	7.6 m	*
	1M/7	10.6 m	
Langue de Cerf Cove	1M/10	17.9 m	*
Dog Cove	1M/10	6.7 m	
	1M/10	19.8 m	*

TABLE 4.2 (cont'd)

LOCATION	MAP SHEET	TERRACE ELEVATION	LATE-WISCONSINAN MARINE LIMIT
Jacques Fontaine	1M/10	9.5 m	
	1M/10	14.5 m	*
Bay l'Argent	1M/10	4.6 m	
	1M/10	17.3 m	
East Bay	1M/10	7.6 m	
	1M/10	18.3 m	*
Little Harbour East	1M/10	18.3 m	*
Terrenceville	1M/10	6.1 m	
	1M/10	14.6 m	
	1M/10	16.8 m	*
	1M/10	18.3 m	
Grand le Pierre	1M/10	16.8 m	*
English Harbour East	1M/10	18.8 m	*
Swift Current	1M/16	8.5 m	
	1M/16	11.2 m	*
	1M/16	13.1 m	
	1M/16	16.7 m	
Black River	1M/16	8.5 m	
	1M/16	10.9 m	*
North Harbour	1M/16	4.9 m	
	1M/16	10.9 m	*
Caplin Cove	1M/16	4.8 m	
	1M/16	6.4 m	
	1M/16	11.8 m	*
Come By Chance	1M/16	6.4 m	*
	1M/16	16.7 m	

Head coast, the Marystown-Garnish lowland and the lower west coast of the peninsula were emplaced one event prior to the last, that is, prior to late-Wisconsinan deglaciation. There are several lines of evidence that may be used to substantiate this claim. The series of raised beach ridges located at Bluff Point, Fortune Bay (Location 7087) are not cut in outwash, but instead occur in an area of washed till and rock outcrop (see surficial maps, Appendix 1). Because this location abuts the Marystown-Garnish lowland and preliminary investigation showed that the ridges were considerably higher than the Garnish area outwash, they were studied in more detail. A series of profiles (Fig. 4.6) were constructed across the ridges near Bluff Point and again at Long Beach (Location 7089). Depending on the location, between 5-10 ridges were discernable on the air photos and the local marine limit has been taken as 15 ± 1 m a.s.l. Between Scott Point (near Point Enragée), and Wood Cove, a series of terraces are cut in what appears to be later, glaciofluvial/glaciomarine material. Its age is considered different because the outwash train pours off the highland north and west of Bluff Head where there were limited patches of late-Wisconsinan ice.

Outwash on the Fortune Bay coast of the Marystown-Garnish lowland (Fig. 4.7) is thought to have been deposited at the end of the short, mid-Wisconsinan stadial and graded to a depressed sea level in Fortune and Placentia Bays. Morphological evidence for this lower sea level may be gained from the coarse nature of the kames and outwash located on the coast at Fortune, south of Clawbonny Brook (Fig. 4.8). The coarse, sub-rounded to well rounded, cobble and boulder gravels contained in these deposits appear to be in a more "proximal" position than the small

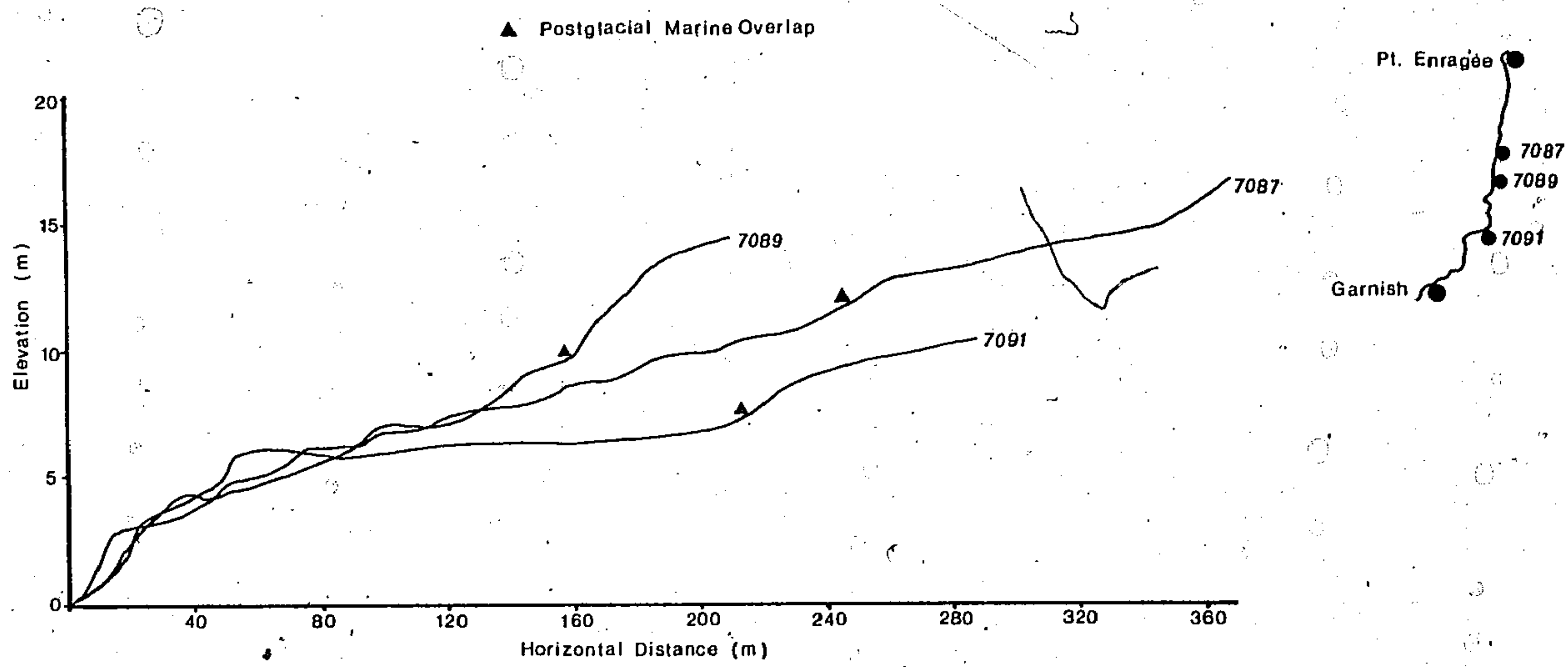


FIGURE 4.6: Profiles of raised marine benches and terraces, Garnish-Pt. Enragée area.

FIGURE 4.7: Doughball Cove coastal section. Shows 6.4 m of glaciofluvial pebble gravel overlying compact, red, silty till. Contact is shown by the altimeter in the lower foreground.

FIGURE 4.8: Coarse, substratified kame-esker complex south of Clawbonny Brook. Deposit is cut by large meltwater channels.

scale, ripple and cross-laminated fine sand and pebble gravel (Fig. 4.9) exposed on the late-Wisconsinan ice limit 1.8 km southwest of Dunn's Pond (Location 7120). On the Garnish River, bedding in weathered, well rounded cobble and pebble gravels strike 355 and dip 15°L; near Freshwater Pond, a strike and dip of 035, 04°R indicate that material was deposited by meltwater pouring towards Placentia Bay. The Main Brook-Winterland area is considered to be one of late, mid-Wisconsinan dead ice (Section 3.3.7) with meltwater channels and glaciofluvial material radiating southeast and northwest from isolated stagnant ice bodies. These deposits interfinger with tills from the previous glacial event. Red, cross-bedded, fine sand and silt with striated pebbles, located 0.9 km northeast of the Main Brook section (Location 7041), oriented 025, 03°R, and overlain by poorly stratified pebble and cobble gravel, are indicative of late, mid-Wisconsinan ice contact deposits (Fig. 4.10). There is limited evidence of marine overlap in the west Freshwater Pond-Winterland area in the form of an intermittent break in slope at ~17 m (see maps, Appendix 1). Exact heights were difficult to obtain and there appear to be no correlative levels along the remainder of the Placentia Bay coast. Because the level is so poorly preserved and is overlain in places by late, mid-Wisconsinan deposits, it is assigned to the mid-Wisconsinan interstadial. At location 7105, south of Salt Pond, there is a coastal section that reveals 4 m of sandy-cobble till overlain by 8 m of stratified, slumped sand and pebble-cobble gravel. This does not represent marine limit, but rather, is a distal remnant of the Freshwater Pond outwash plain. Similarly, the outwash at 13.2 m radiating southwestward from the Creephole Point moraine near Spanish Room Point is thought to predate late-Wisconsinan marine

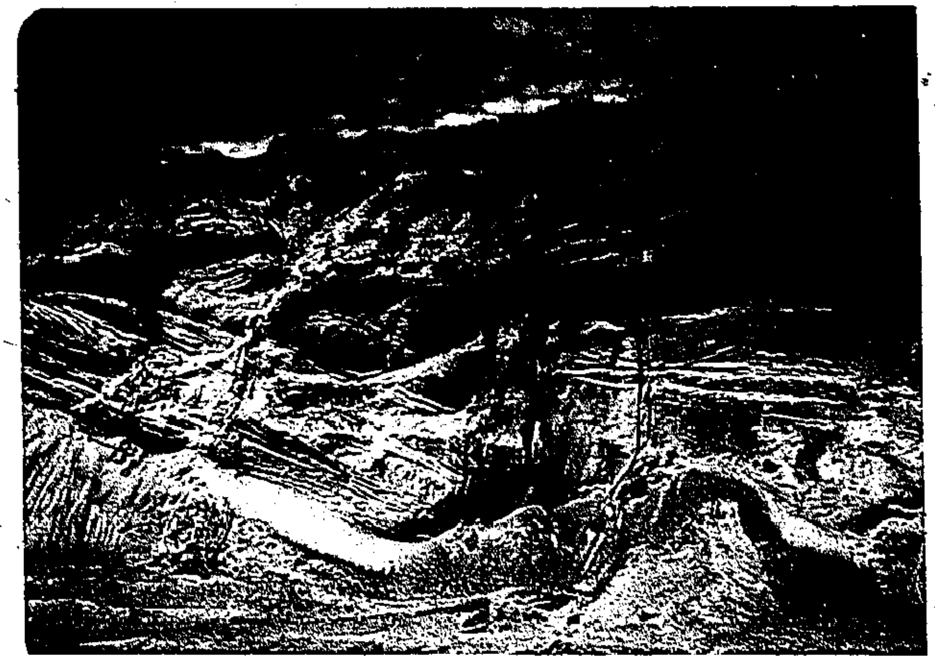


FIGURE 4.9: Well sorted, cross-bedded, post-depositionally faulted sand and pebble gravel in the late-Wisconsinan, Dunn's Pond esker.

FIGURE 4.10: Main Brook ice contact material. Red, fine sand and silt contains striated clasts. It is overlain by glaciofluvial pebble and cobble gravel.

overlap since it does not fit ice limits determined for that substage (Chapter 2), nor is its elevation correlative with others found in the local area.

On the Fortune Bay coast between Grand Bank and Garnish, outwash deposits are sporadic and appear to be truncated at the present coastline. About 1.5 km southeast of White Point on highway 210, there is a borrow pit that provides additional evidence that the outwash and substratified, ice-contact deposits in this area are older than late-Wisconsinan. It shows (Fig. 4.11) >3 m of stratified, rounded, cobble gravel with a significant amount of iron stain on weathered clasts. Compared to known late-Wisconsinan deposits at the head of Fortune Bay, it appears significantly older. A profile was constructed at Brown Harbour (Fig. 4.6) to detail erosional terraces cut in the Garnish River outwash plain. The first well developed terrace level at 6.8 m a.s.l. is developed in aeolian sand dunes, and is considered to be a result of recent marine erosion. Marine limit is taken to be a well developed break in slope 7.5 m a.s.l. at the lowermost edge of an erosional scarp ~170 m farther inland. Because there is no visible evidence of marine erosion inland to the east, and because the deposit grades continuously to a point beyond the present coast, the 7.5 m level is interpreted as being the limit of late-Wisconsinan overlap. The scarp (Fig. 4.12) is discontinuous but appears as a wash limit on the air photographs of the stratified deposits farther south at Doughball Cove. Several terrace elevations were altimetered at Garnish. Of the 10.4, 8.4 and 7 m set, the last is the most pronounced and considered to represent maximum late-Wisconsinan overlap. As well, it is similar to the marine limit

FIGURE 4.11: White Point-highway 210 area. Substratified, iron stained, cobble gravel. Considered to be part of the deglacial phase of the northwest directed, St. Lawrence plateau ice.

FIGURE 4.12: Brown Harbour, 7.5 m a.s.l., late-Wisconsinan, marine terrace cut in late, mid-Wisconsinan outwash.

recorded at Brown Harbour.

For the remainder of the coast along the lower peninsula, it is difficult to determine to what sea levels erosional terraces are graded. A 6.1 m terrace at Dantzic Cove cut through lenses of fluvial, brownish-red, laminated silt and clay and stratified, cobble gravel, all of which overlie a grey, silty, basal till (Fig. 4.13) is thought to be late-Wisconsinan. The material is well sorted and is not morphologically representative of glaciofluvial, or at least proximal, glaciofluvial material. Similar terraces at Little Dantzic Cove were noted at 6.2 and 3.3 m a.s.l. From this point south and east, no raised terraces were recorded along the coast until that previously described at Salt Pond, Burin Inlet.

4.3.1.2 Upper peninsula, Fortune and Placentia Bay coasts

North of Peltry Barasway (1M/6), all the major coves and inlets in Fortune Bay contain pronounced, but eroded, glaciofluvial/glaciomarine deposits which were fed from upland ice sources. At several of the major fjords such as Grand John and Jacques Fontaine, there are raised, ice contact deltas (Fig. 4.14). Because the delta at Jacques Fontaine was considered, by reason of its situation, to be a terminal position for ice in the local area, an attempt was made to retrieve datable material from a kettle hole located on the proximal side (Fig. 4.15). It was thought that since the bottom, encountered at 0.25 m b.s.l. in coring operations, is located close to present sea level, the kettle hole probably contained water since deglaciation and, therefore, had continually collected organic matter. Six bottom samples were obtained with a

FIGURE 4.13: Dantzic Cove, 6.1 m a.s.l. fluvial terrace. The present stream has cut through alluvium and ~2 m of "Fortune Bay" compact, red, silty till. The terrace elevation represents local, postglacial emergence.

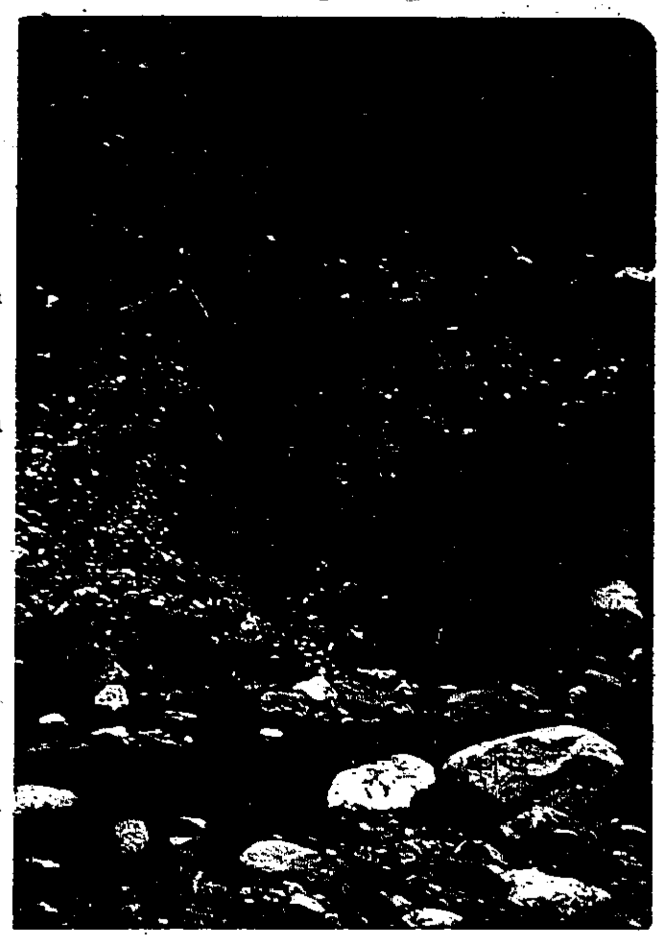


FIGURE 4.14: Ice-contact delta at Jacques Fontaine, 14.5 m a.s.l. Material in the coastal exposure is well sorted, cobble and boulder gravel.

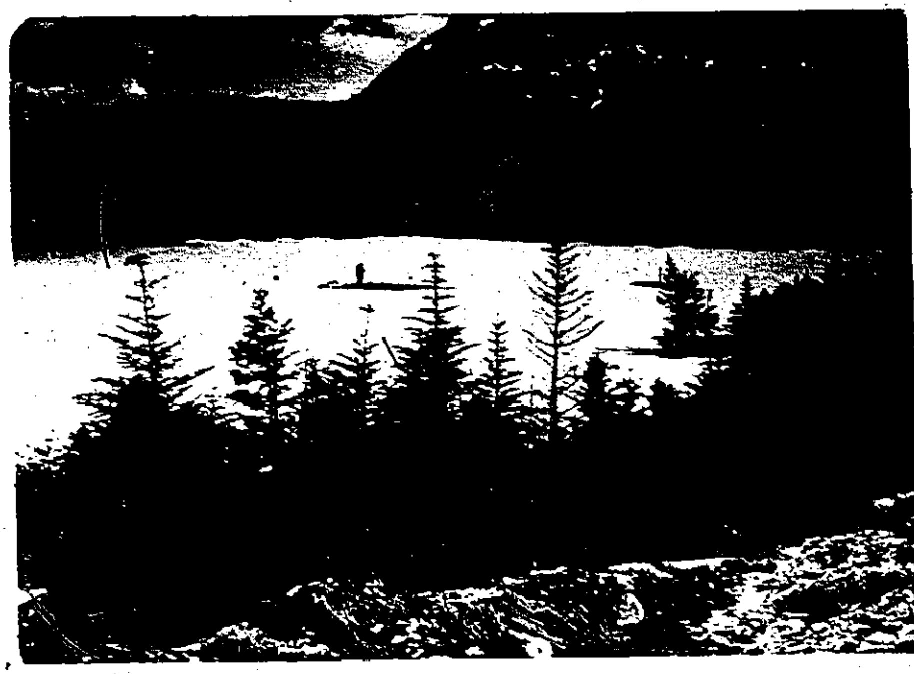


FIGURE 4.15: Proximal kettle hole on the Jacques Fontaine ice-contact delta. Water level is 6.3 m a.s.l. Plate shows palynology coring operations, February 1978.

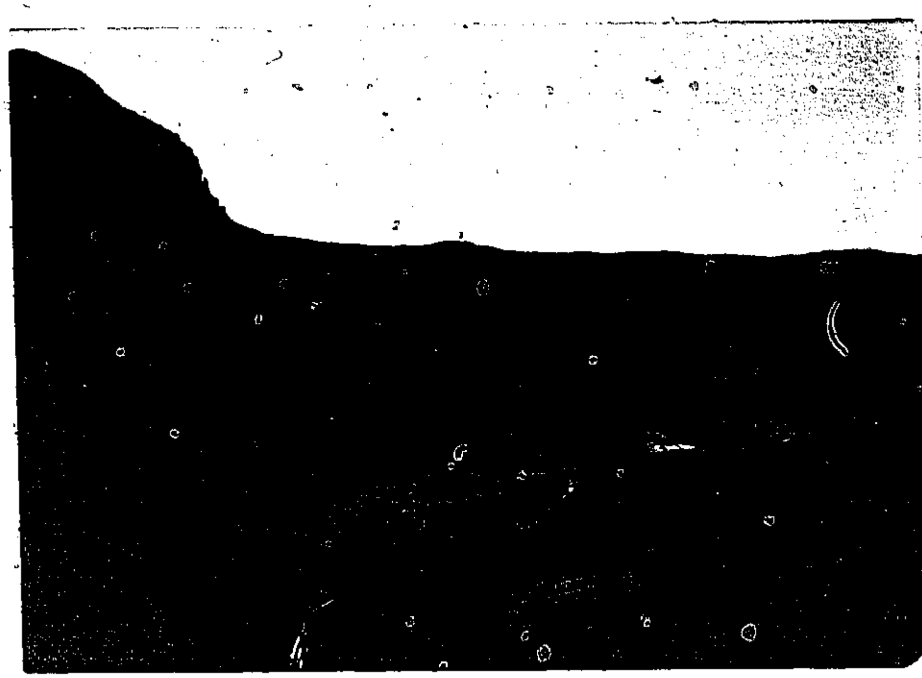


FIGURE 4.18: Emerged, glaciomarine delta at the mouth of Grand le Pierre Brook. The 16.8 m a.s.l., late-Wisconsinan delta was fed by upland sources of meltwater.

Livingstone Corer from various points in the pond. These yielded an average of 100 cm of core that was classified as follows;

0 - 30 cm	dark brown, soft, fibrous gyttja
30 - 60 cm	firmer, dark brown, coarse detritus gyttja
60 - 85 cm	firm, fibrous, peaty sediment
85 - 100 cm	very coarse, fibrous and woody peat
>100 cm	light, buff brown pebbly silt (some organics)

The bottom 40 cm were analyzed by L.D. Farley-Gill, Paleoecology Lab., G.S.C. Ottawa and the assemblages encountered are shown on Fig. 4.16. They are dominated by birch (*Betula*) which increases slightly upward. Fir (*Abies balsamea*) appears relatively constant throughout, and spruce (*Picea*) shows a slight increase at the 90 cm level and above. Other tree genera are present in minimal amounts, some (e.g. *Ulmus*) are a probable result of long distance wind transport. Alder (*Alnus*) is the only shrub present in all samples. Pollen of herbaceous taxa is present in varying small numbers with the exception of *Polypodiaceae* which shows local abundance in the basal assemblages and then declines rapidly upward. Of the aquatic taxa present, *Cyperaceae* increases upward to the 70 cm level and then declines, *Sparganium* displays a local abundance at the time of deposition of the 70-80 cm depths, and *Sphagnum* is somewhat more abundant at the base of the profile.

There are no local correlatives with this profile except that of Terasmae (1963) who reported on three bogs from the Avalon Peninsula, Newfoundland. The beginning of the fir incursion at Whitbourne Bog is radiocarbon dated at 8420±300 B.P. (I(GSC)-4). Below this dated depth pine and nonarboreal pollen (NAP) are relatively high; above it both fir and spruce increase gradually. At the time of deposition of the base of the Goulds Bog core, radiocarbon dated at 7400±150 B.P. (L-3911), both fir and

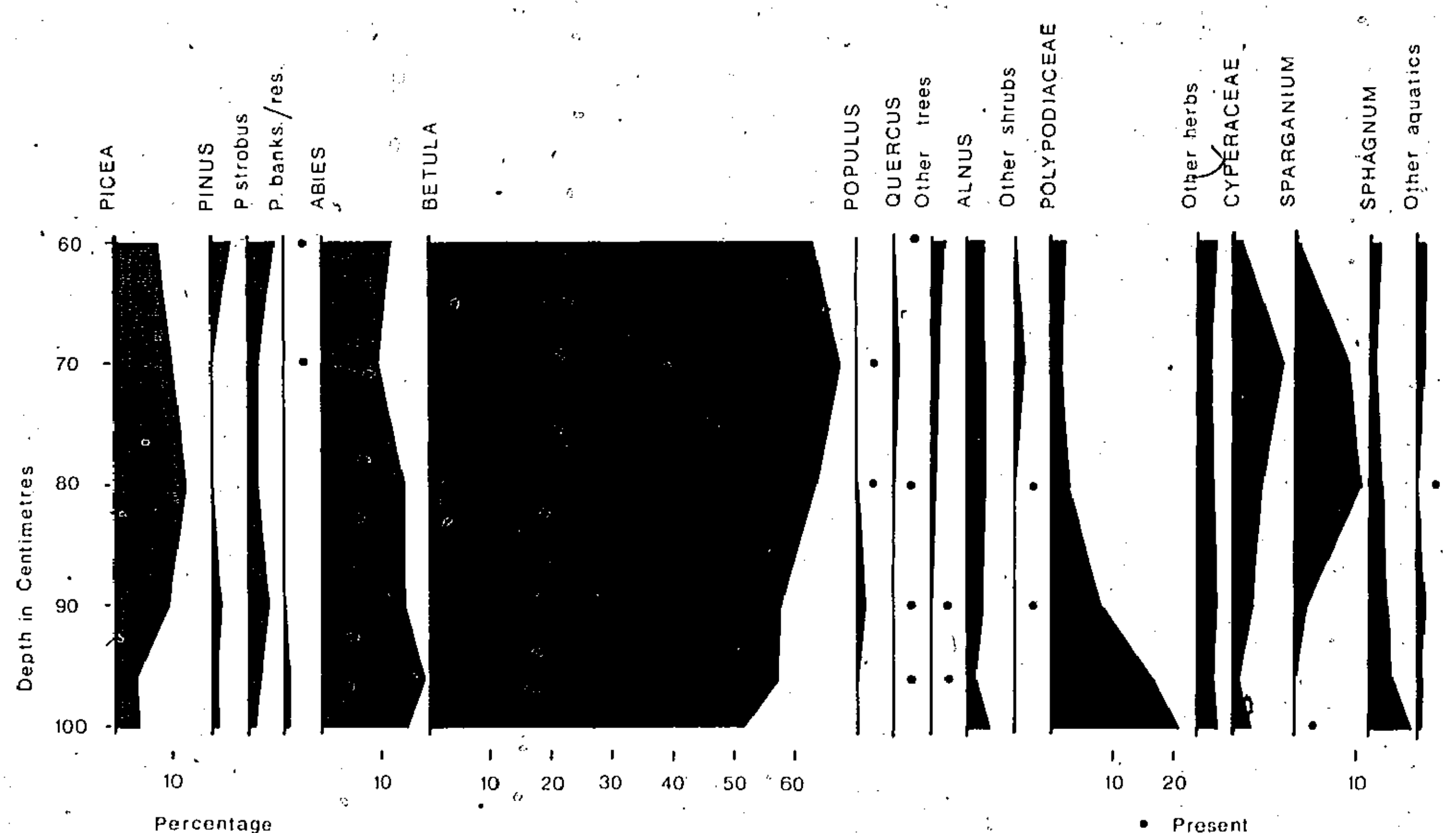


FIGURE 4.16:

Palynology, Jacques Fontaine kettle hole, location 7140 spruce were well established. The third bog reported by Terasmae was much younger. Correlation of the following assemblages with those of Terasmae places the age of the base of this core somewhat younger than 8000 years B.P. because of the relatively large percentages of fir and spruce and low values of pine and NAP. A closer palynological resemblance exists with Whitbourne Bog where more taxa have similar relative percentages. The best correlation with Whitbourne Bog occurs at a depth well above the dated depth. With only one radiocarbon data available for Whitbourne Bog, and a sedimentary change from peat to gyttja, interpolation of age within the core is very difficult due to the change in the rate of deposition. Therefore, the basal age of the profile is less than 8000 years B.P. and could be as little as 5000 years B.P. Subsequent C^{14} dating of the profile yielded an age of 2330 ±50 B.P. (G.S.C. 2685). While it was hoped the date would be much closer to actual deglaciation, the above results do suggest that outwash deposits on the upper peninsula probably relate to late-Wisconsinan ice.

A series of profiles (Fig. 4.17) were surveyed at Jacques Fontaine (Location 7139), Terrenceville (Location 7119) and English Harbour East (Location 7125). From the elevations obtained, marine limit was determined to be 14.5 m a.s.l. at the former and ~18.5 m a.s.l. at the latter two locations. Later erosional terraces have been cut at 7.6, 6.1 and 4.6 m. Similar elevations were obtained on a raised delta at Grand le Pierre (Fig. 4.18) and at Little Harbour East where a raised tombolo was noted at 18.3 m a.s.l.

On the upper Placentia Bay coast, all raised glaciofluvial deposits radiate from inland meltwater sources. This is exemplified at

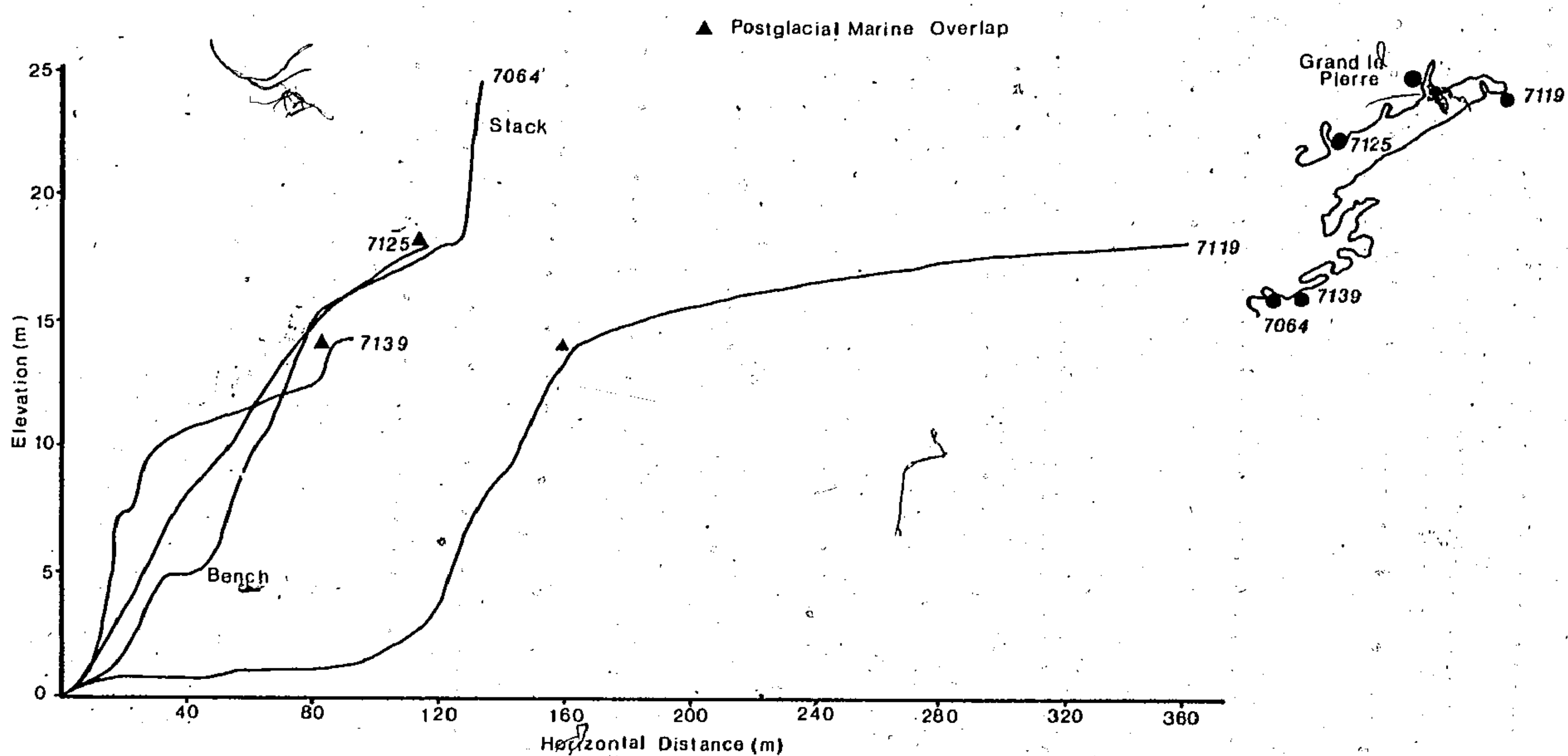


FIGURE 4.17: Profiles of raised marine benches and terraces, upper Fortune Bay area.

the mouth of Sandy Harbour River (Fig. 4.19) where a large expanse of well stratified quartz and feldspar sand, and granitic pebble - cobble gravel oriented 040, 32°R, is located ca. 7.6 m a.s.l. at its most distal position and 10.5 m a.s.l. at the mouth of the river. Further north at Swift Current, North Harbour and Come-by-Chance, the record of postglacial emergence is more complicated. The Swift Current outwash plain (Fig. 2.9) grades from 12-11 m a.s.l. at Mooring Cove to 8.5 m near Black River at the mouth of the bay. However, the terrace levels do not form a continuous surface; several tributary valleys added minor amounts of fluvial material from the north and south. Immediately west of Cannon Hill, cross-bedded sand and pebble gravel that is oriented 090, 09°R overlies a well striated and polished bench at an elevation of 13.1 m a.s.l. and grades northward to a 16.7 m a.s.l. niche-plateau. At North Harbour, erosional terraces were levelled at ~11.8, 6.4 and 4.8 m a.s.l. in glaciomarine sand and gravel. A search of the sediments revealed the presence of marine foraminifera (Table 3.1) that are diagnostic of a low saline, sandy bottom, cold, shallow water environment. Marine limit is taken to be ~10 m a.s.l. At Come By Chance, two terrace levels were measured. The higher, considered to be a kame terrace break in slope and not graded to any water mark was levelled at 16.7 m a.s.l. while the lower, 6.4 m a.s.l. terrace represents late-Wisconsinan marine limit.

One problem which was alluded to earlier in this chapter (Section 4.2.2) concerns the age relationship of raised benches and late-Wisconsinan outwash terraces that are located at approximately the same elevation. The best example of this situation occurs at Jacques Fontaine where there is a raised stack and bench seaward of the fjord, ice contact delta (Fig.

FIGURE 4.19: Great Sandy Harbour, 7.6 m a.s.l., late-Wisconsinan outwash plain. Deposits are dominantly granitic from sources located well inland.

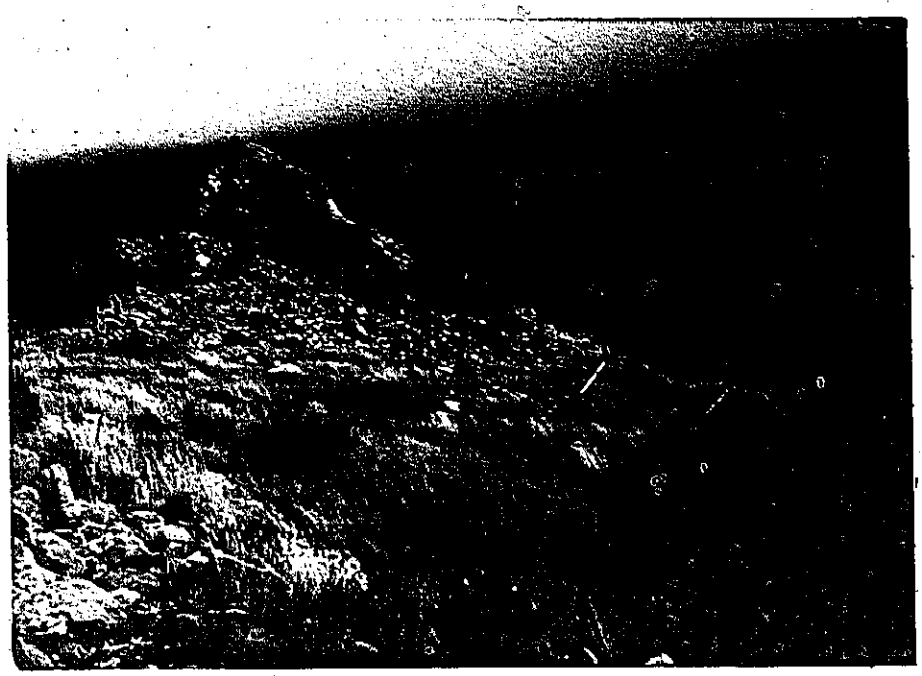


FIGURE 4.20: Jacques Fontaine raised stack and marine bench located 18.5 m a.s.l. The 14.5 m a.s.l. ice-contact delta is visible in the right background.

4.20) that is located at approximately the same elevation (Fig. 4.14). The base of the stack (Profile 7094a) is 4 m above the top of the Jacques Fontaine delta, however, the elevations are close enough to raise the question of contemporanity. Thus, do the stack and bench relate to late-Wisconsinan deglaciation and if so, how would it be possible to cut so pronounced a set of features in so short a period of time with falling sea levels, and if they relate to an earlier period of stable sea levels (St. Pierre interstadial?), why was the stack not toppled by later glaciations? The location of the stack, near the mouth of a fjord and relatively near present sea level, necessarily rules out the possibility of non-erosive ice, which is generally confined to highlands (Sugden, 1977b). Although dates are lacking, the logical answer would appear to be that the stack and bench were cut during the lengthy (ca. 30,000 years, Dreimanis and Raukas, 1975) mid-Wisconsinan interstadial when sea level would have been stable for a longer period of time than since the end of the late-Wisconsinan stade. The reason that the level approximates that of the younger ice contact delta further inland, is that sea level rise and fall through the mid-Wisconsinan is thought to have been similar to that of the late-Wisconsinan postglacial (Andrews, 1975a). A similar situation is envisaged for the homotactic benches and terraces at Brown Harbour further to the south, and the discontinuous wash limit west of Freshwater Pond.

4.3.1.3 Discussion

While no materials were discovered that could be used to precisely date marine limit and deglaciation, several lines of reasoning lead to the conclusion that there is more than one event responsible for the deposition of outwash on the Burin Peninsula. The evidence is somewhat subjective, but considered valid nonetheless. The ice contact deposits and glaciofluvial trains of the Marystown-Garnish lowland are considered to have been deposited by ice that covered the St. Lawrence plateau and from patches located north of and in the Garnish Pond Basin. Evidence for this is derived from the pattern of a pronounced outflow of stratified material from a well defined ice marginal position on the lower, west coast of the Burin (Fig. 2.1). This, along with the highly dissected nature of the deposits in the Winterland-Main Brook area, the iron stained cobble gravels southeast of White Point (1M/3), the apparent grading of trains to a lower sea level, marine overlap of the coast near Long Beach, and the lack of evidence for terracing along the lower south and southeast coasts, implies that the time period involved is the deglacial phase of the late, mid-Wisconsinan stadial discussed in section 3.2.7. The sets of marine benches occurring at 20 ± 1 m and 17 ± 1 m along with the west Freshwater Pond wash limit were formed somewhat before this during the mid-Wisconsinan interstadial, and were not subsequently overridden by ice.

The remaining glaciofluvial material on the peninsula is considered to have been deposited towards the end of the late-Wisconsinan, ca. 13-15,000 B.P. As is shown on Figure 4.21 and the surficial maps in Appendix 1, the source for most of this material was generally some kilometres distant. On the mid and lower west coast, late-Wisconsinan activity was confined to eroding low terraces in contemporaneous, fluvial material at locations such as Little Dantzic Cove and Dantzic Cove, and marking its position by overlapping previously emplaced deposits, such as the outwash plain at Frenchman's Cove and Garnish as well as the till

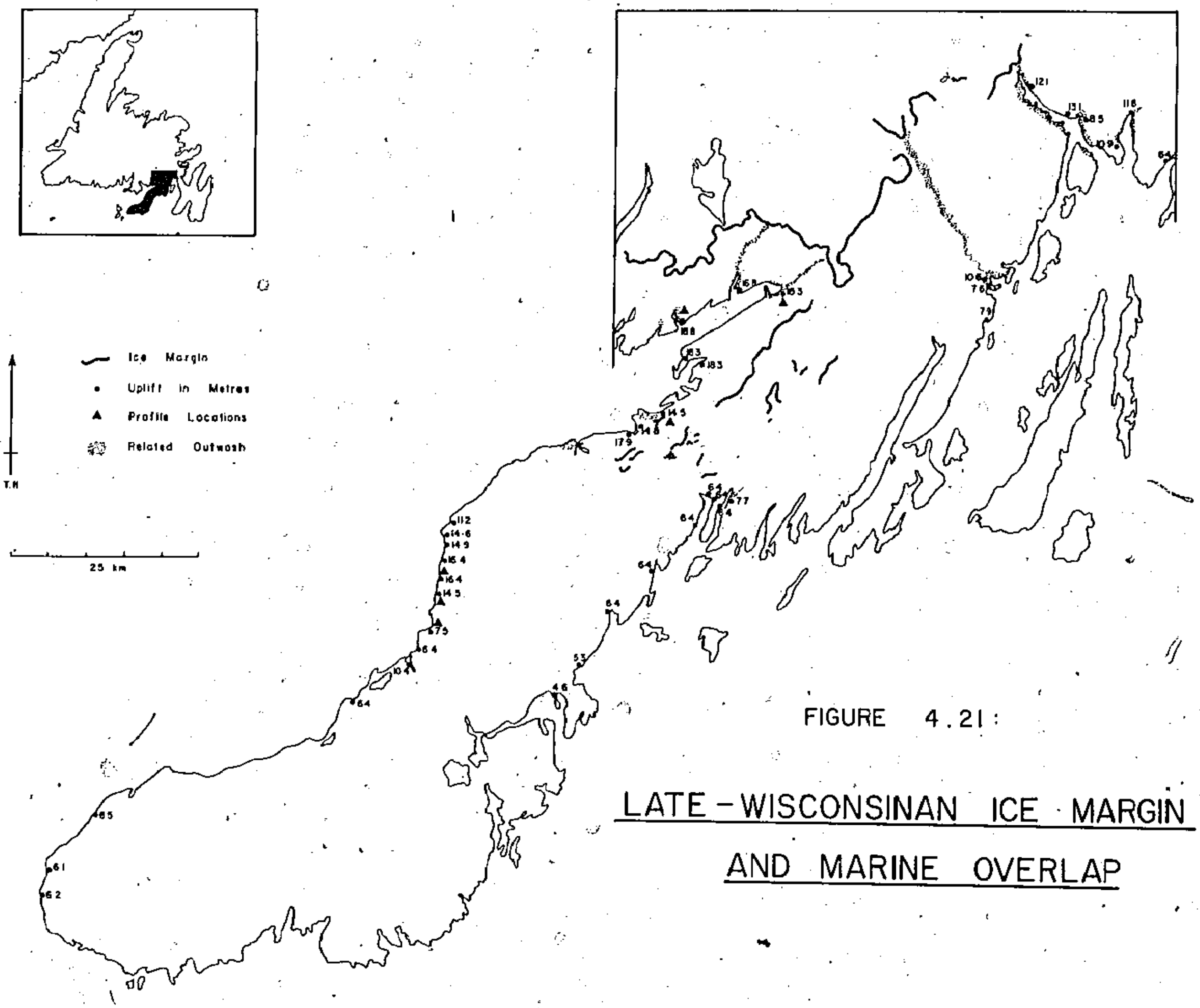


FIGURE 4.21:

LATE-WISCONSINAN ICE MARGIN AND MARINE OVERLAP deposits near Long Beach. Either because of subsequent erosion or simply because mid-Wisconsinan deglacial, meltwater flow was only towards the Fortune Bay coast, there appears to be no evidence of mid-Wisconsinan related, stratified coastal deposits on the Placentia Bay coast north of Jean de Baie. South of this point, deposits relate to the St. Lawrence plateau ice (late, mid-Wisconsinan) and evidence of later marine overlap is sketchy.

4.4 Recent Submergence

There is no distinct evidence of postglacial elevated terraces along the sole of the peninsula i.e., the area from Point May to Salmonier. Also, the coast has a drowned appearance with a preponderance of bay mouth bars, lagoons, bay head cobble and sand beaches, and tombolos. As well as these indicators of submergence, organics were found at both the south-east and southwest corners of the peninsula that help date the rate of submergence. At a point 0.5 km south of Little St. Lawrence samples of what were subsequently identified as birch (*Betula sp.*) and balsam fir (*Abies balsamea*) have been C^{14} dated at 1080 ± 50 B.P. (G.S.C. 2617). Larger stumps of the wood are surrounded by peat dated at 970 ± 50 B.P. (G.S.C. 2569) and overlain by marine sand and rounded cobbles. Although the samples were obtained 1.7 m b.s.l. (sea level means high, high tide as per bench and terrace elevations), the deposit extends well below low tide and is not exposed at high tide. The dates suggest a value of 16 cm/100 years as an approximate rate of submergence which compares with ~25 cm/100 years estimated by Grant (1970b) and Vanicek (1976) for the Maritimes. On the coast 5.2 km north of Point May (Fig. 4.22), marine

FIGURE 4.22: Point May coastal section. Organic deposits and wood (*Picea* and *Larix*) were dated at 5360 ± 70 B.P. and 3620 ± 60 B.P. Samples were obtained 1.1 m above high, high tide level, however, it is considered that the organics extend well below present sea level.

encroachment has covered a low-lying area of peat bog and grassland. At the bottom of a shallow pit, a sample of peat was retrieved from a point 1.2 m a.s.l. The peat overlies a compact, grey clay containing well rounded pebbles and has been dated at 5360 ± 70 B.P. (G.S.C. 2613). Samples of spruce (*Picea*) and larch (*Larix*) branches up to 5 cm in diameter were obtained from the base of a coastal organic section that had been eroded by marine action. The wood which was located 1.1 m a.s.l., surrounded by peat and underlain by a sticky, clay-peat mixture, has been dated at 3620 ± 60 B.P. (G.S.C. 2580).

While only the first two of the four dates, truly represent submerged, terrestrial, organic material, all are indicative of a well developed pattern of marine encroachment and a submerging land mass on the southern Burin Peninsula.

4.5 Discussion

Figure 4.23 is a new construction for isopleths of late-Wisconsinan postglacial emergence. In many respects, it is no more sufficient than the one presented by Wightman and Cooke (1978). Still, out of necessity, one must assume that terraces and outwash deposits used in its construction are generally contemporaneous and that deglaciation occurred ca. 13,500 B.P. However, it is not assumed that late-Wisconsinan ice cover was complete or that all raised, marine terraces grade to this particular sea level (Table 4.2). On the Fortune Bay coast, only those erosional terraces discussed herein and identified as representing late-Wisconsinan marine limit have been used in the diagramatic construction. Similarly for the upper Placentia Bay area though here, the record is not as com-

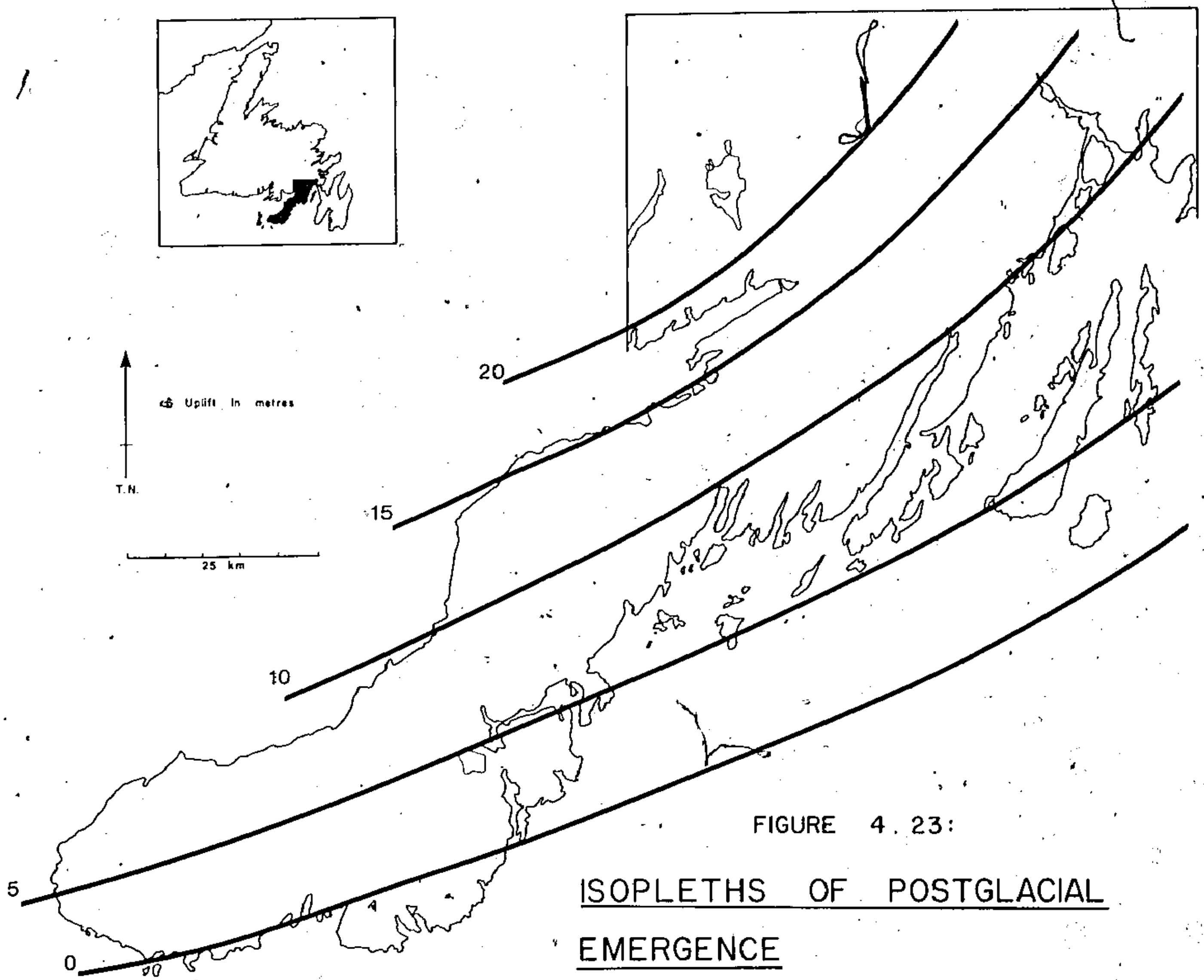


FIGURE 4.23:

ISOPLETHS OF POSTGLACIAL EMERGENCE

plicated. The zero isopleth or line of no net late-Wisconsinan, postglacial emergence is even more approximate since the possibility of some marine overlap existing on the Lamaline to Salmonier coast is not ruled out. It may be masked by the heavy organic cover or be so close to present marine limit and its associated storm beaches as to be indistinguishable. The advantages of this construction over previous ones are several. It has been designed with no attempt to fit data from other "isobase" maps it draws on a far greater number of raised terrace elevations which have been classified into distinct sets, and it uses firm C^{14} dates to indicate that submergence it taking place.

CHAPTER 5

WEATHERING AND PERIGLACIAL PHENOMENA

5.1 Introduction

5.1.1 Weathering concepts

The degree of subaerial weathering of bedrock and surface deposits in an area is, in part, a function of the time that weathering processes have been operating. In many recent Quaternary studies (see, Symposium: Limits of Wisconsinan Glaciation in eastern and northern Canada, 1978) this temporal control on the degree of weathering has been utilized to provide a relative chronology of glacial events on the argument that the longer an area has been ice free, the more pronounced will be the weathering effects. Similarly, the presence of relict periglacial phenomena reflecting more severe climatic conditions than exist today, has also been used as a criterion for distinguishing between glaciated and nonglaciated terrain, or the relative age of glaciation in different areas. Frequently, weathering (*sensu stricto*) and cryogenic effects, including mass movement, have been grouped together in such studies.

Weathering is defined as the process of rock and mineral alteration to more stable forms under the variable conditions of moisture, temperature and biological activity that prevail at the surface (Birkeland, 1974). Pheasant and Andrews (1973) define weathering zones as surficial rock units which may be separated on the basis of the degree of surface physical and chemical weathering exhibited on bedrock, till and other surficial material. An indication of the amount of weathering that has occurred may be gained by noting the thickness of weathered surfaces on exposed bedrock or surface clasts. This measure is referred to as a weathering rind and has been discussed at some length by Birkeland (1974). Another indicator of the intensity and length of surficial weathering may be obtained by recording the projection of crystals and more resistant veins on a given rock surface. In both cases, measurements are usually recorded in millimetres.

Pheasant and Andrews have stated that weathering zones also include certain morphological elements related to weathering such as tors and locally derived felsenmeer. However, Sugden and Watts (1977) have questioned the validity of using the presence of such features as an indicator of long term ice free conditions. Because there is some debate over the relative importance of periglacial phenomena in an area compared to the actual thickness of weathered surfaces, results from the current study will be presented separately for each topic.

Much of the work in the eastern Arctic was pioneered by Daly (1902) and Coleman (1920, 1926), and continued by Ives (1957, 1958a,b) and Løken (1962b). It has lead to the widespread recognition of three, distinct, altitudinally arranged weathering zones. They are assigned, in decending order, to an upper unglaciated zone, a middle zone which was overridden by limited, early-Wisconsinan ice, and a lower zone, affected by severely restricted, late-Wisconsinan ice (Ives, 1978; England and Bradley, 1978). Debate as to whether the highest zone was ever covered by ice, or if it can be subdivided, is still ongoing, but the idea of restricted Wisconsinan ice cover, based on the identification of weathering zones, is firmly fixed. It is, therefore, important that an attempt be made to apply weathering techniques on the Burin Peninsula especially in light of the scarcity of local, datable material.

5.1.2 Weathering and periglacial research in Newfoundland

Information on weathering intensity and periglacial action is sporadic in the Newfoundland Quaternary literature. One of the earliest references is that of Coleman (1926) who discussed the implications of limited till cover and intense weathering with reference to the extent of Wisconsinan ice. As mentioned in Chapter 1, he could not reconcile the presence of intense weathering with an all-encompassing Wisconsinan ice sheet and maintained that complete glaciation of the island had not occurred since the Kansan or Jerseyan. MacClintock and Twenhofel (1940), however, suggested that the erratics and roches moutonnées found on the central uplands were fresh enough to convince them that Wisconsinan ice had completely glaciated the island. More recently, Henderson (1968) described patterned ground on the Avalon Peninsula. He concluded that the presence of active sorted polygons, sorted circles and debris islands in locations farther south than formerly reported was an indication that their genesis should be more rigorously interpreted; that a more severe climate with permafrost is not a prequisite for their formation, rather, they may merely indicate a more recent, intensely marine climate with a moderate winter and low mean annual temperature.

In 1971, Brookes reported on the age and paleoclimatic implications of fossil ice wedge casts in western Newfoundland. He proposed that the casts, which range from 1.8–2.5 m deep and 40-60 cm wide at the top, were related to permafrost activity no more than 1,000 years after the coarse, stratified parent material was deposited between 12,500 and 11,200 B.P. He compared the features with ice wedge casts in Nova Scotia (Borns, 1965) and concluded that the time reported for their formation, pollen zone L-1 of Livingstone and Livingstone (1958) was similar to that in Newfoundland. Brookes later (1977a) expanded his work on periglacial and weathering phenomena in a reinterpretation of the Quaternary succession of the Codroy lowland and adjacent plateaux of southwest Newfoundland. He described granodiorite tors standing in extensive block fields, quartz and feldspar crystal projections up to 7 mm, and 20 mm weathering pits in finer-grained inclusions along the edge of an upper, unglaciated plateau. In a lower, early-Wisconsinan zone, weathering rinds on sandstone blocks ranged from 0.5 to 3.5 mm while coarse grantitic eratics up to 20 cm in diameter had suffered hydration breakdown of the micas and were weathered through completely. Both active and inactive, sorted and non-sorted circles were reported from this zone. Below 400 m, fresh till was recognized and the area was assigned to the late-Wisconsinan.

Further north in the Gros Morne National Park area, Grant (1977a) delineated three weathering zones which he described in qualitative terms by the presence or absence of local relief, etching, grus, large stone polygons, sorted circles, patterned felsenmeer and embryonic tors. Grant proposed that his weathering zones represented separate glacial events. The highest, zone C, was suggested as being >100,000 years old while the intermediate and lower areas were described as early/middle-Wisconsinan and late-Wisconsinan.

Eyles (1977) noted the occurrence of ice wedge casts in post-depositionally folded and faulted glaciofluvial sediments situated in north-central Newfoundland. He roughly correlated them with those described by Brookes' (1971) and emphasized that their age must remain tentative since the casts are only tied to an approximate date of deglaciation (Tucker, 1973), and the presence of buried ice blocks in kettle holes may have disturbed the peat sequences used to date contemporaneous Nova Scotia relicts (Livingstone, 1968).

Periglacial and weathering studies on the Burin Peninsula consist of brief notes appended to more comprehensive bedrock studies. Walthier (1948) described relict masses of blocky rubble, stone stripes, rock tongues and well developed stone polygons near Grand Bank. He considered the polygons to be active and, hence, an indicator of intermittent, but deeply frozen ground. Potter (1949) also observed rock rings and tongues as well as small, active polygons up to a metre in diameter.

5.2 Weathering Rinds

5.2.1 Procedures and results

Ideally, the most useful weathering rind measurements would come from areas of uniform lithology, drainage, micro-climate and vegetation; thus, the remaining variables, elevation and degree of weathering, could be interpreted as a measure of the vertical extent and age of glaciation(s). Birkeland (1974) stated that because of their diverse origins, rind thickness measurements taken from erratic boulders are less meaningful. He also pointed out that biotite bearing rocks commonly weather more rapidly than those that are biotite free. In addition to being the first mineral to weather in granitic rocks, it forms alteration products that can occupy a greater volume than did the original biotite. The result is mineral expansion with numerous localized points of stress within the rock that eventually shatter it and form grus. Basalt is an extreme case of a rock lacking biotite. Weathering proceeds inward grain by grain and the boundary between fresh and chemically weathered rock can be quite sharp. Porter (1975) stated that granitic weathering ratios are a most widely used criteria, but produce results of varied reliability. This is corroberated by Birkeland (1974). Further, Porter noted that weathering rind formation is not necessarily linear, that the rate decreases logarithmically with time. This is possibly due to buildup in the rind of weathering products that retard further weathering of the core thereby resulting in a progressive decrease in the rate of rind formation.

The present investigation of weathering phenomena on the Burin Peninsula has not been as rigorous as the work carried out by Porter in Washington state. There were several reasons for this. The field area contains extensive areas of Carboniferous granite and Precambrian volcanics but generally, the lithology is highly variable (Section 1.7.3). These differences become critical if one is attempting to compare rind thicknesses spatially. Also, elevations are generally limited to <180 m which makes the recognition of altitudinal weathering zones extremely difficult. Therefore, a series of mean weathering rind thicknesses were obtained from various bedrock types by measuring rinds to the nearest millimetre on at least four freshly broken samples at a given site and recording the average. The detailed weathering rind measurements are presented in Table 5.1 and the sample locations are shown on Figure 5.1.

Taken as a whole, rind thicknesses are greatest on the south coast of the peninsula. For example, if at Hares Ears, 1L/13, rinds of 9-12 mm on felsic, lithic tuff located 11 m a.s.l. are compared with values of 6-8 mm obtained from schistose felsite, 168 m a.s.l., north of a triangulation point near Mooring Rock Cove, 1M/16, the more northerly sample is less weathered by a factor of ~0.35 despite the 157 m difference in elevation and an assumed minimal difference in lithology. Similarly, a rind of 7-12 mm taken from breccia atop Bennett Hill, 1M/4, is several magnitudes greater than the 2-4 mm recorded on lithic tuff northwest of Pays Cove, 1M/10. Within this range, rind thicknesses are variable and no well defined trend is determinable. At certain low altitude sites such as Baine Harbour, 1M/7, rind thicknesses are greater than nearby upland measurements, which is the converse of what one would expect. It does appear, however, that a decrease in the range of values occurs in the area north of Grand le Pierre and northwest of Swift Current.

Quartz vein projections (Fig. 5.2) of 12-14 mm at Taylor's Bay, 1L/3, 11 mm near Broad Cove Head, 1M/7, and 15 mm at a location immediately southeast of Big Rock Brook, 1M/15, which were obtained from various types of bedrock, show no directional or altitudinal trends. Similarly, 10 cm of coarse grus measured at a location 1.5 km west of St. Lawrence is difficult to compare with the degree of weathering on coarse grained, granitic cobbles and grus perched on bedrock 4.5 km west of Gisborne Lake (Fig. 5.3) since the latter area is considered to be within the zone blanketed by late-Wisconsinan ice and the former to

TABLE 5.1

Bedrock Weathering Rind Measurements

LOCATION	MAP SHEET	ELEVATION	LITHOLOGY	RIND THICKNESS
North of Dantzic Cove	1L/13	91 m	Quartzite	<2 mm
Lories	1L/13	9 m	Sandstone	4- 7 mm
Allan's Island	1L/13	8 m	Tuff	<2 mm
Point au Gaul	1L/13	5 m	Quartz Vein	12-14 mm
Taylor's Bay	1L/13	11 m	Felsic Lithic Tuff	9-12 mm
Taylor's Bay	1L/13	9 m	Quartz Vein	12-14 mm
Lord's Cove	1L/13	20 m	Felsic Agglomerate	3- 4 mm
Roundabout	1L/13	37 m	Porphyritic Vitrophyre	3- 5 mm
Northeast of Lawn	1L/13	67 m	Granite	14 mm
Hares Ears	1L/14	35 m	Granite	7-10 mm
Capeau Rouge	1L/14	61 m	Granite	10-15 mm
Middle Head	1L/14	15 m	Greywacke	<2 mm
Corbin	1L/14	91 m	Tuff	4- 7 mm
Rocky Pond	1M/3	107 m	Rhyolite	7- 9 mm
Brown Ridge Pond	1M/3	206 m	Granite	7-10 mm
Mortier	1M/3	84 m	Pillow Lava	5- 6 mm
Fox Hummocks	1M/3	12 m	Acidic Tuff	<2 mm
Great Garnish Barasway	1M/3	18 m	Gabbro	4 mm
Garnish River	1M/3	21 m	Ignimbrite	1- 3 mm
Rock Harbour	1M/3	12 m	Conglomerate	4- 6 mm
Bennett Hill	1M/4	82 m	Breccia	7-12 mm
Tilt Cove	1M/6	8 m	Porphyritic Volcanics	4- 6 mm
Long Beach	1M/6	11 m	Porphyritic Volcanics	4- 6 mm
North of Red Harbour	1M/6	137 m	Schistose Tuff	4- 7 mm
Broad Cove Head	1M/7	128 m	Quartz Vein	11 mm
Rushoon	1M/7	23 m	Felsite	3- 5 mm
Baine Harbour	1M/7	12 m	Schistose Felsite	5-10 mm
North of Parker's Cove	1M/7	95 m	Schistose Felsite	5- 7 mm
Parker's Cove	1M/7	61 m	Schistose Felsite	4- 7 mm

TABLE 5.1 (cont'd)

LOCATION	MAP SHEET	ELEVATION	LITHOLOGY	RIND THICKNESS
Rattle Creek	1M/7	98 m	Schistose Felsite	5- 8 mm
Monkstown	1M/9	61 m	Slate	10 mm
Great Sandy Harbour	1M/9	125 m	Schistose Felsite	8-10 mm
North of Sandy Harbour River	1M/9	140 m	Schistose Felsite	4- 6 mm
Paradise River	1M/9	138 m	Schistose Felsite	4- 5 mm
Jacques Fontaine	1M/10	37 m	Schistose Felsite	5- 7 mm
Sugarloaf Hill	1M/10	213 m	Schistose Felsite	7-10 mm
Harbour Mille	1M/10	46 m	Tuffaceous Slate	7 mm
Northeast of Terrenceville	1M/10	168 m	Schistose Felsite	7-10 mm
Northwest of Pays Cove	1M/10	174 m	Lithic Tuff	2- 4 mm
East of Gisborne Lake	1M/15	168 m	Felsite	3- 5 mm
Southeast of Big Rock Bank	1M/15	250 m	Sandstone	5- 8 mm
Southeast of Big Rock Bank	1M/15	250 m	Quartz Vein	15 mm
Long Pond	1M/16	206 m	Schistose Felsite	<2 mm
Triangulation	1M/16	366 m	Schistose Felsite	5- 6 mm
North of Triangulation	1M/16	168 m	Schistose Felsite	6- 8 mm
North Harbour River	1M/16	91 m	Volcanic Rock	5- 6 mm

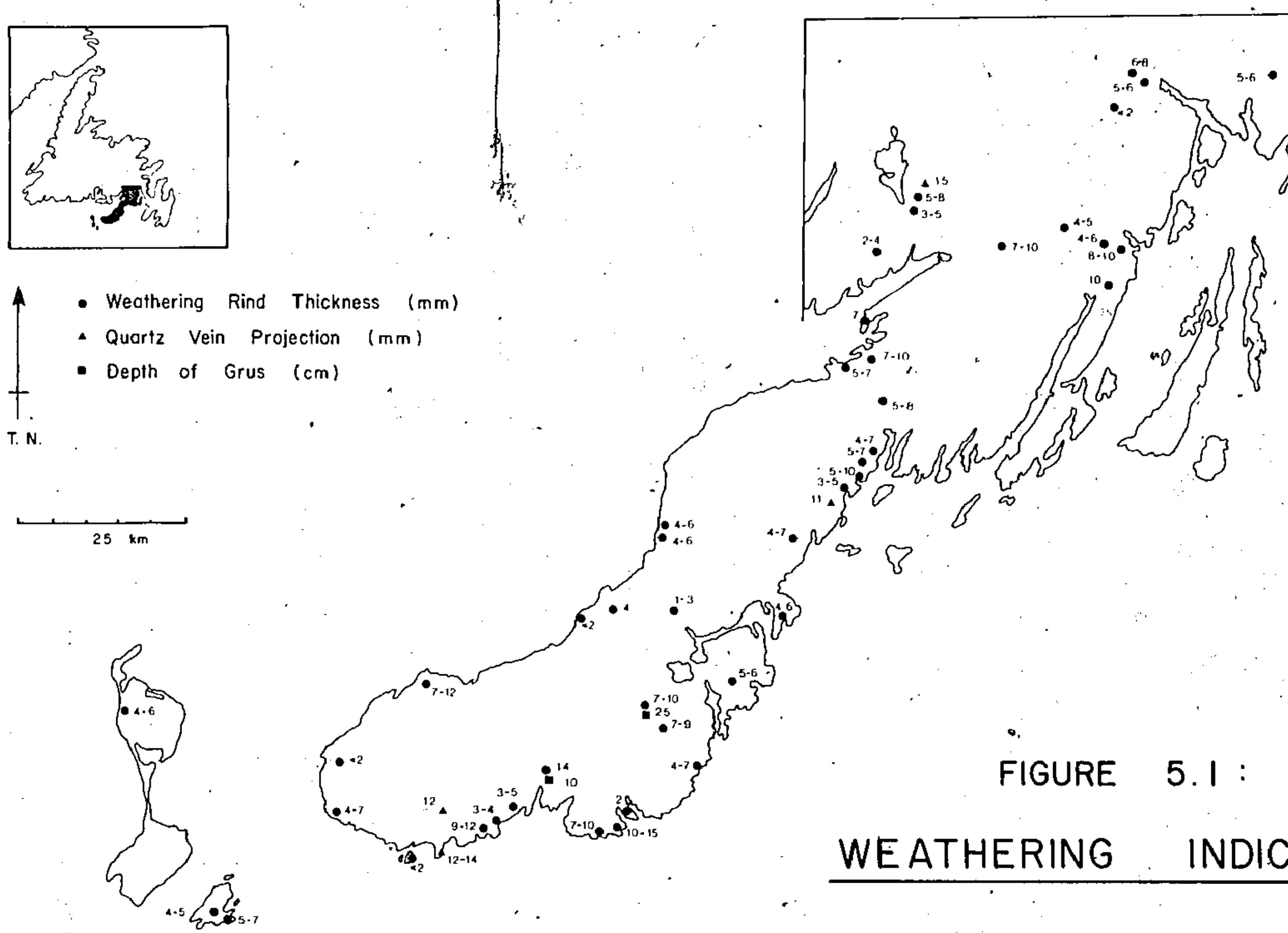


FIGURE 5.1 :

WEATHERING INDICATORS

FIGURE 5.2: Quartz vein projection of 11 mm on Precambrian, schistose felsite located midway between highway 210 and Broad Cove Head.

FIGURE 5.3: Gisborne Lake area. Completely weathered granite cobble and associated grus located inside the late-Wisconsinan limit.

be well outside. In an area of granitic rock east of Brown Ridge Pond, 1M/3, surface granitic cobbles were completely weathered through, yet near this location, nongranitic weathering was recorded as being 7-10 mm. Based on evidence presented earlier in the thesis, this zone is considered not to have been glaciated since the late, mid-Wisconsinan.

Two measurements that might be considered diagnostic were obtained near a road cut in Jacques Fontaine fjord (5-7 mm on schistose felsite at 37 m) and Sugarloaf Hill (7-10 mm on schistose felsite at 213 m). While it might be argued that the difference in rind thickness represents prolonged subaerial weathering at the higher elevation, it may also be due to continued renewal of scree material at the lower, steeper site and the resultant exposure of fresh bedrock from which the measurements may have been obtained.

5.2.2 Discussion

The results of the Burin Peninsula weathering rind study are generally inconclusive. A better outcome might have been obtained from a rigorous study of weathering phenomena by themselves, but initial results were not good. Nonetheless, it may be stated that the north-western corner of the field area appears to have been exposed to sub-aerial weathering for a shorter period than the southern Burin, and that the Jacques Fontaine fjord is less weathered than the surrounding high-lands. Beyond this, it is difficult to place the measurements within an exact chronologic frame of reference. In a similar study, Grant (1977a) spoke vaguely of 10x more surface degradation between the late-Wisconsinan postglacial and his upper zone "C" Illinoian (?) glaciated area. Brookes (1977a), also, was reluctant to go beyond a general discussion of gross weathering features. The reasons for this are understandable, and similarly here, one is hesitant to draw inflexible conclusions from rind thicknesses in an area of not only highly variable lithologies, but also limited elevation and maximum exposure in a cool, maritime climate (Section 1.7.4).

5.3 Periglacial Phenomena

5.3.1 Features on the St. Lawrence plateau

Within the confines of the Burin Peninsula, the greatest concentration of periglacial forms occurs in the Carboniferous granite of the St. Lawrence plateau. Between Black Hill and Welchs Hill, 1.5 km north of Lawn, there are several sets of features that were investigated. Figure 5.4 shows remnant solifluction deposits on the 69 m eastern slope of Black Hill. The stone-banked lobes and dissected terraces are formed in an area of granite bedrock and are thickly covered with heath-like vegetation which makes sub-surface information difficult to obtain. The garlands of large, angular, granitic blocks, 80x50x30 cm to 35x35x20 cm (Fig. 5.5) are devoid of intersticial fines. This is thought to be due to long term surface run-off. A weathering rind of 14 mm, obtained from one of the blocks, is taken as evidence that the features have been stable for a considerable period of time.

On the intervening granite plain, between the two north-trending hills, there is an area near the highway of rubbly, sorted polygons (Fig. 5.6). The subangular-angular, granite blocks vary in size but a consistent average is 70x40x20 cm. The centres of the polygons contain

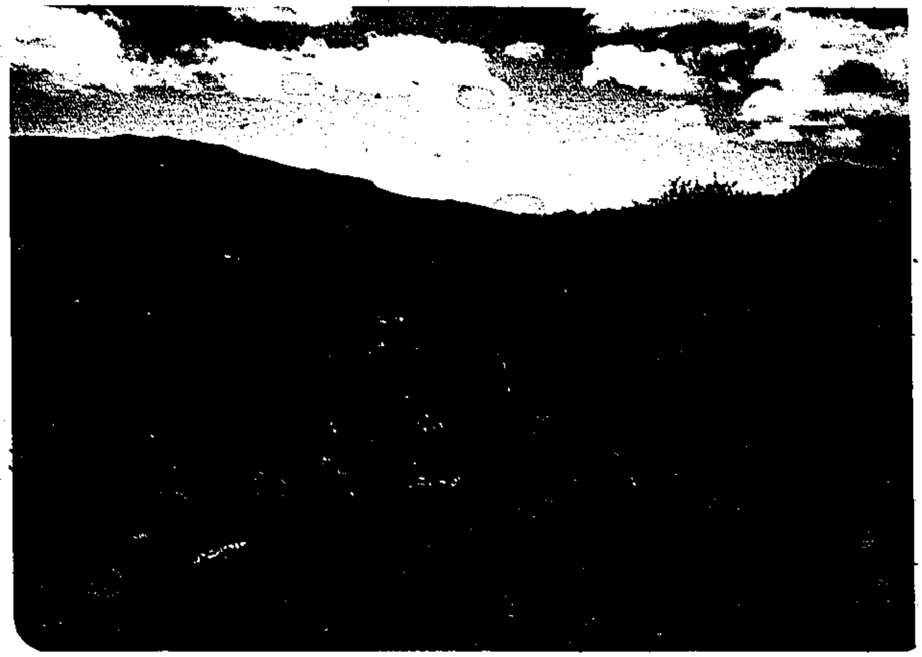


FIGURE 5.4: Solifluction lobe remnants located on the eastern flank of Black Hill, north of Lawn.

FIGURE 5.5: Detail of the solifluction lobe garland shown above. Large granite blocks (80x50x30 cm) have a weathering rind thickness of 14 mm.

FIGURE 5.6: Sorted polygons located near highway 210 north of Lawn, between Black Hill and Welchs Hill. Area of thin till and granite bedrock.

FIGURE 5.7: Polygon detail at the above location. Interior dimensions are 3.5 x 3 m. Centre of polygon is 70 cm in depth. (Scale is field note book.)

finer material and are well vegetated with moss and sedge (Fig. 5.7). The interior dimensions of the polygons range from 3.5-4 m x 3-3.5 m while the outside border of blocky material is roughly 1 m wide. Whether or not these features indicate ancient permafrost conditions is not clear. It is uncertain from their surface expression if fossil ice wedge casts exist below the surface. Because of the rubbly nature of the polygons and the thick vegetation, it was difficult to analyze them in profile. Their dimensions and morphology are similar to active polygons described by Miller *et al.* (1954) in Scotland, but a weathering rind of 14 mm, measured on several of the blocks indicates that the polygons are relict.

North of Rocky Pond, 1M/3, there are large cobble and boulder, stone circles which are approximately 8 m in diameter. They consist of subangular to subrounded, lichen covered granite clasts that average 20 cm in diameter and have weathering rind thicknesses of 7-9 mm. Nearby granite boulders have developed surface grus to a depth of 12 mm.

Large scale periglacial features occur atop the combined kame terrace and bedrock scarp that forms the eastern embankment of Brown Ridge Pond, 1M/3. This location was described in Chapter 2 as being part of the northernmost ice margin on the St. Lawrence plateau and is important in that it has been tentatively dated by stratigraphic methods. The planar, upper surface of the escarpment shows sorted stone polygons of about 4x5 m. The angular clasts average 7x4x4 cm in size and extend without any appreciable increase in the concentration of fines to a depth of 25 cm (Fig. 5.8).

Similar poorly sorted polygons and nets occur west of the highway near Dantzic Cove. Here, the angular blocks average 20x30x40 cm and

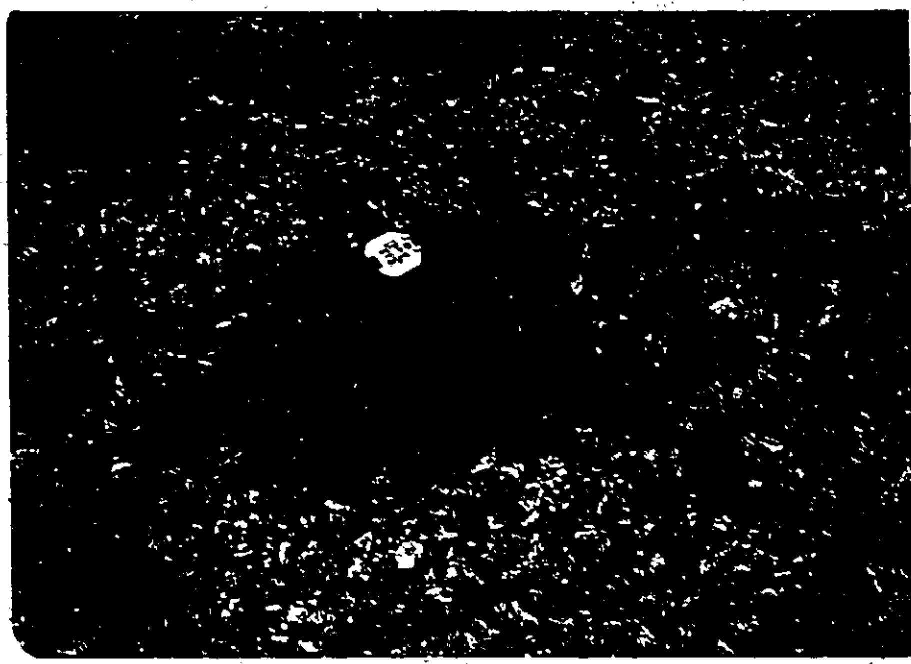


FIGURE 5.8: Brown Ridge Pond. Frost shattered debris in granite bedrock. Pit dug to a depth of 25 cm at nucleus of a sorted stone polygon. Area was ice free during the late-Wisconsinan.

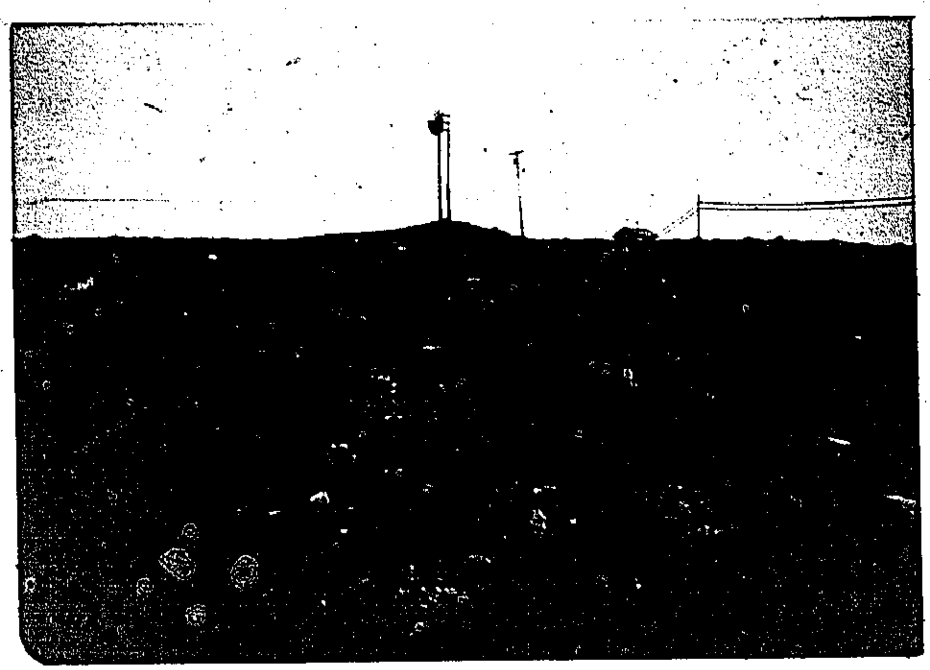


FIGURE 5.9: Allan's Island. Earth hummocks are 60-70 cm in diameter and up to 30 cm in height. Many are rock cored. Weathering rind on bedrock near tower is <2 mm.

have no appreciable weathering rind. Nearby, there are larger angular blocks that range up to 4x3x2 m in size. These have not been transported, but instead, have broken away from the local, northeast trending, quartzite outcrops.

Other features that suggest frost action include earth hummocks which are best exemplified by those visible on Allan's Island (Fig. 5.9). Here the mounds are 60-70 cm in diameter and up to 30 cm in height. Many are rock cored while others contain only peat covered till with frost shattered clasts near the surface. Washburn (1973) found that this morphology is typical for hummocks, but difficult to interpret. He concluded that those with core stones may be a result of frost heave, but many hummocks lack them, and it is uncertain that upfreezing of stones is really the primary cause even when core stones are present.

5.3.2 Features on the upper Burin Peninsula

A compedium of periglacial and recent, freeze-thaw features on the upper Burin is essentially a reflection of those just described. At location 7088 between Bluff Point and Harbour My God Point, 1M/6, there are series of moderately sorted nets that are similar in dimensions to those described on the lower peninsula. The outside diameters of the weathered nets average 8 m, while the well vegetated interiors are 1.5-2 m across. Clasts are mostly local, sub-angular porphyritic volcanics of which the largest are 80x50x20 cm and the smallest 12x4x3 cm.

Active, small scale, sorted circles occur at various locations on the peninsula (Fig. 5.10). Most are 1-1.5 m in diameter and contain fresh, angular 4-6 cm long clasts near their perimeter. The external

FIGURE 5.10: Grand le Pierre area, active sorted circles. Example with scale is 1.6 x 0.9 m in diameter. Note the concentration of coarse material around the perimeter. The other two examples are not as well developed.

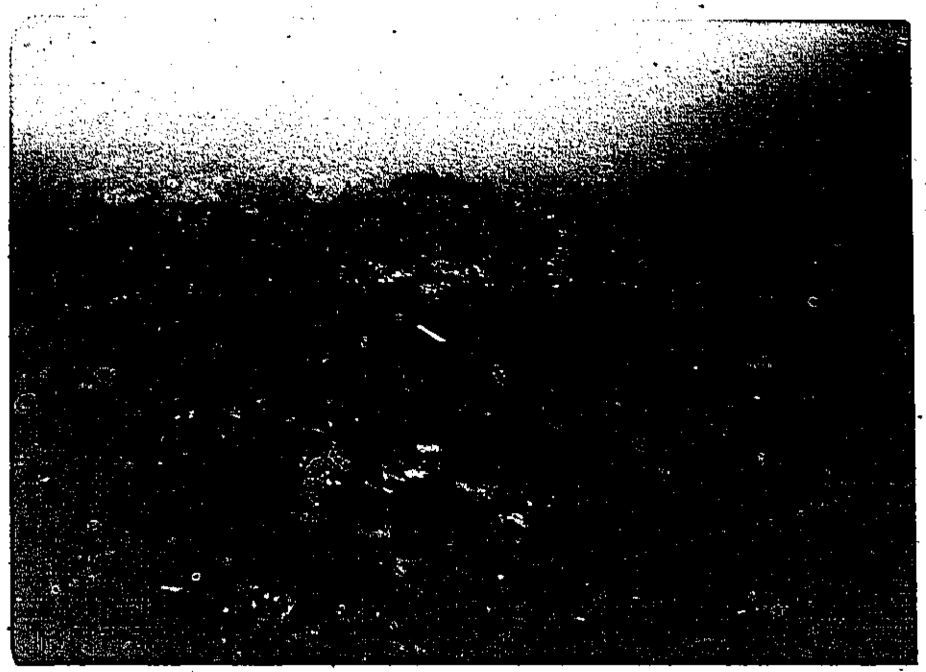


FIGURE 5.11: Bears Folly triangulation point 366 m a.s.l. Stone net is 2.2 x 1.8 m in diameter. Weathering rind is typically 5-6 mm.

dimensions of felsenmeer and sorted stone circles were recorded near the triangulation point, 2.1 km southwest of Bears Folly, 1M/16. The location is significant in that it is close to the height of land on the Burin Peninsula (370 m) and as such, would be expected to have been above the range of limited, mid or late-Wisconsinan ice flows. As depicted in Figure 5.11, the larger, angular schistose blocks range from 90x50x30 cm to 70x50x25 cm. The lichen covered, sorted stone net has an internal diameter of 2.2x1.8 m, and the blocks on its outer perimeter are 70x30x10 cm to 35x35x20 cm. While the angularity of the blocks and the exposure of the site impart a feeling of intense weathering, a rind of 5-6 mm on the schistose felsite makes it difficult to invoke long periods of sub-aerial weathering as being responsible for their formation, especially when compared with values of 6-8 mm recorded on the same type of rock at a point 198 m lower in elevation.

More significant, however, is the occurrence of features interpreted here as ice-wedge casts. They are sited in glaciofluvial deposits at Swift Current near Mooring Rock Cove, 1M/16 and again, in an area of eskers, outwash and limited, proglacial ponding on the late-Wisconsinan ice margin, 2 km southeast of Dunn's Pond, 1M/10. At the Mooring Rock Cove site, the epigenetic cast is located 11.3 m a.s.l. in an area of trough cross-bedded, ripple-laminated, coarse-grained sand and pebble gravel (Fig. 5.12), and is exposed in a borrow pit on the late-Wisconsinan, Swift Current outwash plain. The pit wall is 2.9 m in vertical extent, and is capped by 1-1.5 m of peat which has been locally stripped away. The sediments are not faulted at this location, however, convolutions or brodels are common and elsewhere in the pit, post-depositional faulting

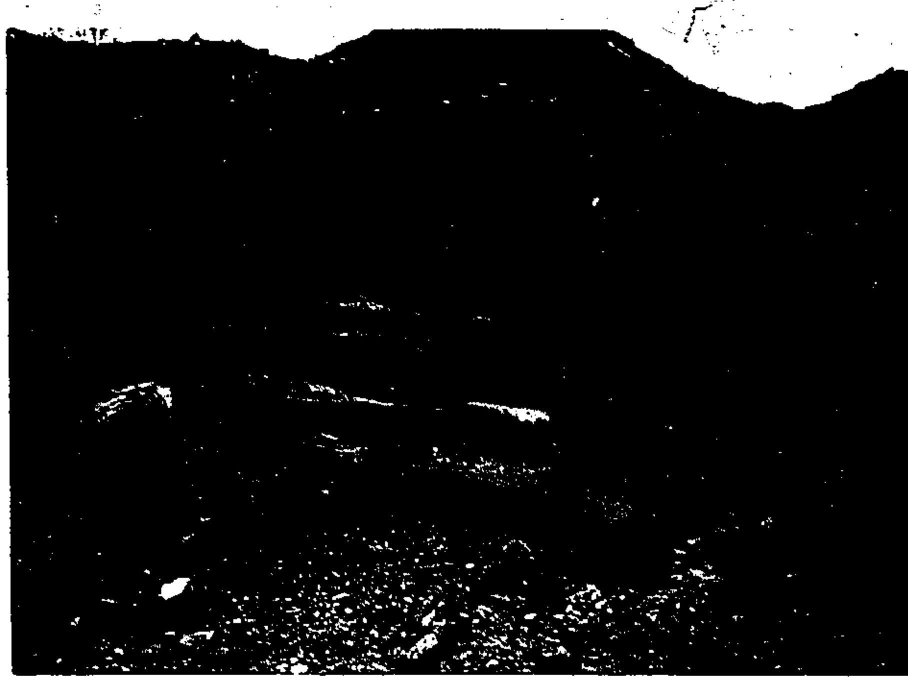
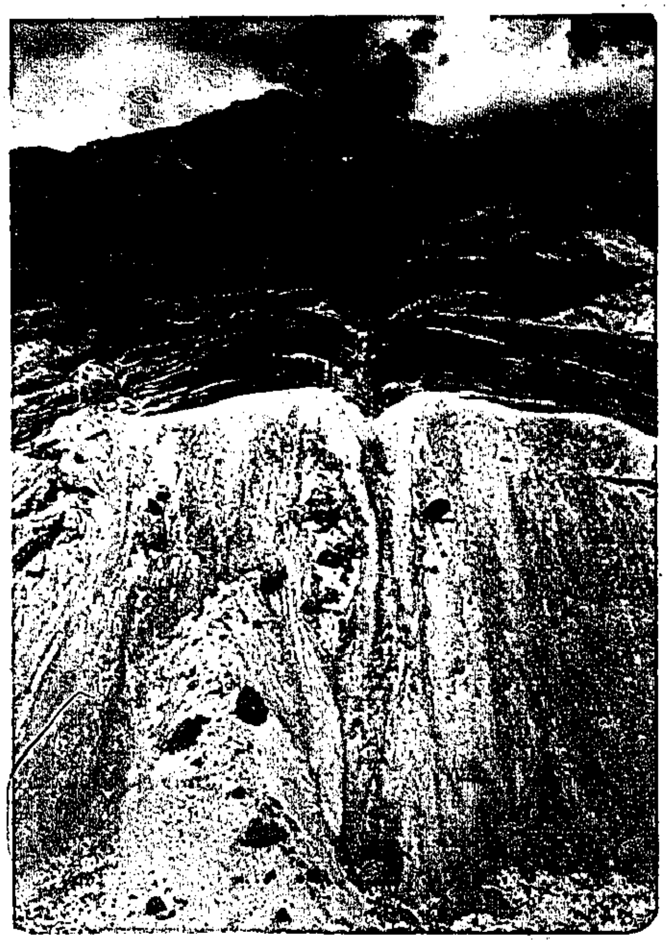


FIGURE 5.12: Mooring Rock Cove ice wedge cast which is 2.7 m wide at the surface and 2.4 m deep. Parent material is late-Wisconsinan.

FIGURE 5.13: Dunn's Pond esker. Ice wedge cast is 70 cm wide at the mouth and 2.6 m deep. It is indicative of permafrost during the early post-glacial.



is visible. The cast itself is 2.7 m wide at the surface and 2.4 m deep at its apex, and while some vertical infilling and upturned clasts are visible at its margins, the coarse sand and pebble core, which is similar in grain size to the host material, is sub-horizontally stratified and concave upwards. This, along with the upturning of the surrounding strata at the cast margins, is claimed by Black (1975) to be important in distinguishing between ice wedge casts and similar, nonperiglacial features such as tension cracks with complete primary, sand infillings.

The Dunn's Pond cast, which is considered similar in aspect and genesis (Fig. 5.13), is situated in contorted and slumped, cross and parallel-bedded, sand and pebble gravel. Convolutions and small scale faults are probably a result of subsurface ice block melt and subsequent infilling. The wedge is 2.6 m deep, 70 cm wide at its mouth and contains a 15 cm thick, cemented Fe-Mn shell along its perimeter. While the top 80 cm of the wedge contains chaotic, slumped infill, the lower 1.6 m consist of sub-horizontal coarse sand similar in size to the surrounding material.

5.3.3 Discussion

If one accepts the necessity of permafrost as being prerequisite for periglacial conditions to exist (Péwé *et al.*, 1969), then many of the features just described (sorted polygons, nets, circles, felsenmeer and earth hummocks) should not be used as criteria in defining such an environment since, according to Henderson (1968), Washburn (1973), and Brown and Kupsch (1974), they do not *sensu stricto* require permanently frozen ground to form. Brunnschweiller (1962), Morgan (1972) and

Watson (1976), however, maintained that polygonal ground, ice wedge casts and near surface involutions are a record of the existence of permafrost during the late-Wisconsinan. To complicate the discussion further, French (1976) does not require the presence of permafrost to define periglacial conditions, and it is easily conceivable that the Burin Peninsula could have been included in his zone of low annual temperature range (8°C) and low annual mean (+2°C) for extended periods of time. However, these arguments do little to resolve the question of whether or not permafrost existed on the Burin Peninsula during the postglacial.

The best indicator of permafrost are the ice wedge casts located near the late-Wisconsinan ice margin. Black (1976) emphasized the importance of distinguishing between ice wedge casts which require permafrost to form, and sand or soil wedges which do not. French (1976) considered that both require permafrost for their generation. He stated that, in fact, sand wedges need much colder and dryer conditions than do ice wedges since the primary thermal crack is not aided by ice wedging, and heavy snow cover limits the amount of aeolian infill. In the case of the present examples, the nearly 3 m cast depths would seem to necessitate permafrost since it is considered unlikely that even intense frost action would be effective at such a depth. Whether the casts were part of a rectangular (orthogonal) or random (polygonal) network is unknown since no surface expression was visible. They are thought to be analagous to those described by Eyles (1977) both in genesis, and in paleoclimatic interpretation, i.e., a severe permafrost environment during the late-Wisconsinan with a mean annual temperature of <-6°C (Péwé, 1966).

Conspicuous by its absence from the preceding section is any mention of tors. Although there is much debate over their origin (Linton, 1955; Thomas, 1968), there is equally as much debate over the implications posed by their presence or absence in glaciated areas. Dyke (1976) has discussed their genesis and preservation in an arctic environment. He noted that they have not been reported from any area of Canada that is known to have been glaciated during the late-Wisconsinan. Both Grant (1977a) and Brookes (1977a) have reported tors in the upper, unglaciated zone of western Newfoundland, though in neither case is there any significant detail on size or morphology. No examples of tors that even remotely resemble the size of those described by Dyke were observed on the Burin Peninsula. Instead, there is an almost continuous presence of small rock knobs with surrounds of frost shattered debris, and bedrock spurs with limited quantities of angular talus. The greatest concentration of these features occurs in areas of vegetated rock or very thin till veneer. To classify them as embryonic or incipient tors does little to resolve the dilemma since then, one can no longer draw upon their size and morphology to invoke long periods of ice free conditions.

5.4 Conclusions

The results of weathering and periglacial form investigation on the Burin Peninsula lead to a very general set of conclusions. The field area contains neither the amount of elevation nor the uniformity of lithology to allow weathering zones to be as precisely defined as either Brookes (1977a) or Grant (1977a) have done. Generally, the greatest density of periglacial and freeze-thaw features occurs in the Carboniferous granite of the St. Lawrence plateau. Gross periglacial forms are virtually absent from the till and outwash covered Marystown-Garnish lowland and the area of thicker drift north and west of the Terrenceville-Swift Current, late-Wisconsinan limit (Fig. 4.22). This, in fact, becomes the overriding criterion; in areas where there is significant till cover, there are few surface "periglacial" forms and those that do occur, such as sorted circles, can be considered active.

Summarily, there is ample evidence of periglacial activity and the presence of permafrost over the whole of the Burin Peninsula following late-Wisconsinan deglaciation. Taken alone, this is insufficient to allow the designation of weathering zones. However, weathering rind thicknesses indicate that a longer period of subaerial weathering has occurred in the area south of the Terrenceville-Swift Current, late-Wisconsinan limit. Also, there appears to have been a shorter period of weathering in the Jacques Fontaine fjord than on the nearby upland. Therefore, at least two weathering zones are present on the Burin Peninsula; the area, covered by late-Wisconsinan ice (equivalent to Brookes' zone 1 and Grant's zone A), and the area that lies south and east of the late-Wisconsinan limit, which has remained unglaciated at least since the late, mid-Wisconsinan (equivalent to Brookes' zone 2a and Grant's zone B). It is important to note that neither of the Burin Peninsula zones can be accurately depicted from weathering data alone. Also, they exist more in a spatial context than in a vertical sense. This is a significant departure from the western Newfoundland weathering zones which have sharp, easily defined vertical limits. Additional zones may exist on the Burin Peninsula but their definition would require a separate, detailed study.

CHAPTER 6

ST. PIERRE ET MIQUELON

6.1 Introduction

6.1.1 Preamble

Because the islands of St. Pierre et Miquelon are in proximity to the Burin Peninsula, and because they are situated well south of the late-Wisconsinan margin proposed by Grant (1977b), it was considered essential that they should be included in the study area. This presented several problems in that Quaternary information about them is sketchy, and access to more interesting parts of the archipelago is difficult. Ferry connections to St. Pierre operate daily from Fortune, but sea voyages to Miquelon are scheduled only once a week, and Langlade is reached only on foot or four wheel drive taxi from Miquelon, or by chartered boat from St. Pierre. For reasons of cost, only a brief reconnaissance was carried out. Nevertheless, several important new insights on the Quaternary record were gained and are discussed below.

6.1.2 Location and physiography

The French archipelago of St. Pierre et Miquelon is situated at the entrance of Fortune Bay approximately 25 km southwest of the Burin Peninsula (Fig. 1.1), and is contained within the area defined by 46°45'-47°10'N latitude and 56°05'-56°25'W longitude. The territory consists of three principal islands, St. Pierre, Langlade, and Miquelon, as well as a number of smaller islands located to the northeast of St. Pierre. The two major urban centres of St. Pierre and Miquelon have a combined population of 6,500 people, of whom all but 700 inhabit St. Pierre. The towns are supplemented by summer habitations at Ile aux Marins, east of St. Pierre, as well as Anse du Gouvernement and Petit Barachois on Langlade. Langlade and Miquelon although considered seperate islands, have been connected by an isthmus of sand dunes (Fig. 6.1) some 12 km in length since the end of the eighteenth century (Aubert de la Rüe, 1951).

The physiography of the 240 km^2 territory is similar to that found on the lower Burin Peninsula (Section 1.7.3) in that its surface of 120-150 m rises gently to the northeast and is broken only by occasional hills of 150-200 m in elevation. The highest, Morne de la Grande Montagne, is located on Miquelon, and extends 240 m a.s.l. Surficial cover of the islands is variable. For the most part, St. Pierre is drift-free while Langlade and Miquelon have more extensive thicknesses of surficial material in their uplands. It is heavily masked by organic cover which makes it difficult to interpret depths precisely. Weathered, tor-like rock knobs are more common on Miquelon, which indicates that deposits are thinner than on Langlade. Below 20 m, surficial material is thicker and has a subdued, rolling to planar appearance. This is especially so along the south coast of St. Pierre, the perimeter of Miquelon, and along the west and south coast of Langlade.

Drainage is poorly developed on the islands. Ponds are contained in shallow bedrock depressions or troughs from which streams randomly find

FIGURE 6.1: Isthme de Langlade. Well fixed dunes and blowouts are derived from uplifted, nearshore, interglacial sands and gravels. Example shown is 18 m a.s.l.

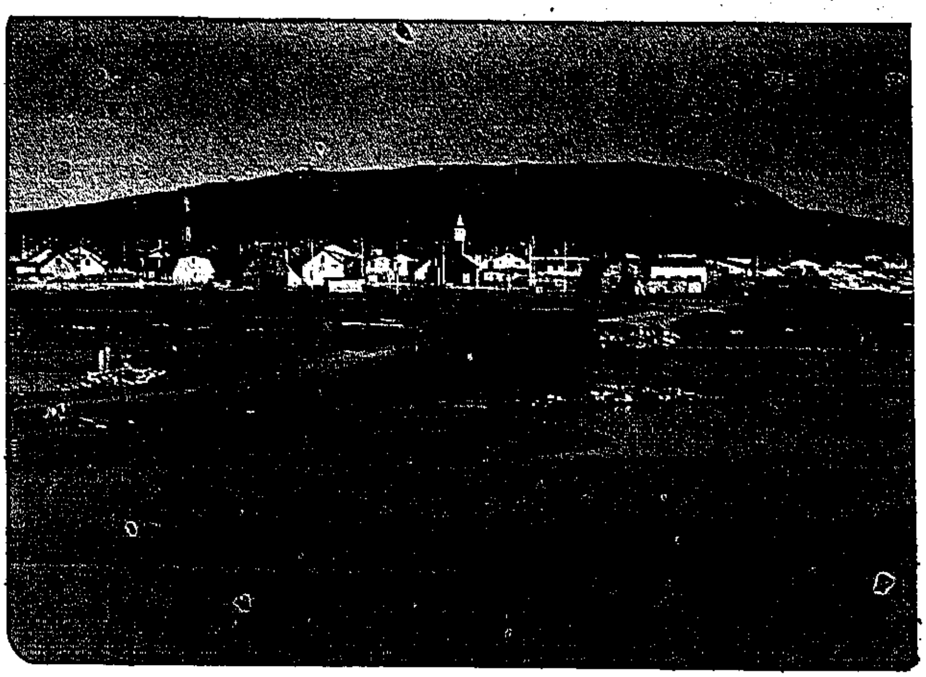


FIGURE 6.2: The town of Miquelon is built on a raised foreland ~4 m a.s.l. To the north is le Cap, 116 m a.s.l.

their way from the local heights of land to more level ground. An exception of this occurs along the west and south coast of Langlade where streams such as Deuxième Ruisseau Maquine are incised to a depth of 50-60 m in the 150 m plateau. At a point ~20 m a.s.l. the streams have developed a well entrenched pattern of meanders and flow through surficial cover to the coast. A similar pattern occurs on the east and northeast coast of Miquelon, though here, the meanders extend further in elevation because of greater thicknesses of unconsolidated material.

Features of coastal submergence are ubiquitous with major barrier islands, beaches and lagoons occurring around the perimeter of Miquelon and along the south coast of St. Pierre. The town of Miquelon is built on a raised, cobble gravel foreland that although >1.2 km in east-west extent, is <10 m a.s.l. in elevation (Fig. 6.2).

6.1.3 Bedrock geology

The bedrock geology has been interpreted mainly through the work of Aubert de la Rüe (1932, 1946, 1951). More recently, it has been generalized by Williams (1978) whose description is cited in Figure 6.3. The oldest units are the Precambrian, sedimentary volcanic rocks found on St. Pierre and Miquelon. These are correlative with the northeast trending zone of acidic-basic volcanic rocks, schistose, porphyritic felsite and tuff located on the southwest coast of the Burin Peninsula. Le Cap, north of Miquelon consists of Precambrian metamorphics with zones of quartzite, gneiss, paragneiss and granitization. The bedrock on Langlade is Cambrian to Middle Ordovician in age and reveals suites of rock similar to those in the Dantzic Cove-Fortune area of the Burin

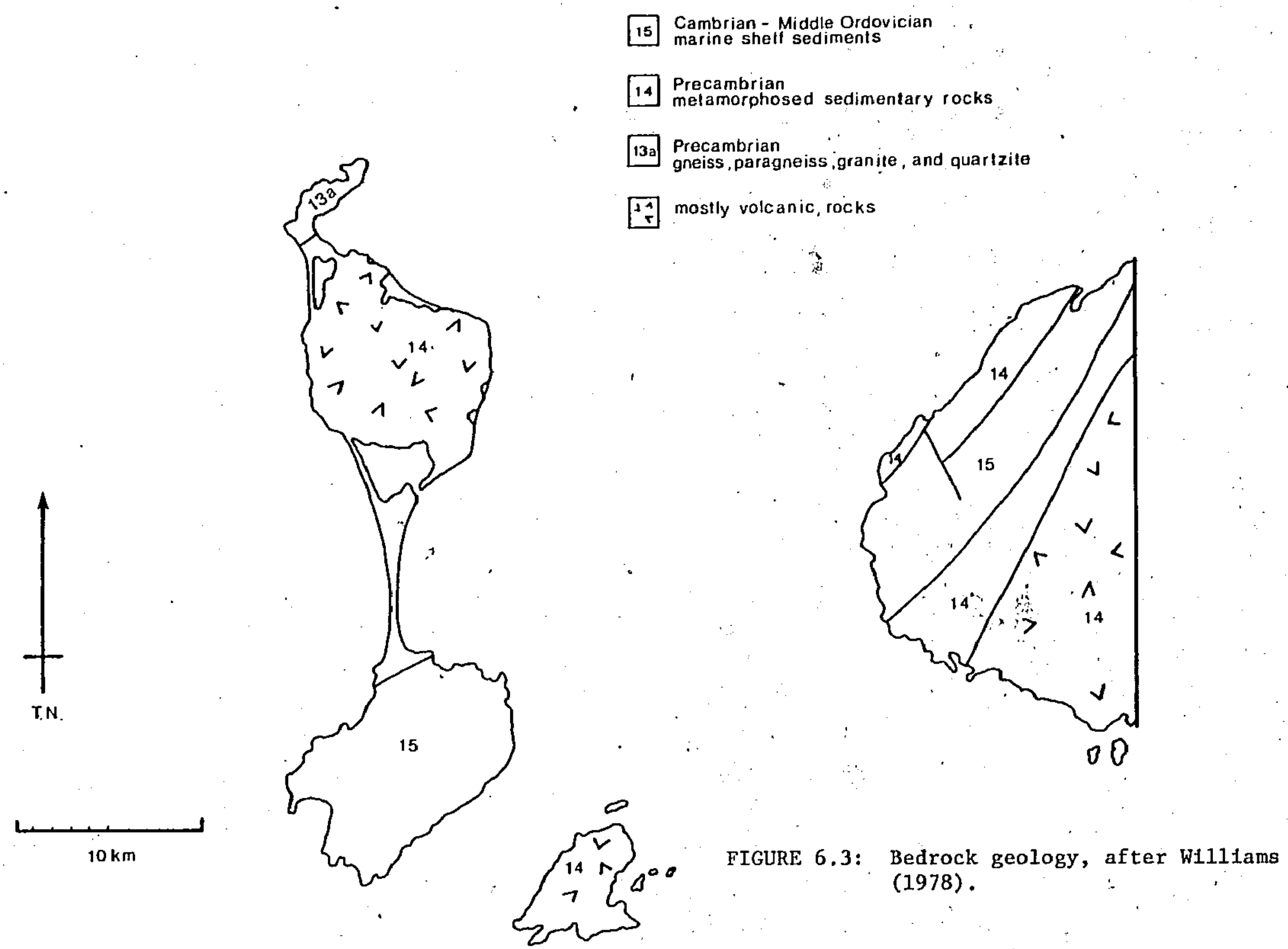


FIGURE 6.3: Bedrock geology, after Williams (1978).

Peninsula. These marine shelf sediments contain northeast trending belts of red to grey sandstone and siltstone, black slate, quartzites and minor limestone. As well, minor plugs of intrusive rhyolites are present at the northeast corner of Langlade.

6.1.4 Previous research

Information on Quaternary deposits is contained in the various reports of Aubert de la Rüe. He contended (1932) that the islands were completely glaciated by ice originating in Newfoundland. This was indicated by the presence of foreign, coarse grained granite erratics on quartzite at Belle Rivière, Langlade, as well as on the lowland north of Miquelon. He further suggested that a terrestrial link with Newfoundland occurred during this stage. Ground moraine is described as being 3.5 m thick, except at Petit Barachois and on the lower east coast of Miquelon where deposits are >30 m thick. Small frontal moraines, a result of local cirque glaciers, were noted at Miquelon, though their exact locations were not described. Aubert de la Rüe mentioned the occurrence of microindicators of ice movement such as roches moutonnées, glacial polish, and striae oriented 110-150 located northeast of the town of St. Pierre and near Pointe au Cheval, Miquelon. Periglacial features such as solifluction lobes, talus and felsenmeer are also described at various locations, as are aeolian ventifacts and grass covered dunes at Petit Barachois which are said to overlie till. He determined the source of the dune material to be postglacial marine sands and gravels, so called because of the lack of overlying erratics. Although he was aware of the 15-20 m a.s.l. raised terrace remnants at the head of

Fortune Bay, Nfld., he did not consider that the French territory had been affected by isostatic uplift since the end of the last glaciation, rather, that bay mouth bars and tombolos indicate that submergence is occurring.

6.2 Glacial Patterns

6.2.1 Glacial deposits as macroindicators of ice movement

The St. Pierre et Miquelon archipelago could most aptly be described as having a homogenous surface morphology with a distinct lack of glacial features indicating directions of former ice movement. There are, however, several limited patterns that were developed and are detailed in Fig. 6.4. Along the lower south coast of St. Pierre there are two recessional moraine remnants that are oriented northwest-southeast, and are open towards the northeast. They are <15 m in height, highly dissected and rock-cored. At Anse de Savoyard, 2.5 km to the west, an esker that is oriented approximately west northwest, crosses the harbour and extends below sea level. This suggests that the last glacial, hydrologic gradient was to the west or northwest. Above 25 m a.s.l., St. Pierre is essentially free of either drift or glacial features.

Both Langlade and Miquelon have significantly different surface morphologies to that of St. Pierre. The valleys along the steep south and east coasts of Langlade contain thick sequences of surficial material that have been cut by fluvial action. As well, coastal sections contain as much as 50 m of unconsolidated deposits that have been well exposed because of coastal storms and marine erosion. The highland areas are drift covered, but generally, bedrock is close to the surface. Air

FIGURE 6.4:

GLACIAL FEATURES

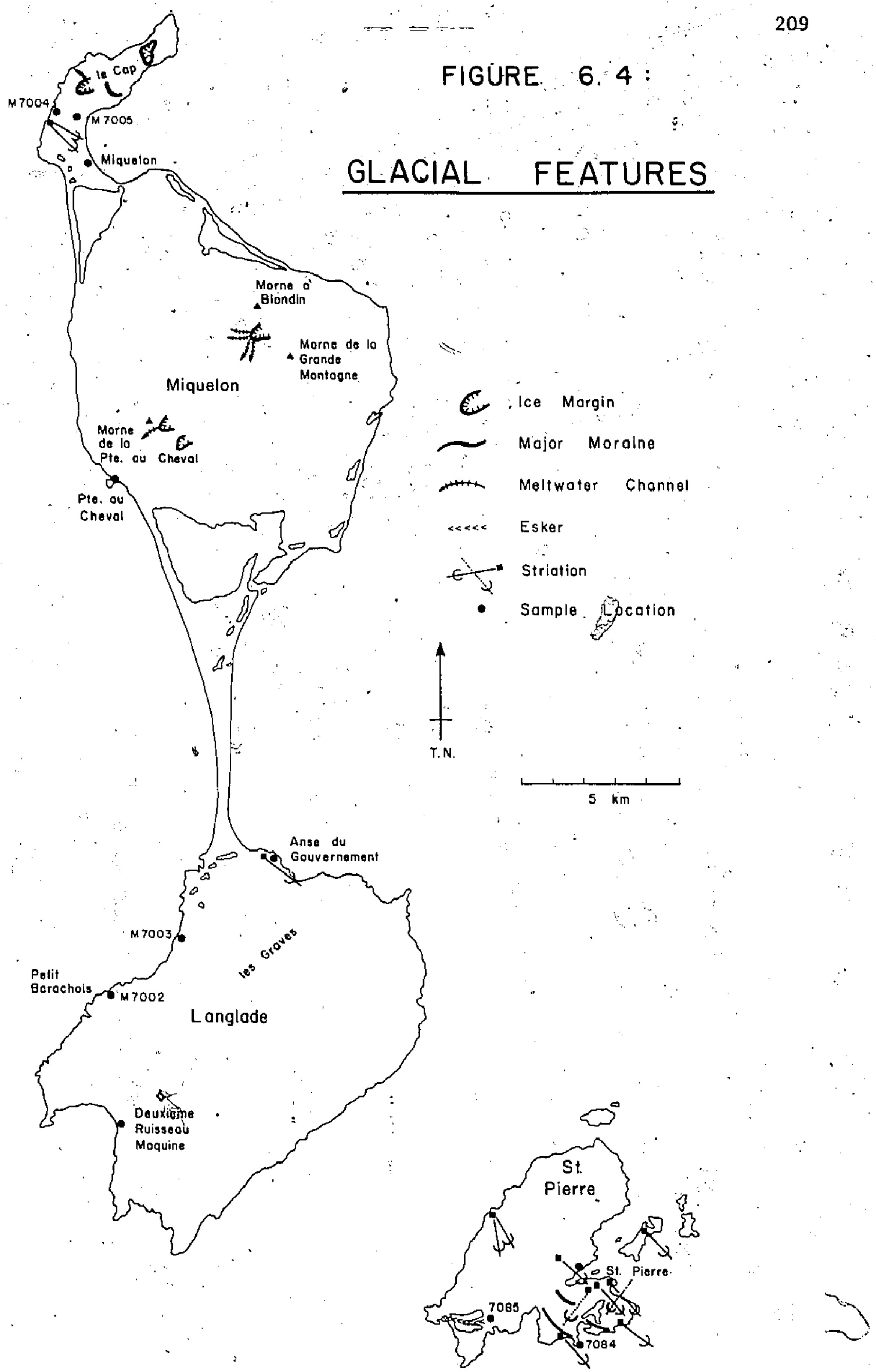


photo analysis reveals no features that might be termed ice marginal, and drainage is well integrated with the present landscape. Near the northwest corner of the island, several fossil drainage channels are evident, but these are considered to represent normal incision of a fluvial system rather than meltwater flow.

The surficial cover of Miquelon is not as subdued as that on Langlade. The highlands have a more rugged appearance and till is not as thick either in the uplands or in coastal sections. Interestingly, the central uplands do contain several arcuate ice margins that are open to the northeast. They are located at 120-130 m between Morne à Blondin and Morne de la Grande Montagne in the east, and Morne de la Pointe au Cheval in the southwest. All three ice margins are poorly preserved, and were identified mainly because of the presence of meltwater channels that radiate away to the southwest. On le Cap of Miquelon, there are three ice marginal positions. The most prominent is situated just south of Butte au Berry and consists of a small cirque with a recessional moraine on its southwest slope. In all cases, meltwater flow from these positions was to the west and southwest.

Because of the limited number of ice margins, and because they all open to the northeast, along with the fact that all indicators of meltwater action are oriented to the west, it is considered that final ice on the archipelago was not all encompassing, and that it was centred to the east, i.e. over the lower Burin Peninsula. Alternatively, based on this evidence alone, one might conclude that the margins, but especially those on the Miquelon highlands, simply represent final positions to which local ice retreated.

6.2.2 Glacial striae as microindicators of ice movement

Field work on St. Pierre et Miquelon was limited, hence, the pattern of striae that was discovered is less than ideal, however, two interesting trends develop. The most well developed mirror ice flow from the south coast of Newfoundland and are oriented 135-160 (Fig. 6.4). The younger were measured only southeast of the town of St. Pierre, but significantly, are directed 220 which is perpendicular to the long axis of the recessional moraines mapped along the south coast of the island.

6.3 Glacial Deposits and Stratigraphy

Surficial material was collected on St. Pierre for later textural and provenance analyses. There were several reasons for this. It was hoped that a more precise insight could be gained on the distance and directions of glacial transport. As well, it appeared from air photo analysis that much of the lowland had been inundated by the sea at some point, and again, this needed clarification.

Sample 7084 was retrieved from a 3 m coastal section located at Tête du Petit Havre (Fig. 6.4). The material is a washed, medium brown, sandy till with angular to sub-angular clasts averaging 8-10 cm in diameter. More than 80% of the clasts are local, Precambrian rhyolites, and rhyolitic breccias and tuffs. Transport from Miquelon is indicated by the presence of Paleozoic phyllites and Cambrian quartzites. No distinct transport from Newfoundland was readily discernable from the analysis. The texture of the sample (Appendix 3) is very sandy, with a mean grain size of 0.70ϕ, and very poor sorting. The mean grain size parameters compare favorably with those of the upper tills of the St. Lawrence plateau described in

Chapter 3. A distinct lack of matrix in the upper half metre of the section would suggest that the material had been reworked to some extent by marine action following deposition.

Lithologic sources were also determined for clasts contained in the esker at Anse de Savoyard (Location 7085 and Figs. 6.4, 6.5). Although the majority were locally derived from rhyolites, agglomerates, rhyolitic tuffs and breccias as well as basalt, 10% had sources on Langlade. The possibility exists that some of this material may have been from Newfoundland especially when considered in light of the onshore striae near St. Pierre, although, with local sources so near at hand, proving a Newfoundland source becomes difficult.

Based on a preliminary interpretation of air photos, a foot traverse was carried out from Miquelon to Petit Barachois, which is located about mid-point on the west coast of Langlade. It was felt that even a cursory appraisal of the nearly forty metres of surficial material at this site would significantly aid the interpretation of Quaternary events on the southeast coast of Newfoundland. Aubert de la Rüe (1946) described the west coast of Langlade as containing till derived from the Newfoundland ice sheet overlain by as much as 7 m of aeolian sand. Between the two units, he reported finding roots which he interpreted as being postglacial in age. Unfortunately, they were not rediscovered during the present writer's brief visit to Langlade in 1977.

The section is located on the coast 0.9 km southwest of Petit Barachois and in detail (Fig. 6.6), reveals 2.4 m of red sandstone which is overlain by 18 m of compact, grey-pink marine silt and sand. The unit contains rounded to subrounded cobbles and pebbles many of which, though

FIGURE 6.5: Esker at Anse de Savoyard (arrow). Ridge is oriented 315 and its crest is ~8 m a.s.l. Area is currently submerging.

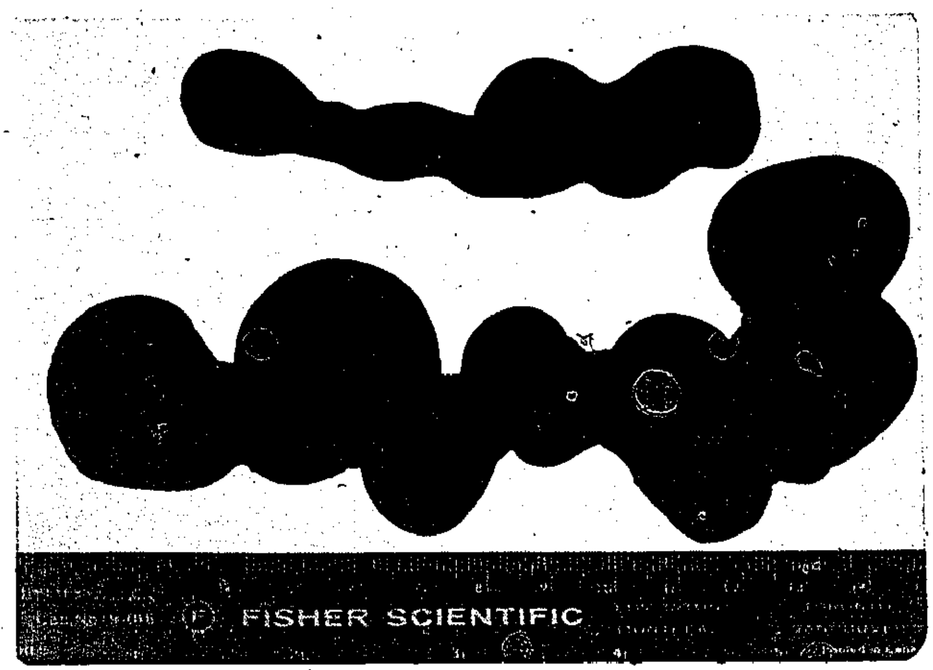


FIGURE 6.7: Marlekor obtained from lower unit of marine silts and sand. The subaqueous forms are thought to be mid-Wisconsinan in age.

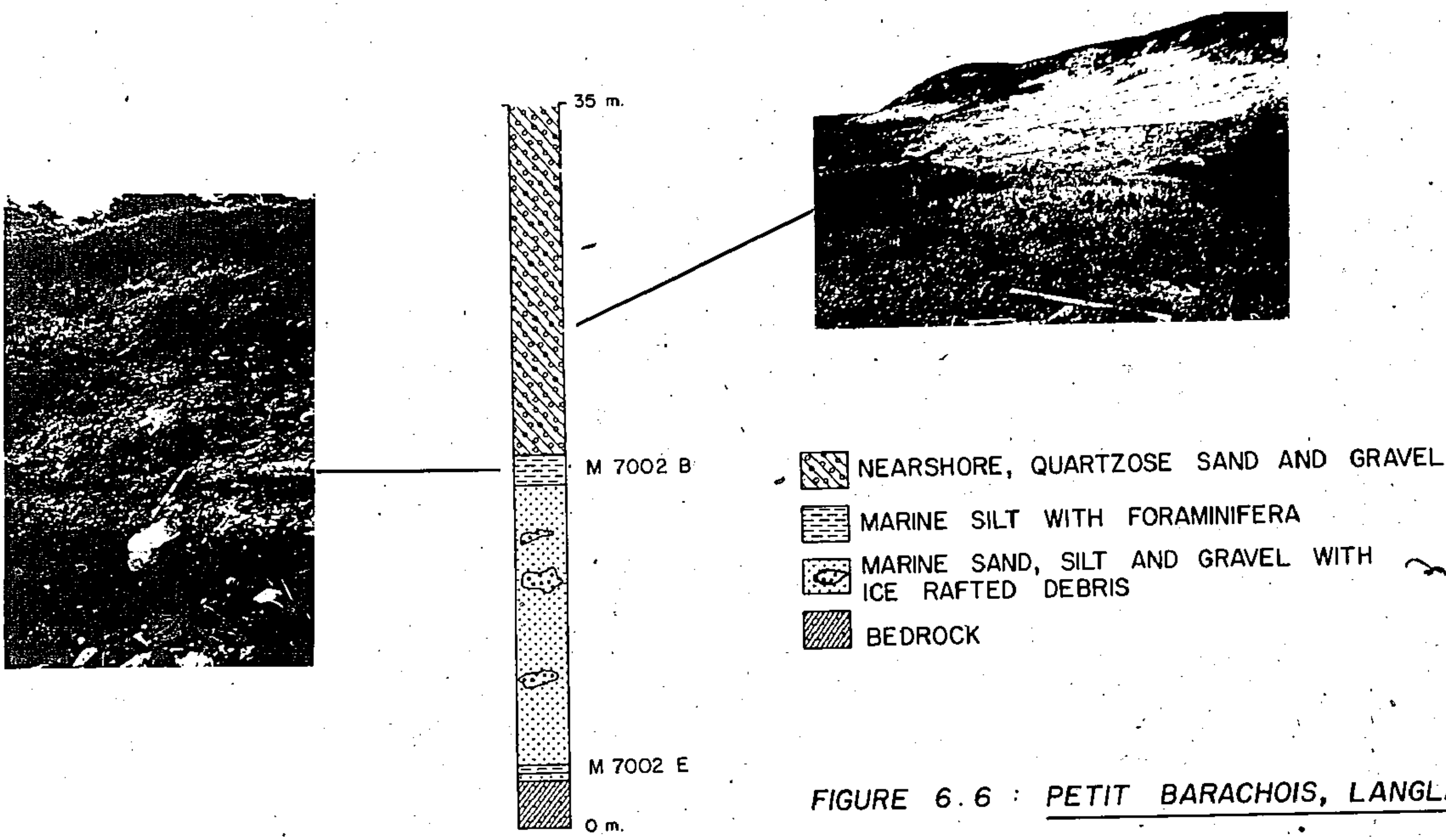


FIGURE 6.6 : ***PETIT BARACHOIS, LANGLADE***

not all, are striated. These are considered to have been deposited by ice rafting from Newfoundland sources. Provenance of the clasts (Sample M7002A) indicates that while most is local, Cambrian and Paleozoic material, 4% is coarse grained, Devonian granite that probably originated in the Cape la Hune-Rencontre West area of Newfoundland (see Williams, 1971). At 2.6 m and 16.6 m, two, distinct, horizontal beds of grey, laminated marine silt were noted. The first is 30 cm thick while the second was measured as being 1.4 m in depth. Significantly, both contain benthonic marine foraminifera of species similar in age and paleoenvironment to those occurring at Dantzic Cove (Table 3.1). Again, the presence of *Glabratella sp.* and *Bulimina sp.* suggest a possibility of sediments older than Holocene.

At several points on the surface of this lower marine unit, small concretions were discovered that have been termed marlekor or imatra stones by Pettijohn (1975). The examples shown (Fig. 6.7) have irregular central columns with round nodules up to 3 cm in diameter. In addition, simpler, discoid forms of varying dimensions were found at the site. Marlekor were also noted on Langlade by Aubert de la Rüe (1946) who considered the "pseudo-concretions argilosableuses" to be a postglacial form. He suggested that they originated at the interface of 7 m of dune sands overlying 25 m of till when calcite rich groundwater reached a subaerial environment. The present author disagrees with Aubert de la Rüe on both interpretations. The lower unit is not considered to be till despite the foreign clasts, and the concretions are not a subaerial form. Because specimens were dug from within, as well as being collected on the surface of the unit, the origin described by Tarr (1935) for similar, glaciolacustrine features is thought to be more likely. He believed their source to be calcite and Al-Fe-Mn compounds brought into the submarine environment from glacier fed waters both as clastic grains and in soluble form. These were deposited mechanically, chemically and organically, chiefly in the silts. The cold, CO_2 rich waters that were buried with the silts gradually dissolved the deposited particles. Subsequently, due to climatic changes, these waters became warmer, which caused a loss of their CO_2 content, and deposition of the various compounds with changes in water pH. Later, subaerial groundwater flow added to the forms, with the greatest increase in material occurring on their upsurface sides. This genesis adds credence to calling the lower unit marine, expecially since silty tills known in the local area are so lacking in calcite and Al-Fe-Mn compounds as to be unsuitable as a direct source. In fact, the Langlade marlekor contain so little calcite that no attempt could be made to date them by isotope methods.

Above the marine silts, at 16.6 m, there is a distinct facies change to very loose, planar-cross-bedded, coarse, quartzose sand and cobble gravel. At Petit Barachois, this unit extends to a height of 35.2 m of which the upper 10 m or so has been dissected by fluvial action and reworked by aeolian processes. Similar stratigraphy exists in a river cut near the mouth of Ruisseau Debons, 1.8 km northeast of Petit Barachois (Location M7003). Here, 11.5 m of contorted marine silt, sand and ice rafted debris containing foreign clasts are overlain by quartz rich aeolian sands derived from the marine sands and gravels. Farther north, this material has supplied much of the sands which constitute the isthmus between Langlade and Miquelon.

The whole sequence of material along the west coast of Langlade is thought to be a coarsening upward, regressive sequence of shallow water marine to nearshore and subaerial silts, sands and gravels. One would hope, with closer study, to find that the marine unit is underlain by a grey-pink, silty, "Fortune Bay" till. This would complete a sequence similar to that exposed along the lower, southwest coast of the Burin Peninsula and extend the range of deposits back to the early-Wisconsinan. No detailed analyses were attempted on Miquelon, but it is thought that all deposits below 20 m have been reworked by marine action to some extent. This conclusion is based on cursory examination of coastal material near Grande Anse du Ouest (M7005).

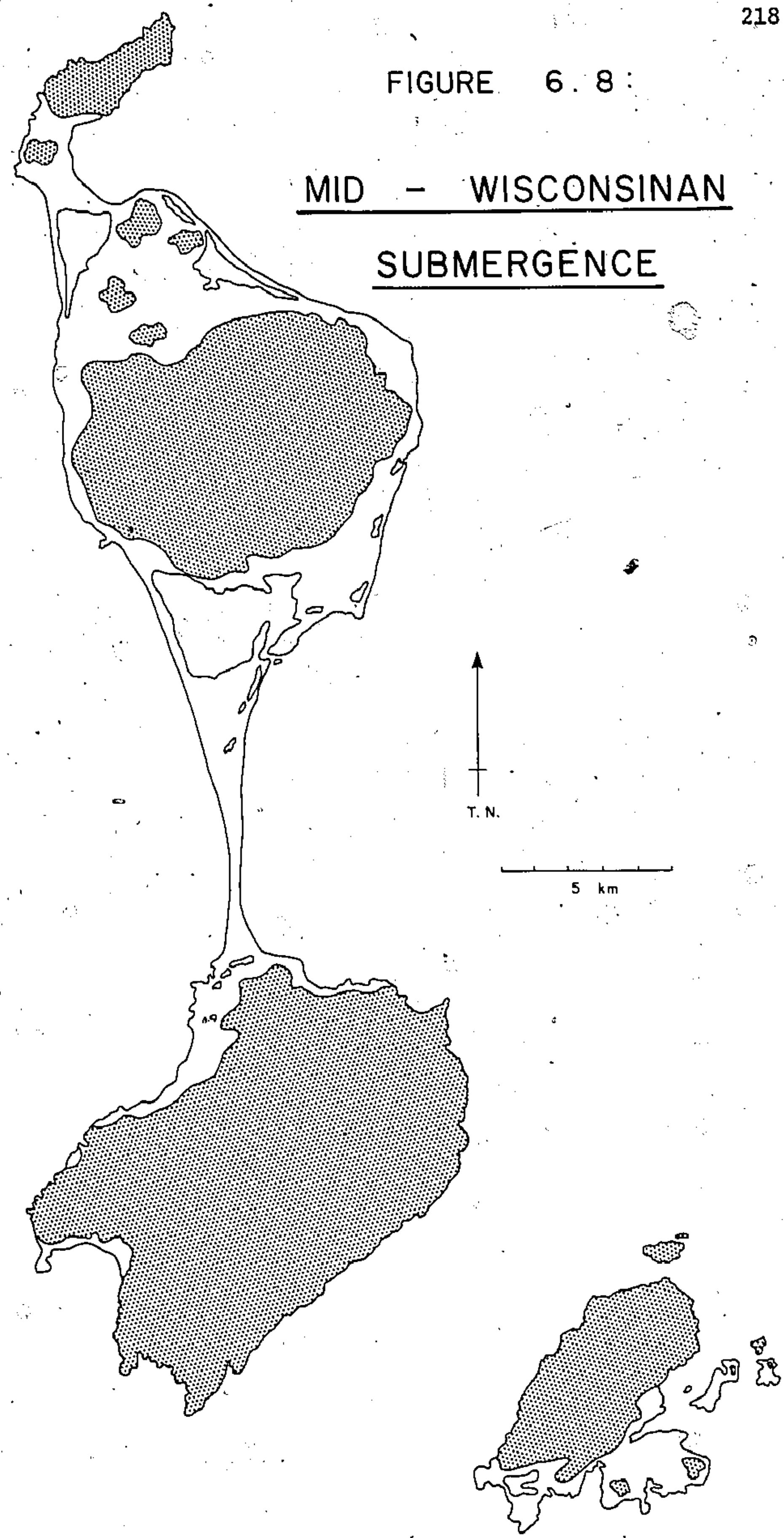
6.4 Raised Benches, Terraces and Marine Overlap

As well as the stratigraphy, there is ample morphological evidence of marine overlap, despite the contrary findings of Aubert de la Rüe. At locations such as le Cap, Miquelon, and near Petit Barachois, bench remnants are visible at 2.4 and 2.6 m. These have been assigned to the 4 ± 1 m Sangamonian set visible around the perimeter of the Burin Peninsula because they are striated and capped by surficial material.

Between 20 and 25 m of submergence is recorded around St. Pierre, Langlade and Miquelon (Fig. 6.8). It is shown by a distinct break in slope between an upland of till, vegetated rock and deeply incised streams, and a lowland of subdued terrain. The lowland is capped by marine sands and gravels, and aeolian material (Fig. 6.9). Since the break in slope occurs at approximately the same height above sea level as the 20 m a.s.l. collapsed stack at Jacques Fontaine and other raised

FIGURE 6.8:

MID - WISCONSINAN SUBMERGENCE



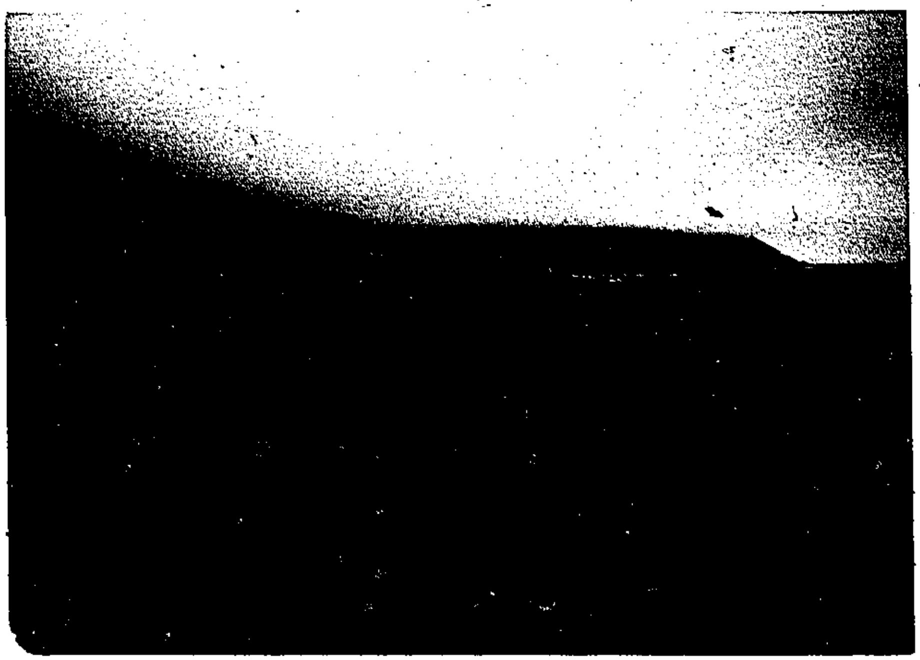


FIGURE 6.9: Mid-Wisconsinan marine overlap in the Petit Barachois-Ruisseau Debons area of Langlade. Elevation of the marine-aeolian sand and gravel is ~18 m a.s.l. Terrain has been highly dissected and streams are well incised.

marine features located farther south on the Burin Peninsula (Section 4.3.1.3), it is thought to represent the relatively stable and long-term marine stand occurring during the mid-Wisconsinan. A 9.6 m raised spit at le Cap, Miquelon, along with similar, raised marine bars on the north coast of the island of Miquelon, and a 6.4 m marine terrace at Anse du Gouvernement (Fig. 6.10), are thought to be late-Wisconsinan in age because of their northward tilt and general agreement with the pattern of postglacial emergence derived for the Burin Peninsula.

6.5 Weathering and Periglacial Phenomena

Several measurements of weathering rinds were taken from bedrock on St. Pierre et Miquelon. Rind thicknesses of 4-5 mm were obtained from rhyolitic breccia on the central highland of St. Pierre. This compares with a value of 5-7 mm on similar material near Tête de Galantry at 10 m a.s.l., some 130 m lower in elevation. A similar figure of 4-6 mm was measured on andesite near Rivière de la Carcasse on Miquelon (Fig. 5.1). Felsenmeer containing blocks up to 2 m across is situated on the St. Pierre highland. Aubert de la Rüe (1951) described similar features developed in quartzite near les Graves, Langlade. With so few measurements, it is difficult to make precise conclusions beyond saying that St. Pierre et Miquelon have been subjected to a period of subaerial weathering at least as intensive and as long as that which occurred on the lower west coast of the Burin Peninsula.

6.6 Discussion

These rather piecemeal observations on the Quaternary of the

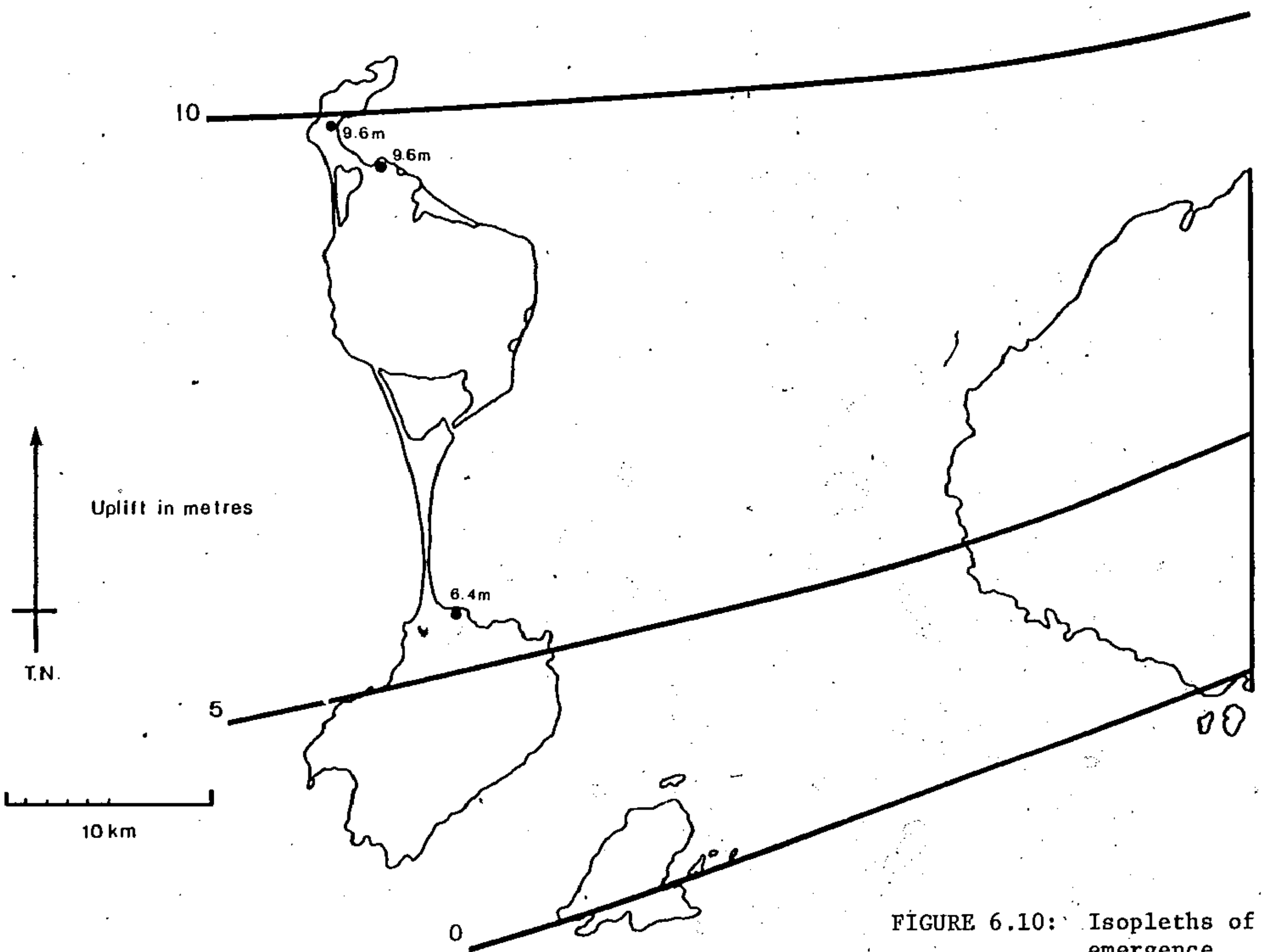


FIGURE 6.10: Isopleths of postglacial emergence.

French archipelago lead to several interesting conclusions not previously documented. Most important is that it appears that all of Langlade, most of Miquelon and the highland of St. Pierre were not glaciated during the late-Wisconsinan. This is suggested by the distinct lack of till at the Petit Barachois section of Langlade, the presence of Salmon River, N.S. - correlative forams at the same location, and the general absence of ice stagnation features in the uplands. The southwest, onshore directed striae, cutting earlier striae resulting from mainland, Newfoundland ice, along with southwest oriented, morainal remnants, eskers and meltwater channels, imply that the last ice to affect the south coastal portion of St. Pierre and the west coast of Miquelon was the same that influenced the lower Burin Peninsula during the late, mid-Wisconsinan. It is not clear if the Burin Peninsula ice was continuous with that in the Miquelon highlands. It may be that limited patches of ice existed beyond a well defined terminus in a manner similar to that described for the late-Wisconsinan limit near Terrenceville and Swift Current (Section 3.4.8). Certainly, the >275 m deep channel between Miquelon and the Burin Peninsula (Can. Bathymetric Chart 802) would deem this situation plausible since it is unlikely that so limited a cap would have been able to cross such a barrier. Although stratigraphic work on Langlade is incomplete, and only loosely correlated by way of the foraminifera with that on the southwest Burin Peninsula, it is considered precise enough to more accurately place the dispersal centre of the late, mid-Wisconsinan ice to the southeast, but west of the 250 m channel which cuts the centre of Placentia Bay (Can. Bathymetric Chart 802).

Three periods of marine overlap are thought to have occurred; one during the Sangamonian, which cut the marine bench at ~2.6 m, one during the mid-Wisconsinan, from which ~20 m of overlap is recorded over unconsolidated deposits, and a final, lower, late-Wisconsinan overlap on the north tip of Langlade and around the coast of Miquelon. The southern portions of Langlade and St. Pierre are considered to be submergent in a manner similar to the southeast coast of the Burin Peninsula.

CHAPTER 7

CONCLUSIONS AND DISCUSSION

7.1 Conclusions

The research described in five of the preceding six chapters has lead to the proposal of a revised and extended sequence of late Quaternary events on the Burin Peninsula and St. Pierre et Miquelon.

1. The oldest glacial event recorded on the peninsula is thought to be pre-Wisconsinan (Illinoian) or early-Wisconsinan, pre-St. Pierre interstadial in age, and to have originated with Newfoundland centred ice. Stratigraphic evidence is limited to five sections of which the most diagnostic occurs at Main Brook (Section 3.3.1). The exact nature of the following nonglacial interval is unknown. However, if the stade was pre-Wisconsinan in age, then it was followed by the Sangamonian interglacial. The more or less continuous, 4 ± 1 m a.s.l. rock bench, cut by marine erosion, is attributed to this period.

2. This was followed by the Fortune Bay event, which has been assigned to the early-Wisconsinan, post St. Pierre interstadial. Ice was centred to the north-west (Section 2.2) and completely covered the peninsula. It deposited a grey-pink, marine derived, silty till along the west coast of the peninsula and a sandier, granite rich till on the area north and east of Fortune Bay. Diagnostic stratigraphy for the event is recorded and explained in Sections 3.2.1-3.2.4, 3.2.6, 3.4.3 and 3.4.5. This stade is considered to be the last to affect the whole of the Burin Peninsula and St. Pierre et Miquelon.

3. Mid-Wisconsinan marine overlap to a height of at least 20 m (Sections 4.3.1.3 and 6.4) is indicated by fossiliferous silts and sands located at Dantzic Cove and Salmonier Pond on the Burin Peninsula, and at Petit Barachois, Langlade (Sections 3.2.1, 3.2.4 and 6.3). Following this, the lower Burin was covered by ice

centred to the south and east, which overrode the marine unit and moved generally northwest at least as far as the Marystown-Garnish lowland, and probably into Fortune Bay (Fig. 7.1). Its passage is recorded by northwest-oriented striae along the south coast (Section 2.2) and a well defined, arcuate ice margin along the northern perimeter of the lower peninsula (Section 2.1.3).

4. On the French islands, the late, mid-Wisconsinan stade is recorded by southwesterly-oriented striae (Section 6.2.2) and poorly defined ice margins on the St. Pierre lowland and the east coast Miquelon highlands (Section 6.2.1). St. Pierre ice is thought to have been contiguous with the lower Burin cap, but ice on Miquelon remained isolated. The island of Langlade was not reoccupied by ice during or subsequent to this stade.

5. The east coast of the Burin Peninsula as far south as Jean de Baie and Creephole Point was probably influenced by the same event, except that ice was domed over Placentia Bay or the Avalon Peninsula (Fig. 7.2). This view is based on the occurrence of southwesterly-directed striae along the Placentia Bay coast (Section 2.2). Because the onshore striae are much fresher than the southeast oriented sets protected in the lee of rock outcrops, a sustained period of weathering (mid-Wisconsinan interstadial) is thought to have separated this limited ice from the earlier, all-encompassing Newfoundland ice. Limited deglaciation probably took place prior to the onset of the late-Wisconsinan stade (Sections 4.3.1.3 and 5.3.3).

6. The final glacial event (late-Wisconsinan) had limited influence on the Burin Peninsula and is considered not to have advanced south or east of the Terrenceville-Swift Current margin defined on Figure 7.1. In front of this well defined margin, there was limited highland ice generated *in situ* that did not extend above 200-230 m a.s.l. (Sections 2.2.2 and 4.3.1).

7. Late-Wisconsinan deglaciation resulted in the formation of glaciomarine deltas at the heads of Fortune and Placentia Bays, and except for specific cases, such as the ice contact deltas at Jacques Fontaine and Grand John Point, meltwater sources were located well inland. As much as 18.8 of uplift has occurred at the head of Fortune Bay, while the lower Burin Peninsula and St. Pierre are presently submerging (Fig. 7.3). An approximate rate of submergence of 16 cm/century is suggested for this area.

8. Permafrost activity following late-Wisconsinan deglaciation is indicated by the presence of fossil ice wedge casts which are located on distal, stratified deposits

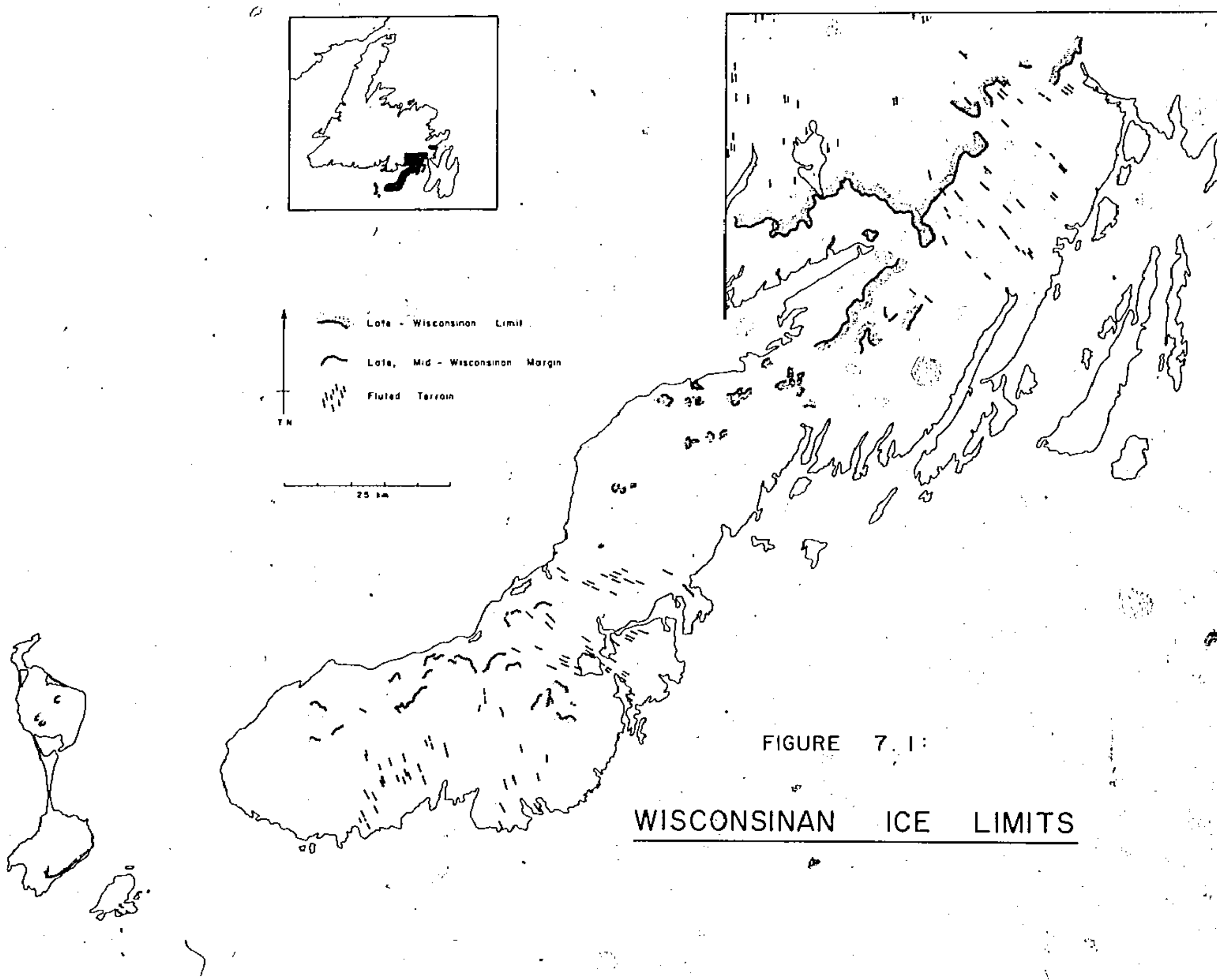


FIGURE 7.1:

WISCONSINAN ICE LIMITS

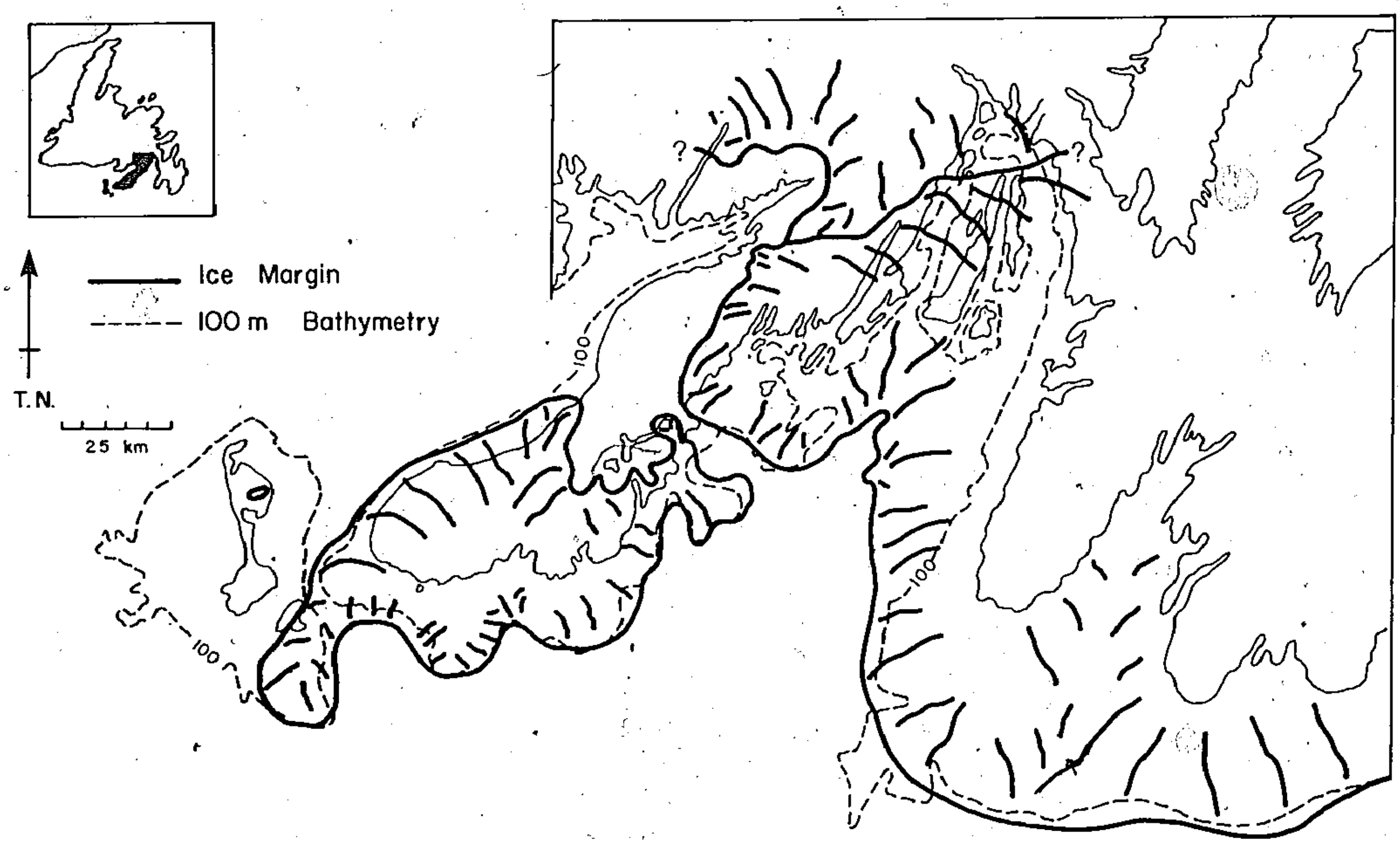


FIGURE 7.2: HYPOTHETICAL LIMITS, LATE, MID-WISCONSINAN ICE CAPS

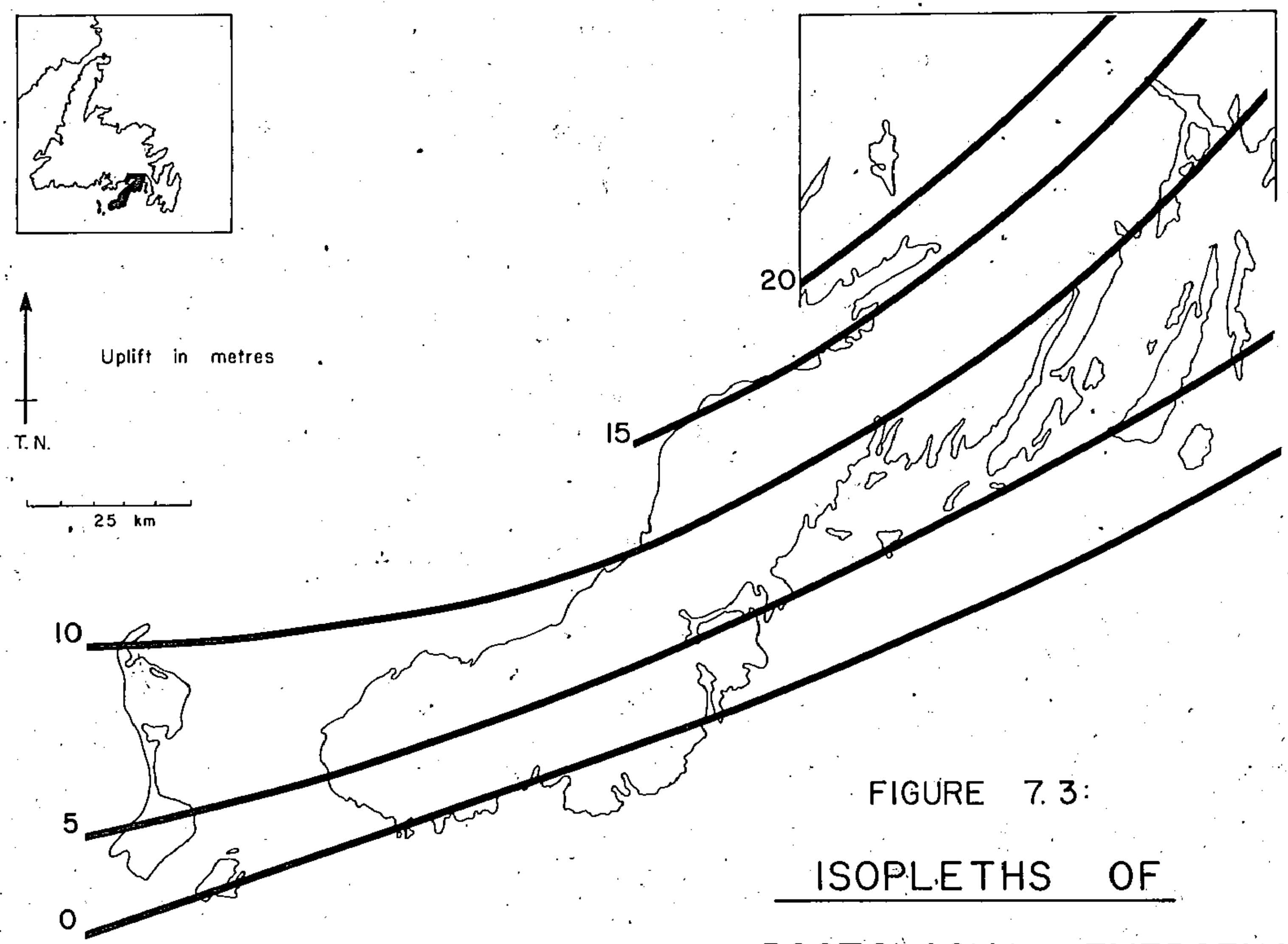


FIGURE 7.3:

ISOPLETHS OF POSTGLACIAL EMERGENCE

associated with this event. Weathering phenomena are conclusive only to the point that they indicate that subaerial exposure and freeze-thaw action was more prolonged in the area south and east of what has been termed the late-Wisconsinan limit.

7.2 Discussion

7.2.1 Limits and chronology

The above results are a significant departure from the traditional view of complete, late-Wisconsinan ice cover on Newfoundland (McClintock and Twenhofel, 1940; Van Alstine, 1948; Jenness, 1960; Prest, 1970; Eyles and Slatt, 1977; Slatt, 1977; Piper and Slatt, 1977; Vanderveer, 1977). Rather, they are in general agreement with recent proposals by Brookes (1977a) and Grant (1976b, 1977b) for western Newfoundland (Fig. 7.4). It may be recalled from Chapter 1 that Brookes delineated three weathering zones. In decending order; zone 3 remained unglaciated throughout the Wisconsinan stage, zone 2b was affected by pre-/(?) early-Wisconsinan ice, zone 2a by early-Wisconsinan ice, and zone 1 was covered by late-Wisconsinan ice. Grant's tripartite system contained; an upper zone C, possibly not glaciated since the last interglacial, zone B, probably not glaciated since early or middle-Wisconsinan time, and zone A which was covered by late-Wisconsinan ice. Hence, Grant's zone C correlates with Brookes' zone 3, B with 2a,b and A with Brookes' zone 1. From the present work, it is considered that only zones A and B are discernable on the Burin Peninsula, i.e., that the last, complete ice cover was attained in the early-Wisconsinan. This is reasonable if for no other reason than one of elevation; both Brookes and Grant were dealing with as much as 650 m a.s.l. plateau surfaces. Highest peaks

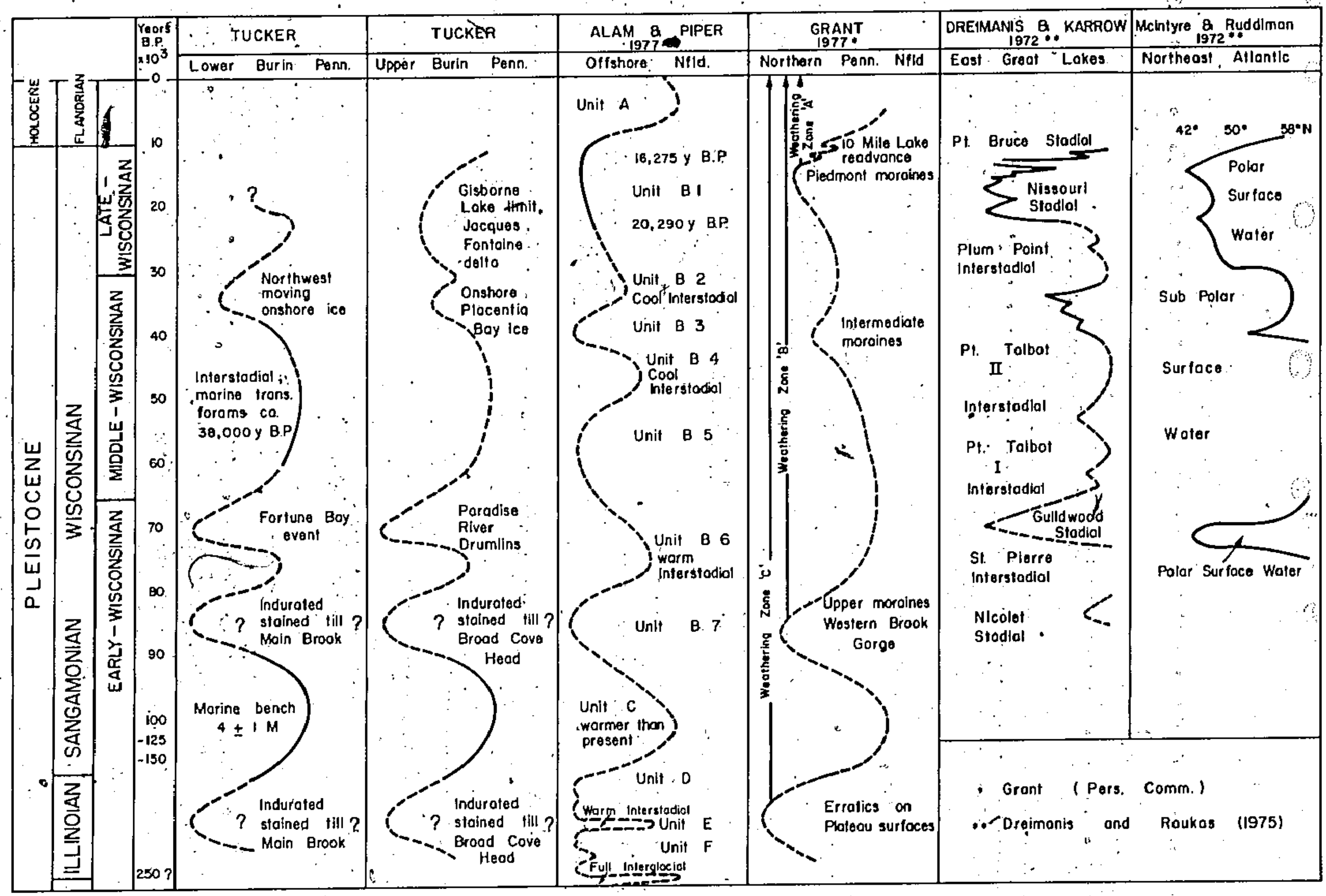


FIGURE 7.4 : LATE QUATERNARY EVENTS CORRELATION CHART

on the Burin Peninsula are no more than 370 m in elevation, and only those above ~230 m a.s.l. are drift free. Thus, early-Wisconsinan, Newfoundland centred ice, moving southeastward, simply did not have the topographic barrier that was imposed by the Long Range Mountains on the west coast, and overrode the peninsula even though it would have tended to have been drawn down into the 350 m deep central channel of Fortune Bay, and deflected away to the south.

Significantly though, both the late-Wisconsinan margin in the Gisborne Lake area, and the late, mid-Wisconsinan margin on the lower peninsula were influenced by topography. In the case of the Gisborne Lake limit, the terminus was located at about 230 m a.s.l. on the proximal flank of the hills immediately north of English Harbour East and Terrenceville. Similarly, the limit on the St. Lawrence plateau occurs along the northernmost height of land. Farther to the west, the terrain is lower and less rugged, thus, ice was able to flow out onto the Marystown-Garnish lowland and the west coast of the peninsula (Sections 3.3.6 and 4.3.1). Reconstructing the western limit of ice flow on the Placentia Bay coast of the upper Burin Peninsula is more difficult because the evidence is lacking. There is no morphological indicator for this event reflected in the surface deposits. This may be because of the masking caused by late-Wisconsinan, highland ice and its subsequent dispersion (Fig. 2.1, 7.1 and surficial maps). One might speculate that if ice was centred over the Avalon Peninsula during this event, the deeper part of Placentia Bay (the Halibut Channel) would have caused draw-down similar to that which occurred in Fortune Bay. However, since it is not as deep (<250 m) or as wide as Fortune Bay, ice could have moved up onto the east coast of the Burin. This proposal is similar to one presented diagramatically by Stow (1977). On the northeast coast of the peninsula, onshore ice movement would have been hampered by coeval Newfoundland centred ice moving off to the southeast (Fig. 7.2). Evidence for this is provided by the lack of onshore striae north of Sandy Harbour River (Fig. 2.13). This is a departure from Stow's work in that he indicated that all of the upper Burin Peninsula was ice free at this time.

The chronology developed for the Burin Peninsula has evolved largely by working away from the mid-Wisconsinan marine unit. The age of this horizon is, admittedly, tenuous (Sections 3.2.1, 3.2.4 and 6.4) but the correlation between it and Salmon River, Nova Scotia which has been dated at 38,000 B.P. (Nielson, 1974; Grant, 1976a; Wagner, 1977) is the only one available for the present. Further stratigraphic work on Langlade along with a more rigorous search for datable material should do much to better fix the various events in a time frame. The chronology itself warrants further discussion. In general, it is in agreement with the events developed from the offshore stratigraphic record by Alam and Piper (1977). They recognize full interglacials at 125,000, 250,000 and 400,000 B.P., and warm interstadials comparable to the St. Pierre, as well as cool interstadials similar to the Plum Point. Four types of glacial conditions were recorded; the late-Wisconsinan with cool water surface temperatures, the mid and early-Wisconsinan with cold surface temperatures, and the latest Illinoian with cool surface temperatures. The complete Illinoian was considered by Alam and Piper to be a more severe glaciation than the Wisconsinan.

Similarly, the Burin Peninsula events may be compared with the worldwide correlations described by Dreimanis and Raukas (1975), but there is a real danger in attempting to correlate what is, basically, an un-dated chronology. It is for this reason that Andrews (1968) and Miller *et al.* (1977) refer to the Baffin Island equivalent of the more southern, Wisconsinan event as the Foxe Glaciation. It may be that the Burin Peninsula presents an analagous problem. This situation is exemplified in Grant's work in which he has variously called the lower Burin Peninsula cap; late-Wisconsinan (1975c), "earlier" Wisconsinan (1976b), and early-Wisconsinan (pers. comm.). All three descriptions are compatible with the eastern North American chronologies. However, the mid-Wisconsinan marine unit which is overlain by the lower Burin, sandy till, now provides a firm maximum age for this event, and it is further bracketed by late-Wisconsinan marine overlap of its associated outwash.

As a final point for discussion, one might speculate that the ice margin proposed by Jenness (1960) and Lundqvist (1965) (Fig. 1.4) could, with minor modifications, represent the maximum late-Wisconsinan stand for the north-central and eastern part of the island of Newfoundland, excluding the Avalon Peninsula. Certainly, in the Burin Peninsula area it appears so, though as yet, no real correlations can be proved between the raised deltas at the head of Fortune Bay and, for example, those around the perimeter of Halls Bay (Tucker, 1974a). A similar idea was recently voiced by Andrews and Ives (1978) with reference to the Cockburn Substage during which, in selected places, the Laurentide ice sheet may have readvanced to reach its maximum, late-glacial extent.

7.2.2 Ice dynamics

A further dilemma revolves around the generation of offshore ice in a lowland area. This is not necessarily difficult here in that much of the shelf area to the south and east of the Burin Peninsula and St. Pierre et Miquelon is <100 m b.s.l. and the present height of land generally <150 m a.s.l. (Section 1.7.1). Also, the nearby Gulf Stream would have provided an ample moisture source, despite the fact that it was probably positioned farther south than at present (Ruddiman, 1978). But this idea is diametrically opposed to the classical dogma which states that ice is first generated in coastal mountains with later, radial flow to central lowlands and the coast (Flint, 1971, pp.596-601). Ives *et al.* (1975) provided a new model of instantaneous glaciation which relies upon the lowering of a regional snowline. The process, while allowing for cirque glacier growth, would induce rapid expansion and coalescence of permanent snowbanks across a plateau. They suggested that this would occur long before any significant ice mass had been produced in coastal mountains, and would serve to engulf more intensive and localized growth. Andrews and Mahaffy (1976) stated that the demands for rapid glacierization of large tracts are tantamount to a declaration of the importance of a change in precipitation regimes during the onset of glacial conditions (the warm/wet phase of the glacial). Thus, overall climate change, as might have occurred on the lower Burin Peninsula, rather than a highland centre and radial expansion may be considered a more important requirement for the development of an ice sheet.

Locally, the discussion on ice dynamics (and late-Wisconsinan limits) is complicated by the work of Eyles and Slatt (1977) in which they stated that, from evidence gathered on the Avalon Peninsula, it was probable that (late)-Wisconsinan glacier lobes in southeastern Newfoundland were of the cold, arctic type. The authors drew upon CLIMAP (1976) models for the support of their ideas; i.e., that Newfoundland coastal waters had the area of greatest temperature anomally in the North Atlantic. However, since CLIMAP used assumed 18,000 B.P. ice margins which are, themselves, no longer assuredly fixed, then the Eyles and Slatt proposal must be viewed with some caution. In his latest view of the "Laurentide maximum", Sugden (1978) considered both the Avalon and Burin Peninsulas to have been covered by warm-melting ice with resultant abrasion, fracture and meltwater deposition. It would, therefore, seem unlikely that a model with limited, late-Wisconsinan ice, as has been determined here for the Burin Peninsula, could provide for extensive enough ice in adjoining areas to allow cold based thermal conditions to exist in coastal locations.

It is satisfying when remote areas such as the Burin Peninsula contain the morphologic and stratigraphic evidence to substantially revise and extend the Quaternary record, and more so when one realizes that much of the "accepted" glacial record in eastern Canada has been based on limited evidence gained from even more limited field areas. It is hoped that results obtained from future work along the south coast of the island will add weight to the conclusions of this document.

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APPENDIX 1

MAPPING SCHEME AND MAPS

Some of the problems that pertain to the mapping of surficial deposits have been discussed in Chapter 2. For a more complete review of the mapping philosophy, the reader is referred to Fulton *et al.* (1975). Much of the description that follows is abstracted from this work, but a major portion of the legend presented by Grant (1972d) is also incorporated. It is hoped that by following the morphogenetic mapping schemes that are currently being used in eastern Canada, the Burin Peninsula maps (see map pocket) will be compatible with existing products from nearby areas.

1. Primary Level of Subdivision

The objective of the primary subdivision was to set up several general classes of landform materials which could be delimited with a relatively high degree of certainty on air photographs. This was done by grouping related sediments into eight broad materials, genetic categories. The categories used are:

till (T)
lacustrine (L)
marine (M)
fluvial (F)
colluvial (C)
aeolian (E)
rock (R)
organic (O)

Each category is defined in Chapter 2. The deposits of each of these general categories consist of a moderately limited range of materials. For example, areas falling in the till category (sediments deposited by the direct action of glaciers) probably would be composed of poorly sorted material ranging from clay to boulder in grain size. Areas mapped as fluvial (deposits formed by the action of streams) probably would consist of stratified, well washed and sorted sand and gravel. As each of the categories contains groups of genetically related sediments, a general understanding of the processes involved may permit prediction of the probable distribution of sediment textural classes. For instance, in an estuarine situation, coarse material tends to be deposited near the axis of the valley, whereas fine material settles out in quiet-water basins at the valley margins.

2. Genetic and Process Modifiers

This category is used to differentiate modern and past processes. The symbol appears as an upper case superscript such as X^G, which indicates past glacial activity, and is starred (*) if it is still active. A complete list of terms includes:

deflated (D)
glaciated (G)
weathered, washed or winnowed (W)
eroded by meltwater channels (E)
gullied or dissected (V)
soliflucted (S)
congeliturbated (C)
"karst" or collapse by solution (K)
avalanche (A)
thermokarst (T)
piping (P)
nivated (N)
biotic mounding (B)
failing stope (F)

The symbols are arranged in order of overprint on the genetic category.

3. Textural Modifiers

Textural modifiers are placed with the landform material as a lower case prefix in order of size sorting. The categories are:

rubbly (r) - angular, fragmented material, no specific size
bouldery (b) - $>-8\phi$
gravelly (g) - $>-1\phi$, $<-8\phi$
sandy (s) - $>4\phi$, $<-1\phi$
silty (z) - $>8\phi$, $<4\phi$
clayey (c) - $<8\phi$

4. Morphological Modifiers

The morphological modifier expresses the pattern of the landform or genetic category. It is located as a lower case subscript in order of overprint.

plain (p)-flat and deep
rolling (m)-undulating and deep
hummocky (h)-sharply undulating
veneer (v)-<3 m
blanket (b)->3 m
ridged (r)
apron (a)
terraced (t)
lineated (l)-fractured bedrock or fluted till
steep slope (s)
fan (f)
mixture (x)

5. Explanatory Notes

Lateral Relationships

Where two or more classes of terrain are interspersed in a mosaic or repeating pattern on a scale too small to warrant meaningful differentiation, the proportion of each component in the combination is given in a designation set off by symbols denoting arbitrary percentage limits. For example "Tv=0" means that 50% of the area is underlain by thin till, and 50% is organic (bog or fen). "Tv/0" is 60-70% till veneer, and 40-30% organic cover. "Tv:0" indicates that 90-95% of the enclosed terrain is covered by thin till, and the remainder is organic. In practise, the combinations may be more complex than these examples.

Morphologic Overprint

Where a sequence of geomorphic processes has produced a multi-aspect or compound terrain fabric, the geomorphic modifier suffixes are appended in the inferred order of superposition. "$Tvlh^{E}$" means that a veneer of till has been moulded into a smeared or drumlinoid form, then mantled with hummocky till during ablation, and finally channeled by former meltwater streams.

Transitional Associations

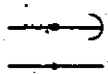
Locally, two or more terrain units are juxtaposed by reason of related origin, temporal sequence, or ambiguous geomorphic distinction. Such situations are identified by a compound designation marked by a hyphen. Examples are: an outwash plain that slopes down and is transitional to a marine terrace ($F^{G}p$-Mt) or kame and kettle glaciofluvial topography that blends with hummocky disintegration moraine ($F^{GE}hr$-Th^{WE}).

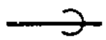
Stratigraphic Sequence

Natural exposures are rare, except along coasts, and are minimally shallow along roads, but where materials of different origin or texture are known to be superimposed, or can be reasonably confidently inferred, the sequence is indicated in conventional order using horizontal separators, such as, "$\frac{Ov}{\frac{Mv}{Tl}}$", which indicates that thin muskeg has developed over a marine mantle on drumlinoid till.

6. <u>Symbols</u>

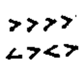
 Boundary of terrain units; defined, approximate, transitional

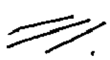
 Longitudinal ice-flow features: drumlin, drumlinoid, fluting, stoss-and-lee hill; direction of ice movement known, unknown

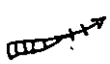
 Striation

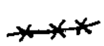
 Transverse ice-flow features, crestline of end moraine; prominent and continuous, subdued and broken

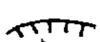
 Ribbed moraine, De Geer moraine, minor moraine

 Esker, crevasse filling; direction of flow known, unknown

 Depressional lineament along fracture or fault trace

 Abandoned channel of former meltwater stream

 Emerged shorelines of former proglacial lake or marine submergence

 Scarp of terrace, bench, delta, or ice margin

 Sinkhole, pond, kettle hole

■ Location of radiocarbon-dated organic material

APPENDIX 2

PROVENANCE OF TILLS

The following is a compendium of till samples that were analyzed to determine directions of transport. Up to 1.5 kg of clasts coarser than -4ϕ and finer than -5ϕ were retrieved and identified solely on the basis of physical properties visible in a hand specimen. Several different maps and reports along with relevant bedrock samples were used to identify sources. Because the maps are at different scales and of varying complexity, they are not particularly compatible with one another. Nevertheless, directions of transport have been determined for all samples. The reader is referred to the following reports for details on the bedrock types involved; the Burin Peninsula and Hermitage areas - Anderson (1965), the Marystown and St. Lawrence map areas - Strong *et al.* (1976), the Grand Bank and Lamaline map areas - O'Brien *et al.* (1977), the Gisborne Lake and Terrenceville map areas - Bradley (1962), the western Avalon Peninsula - McCartney (1967) and St. Pierre et Miquelon - Aubert de la Rüe (1951).

Source	Lithology	Percentage Composition
Sample 7001a	West coast of Allan's Island	1L/13
p€tb?	lithic tuff	16.6%
PPr	red micaceous sandstone	13.3%
p€h	volcanic breccia	16.6%
Csu	granite	3.3%
pCh	rholite	5.4%
pCh	undifferentiated volcanics	41.6%
p€bg	basalt	1.6%
PPr	red, basal conglomerate	1.6%

Notes: PPr, p€h all indicate transport from the northwest. Granite is of unknown direction. p€tb is local bedrock.

Source	Lithology	Percentage Composition
7001c	West coast of Allan's Island	1L/13
CSu	granite	4.1%
p€tb?	lithic tuff	10.3%
PPr	red sandstone	11.5%
p€tb	red porphyritic vitrophyre	14.4%
Csu	granodiorite	10.3%
p€h	undifferentiated volcanics	44.3%
	unknown	5.1%

Notes: Transport appears local except for Csu granite and granodiorite. These are unknown beyond a general southward direction.

Source	Lithology	Percentage Composition
7004a	Dantzic Cove	1L/13
Unit 6	slate	33.8%
3	felsite	24.3%
3	intrusive porphyritics	5.4%
3	greywake conglomerate	6.8%
19?	granite	1.4%
17?	granite	1.4%
5	quartzites	16.2%
4 and 6	siltstone and limestone	8.1%
	unknowns	2.6%

Notes: Units 17 and 19 define transport across Fortune Bay. Remainder are local.

Source	Lithology	Percentage Composition
7004c	Dantzic Cove	1L/13
Unit 4	red, black, grey, green shale	1.2%
17	granite	4.7%
5	massive quartzite, red and brown sandstone	23.5%
6	grey, green siltstone	58.8%
3	rhyolite and agglomerate	7.1%
3	red, basal conglomerate	4.7%

Notes: Material is dominantly local though units 5 and 17 also have sources to the northwest.

Source	Lithology	Percentage Composition
7008	Road cut, Great Garnish Barasway	1M/3
Unit 3	greywake conglomerate	5.0%
3	red felsite	24.0%
3	yellow and green felsite	67.0%
	unknown, weathered	4.0%

Notes: Local till - no distant transport.

7019	Lawn-St. Lawrence area	1L/13
?	epidote	2.4%
p€m	basalt	6.3%
Csu	granite and alaskite	43.1%
p€m(a)	undifferentiated volcanics	26.4%
p€m	felsites and tuff	12.0%
p€m	porphyritic volcanics	7.1%
	unknown	2.7%

Notes: Transport from north and west. Onshore transport not shown.

7018	East of Waterfall Pond, near Little St. Lawrence	1L/14
Csu	granite	4.7%
p€ab?	conglomerate	39.4%
p€rh	limestone	2.3%
p€w(a)	metagabbro	25.6%
p€bp	mafic pillow lava	23.3%
	unknown	4.7%

Notes: Transport directions difficult to show as onshore. Mostly flow from west. p€bg and p€w(a) may be from east but not definite since could reflect local transport into Salmonier valley.

7019	South of Beaver Pond	1L/14
Csu	granite	15.6%
p€bp	flow breccia	33.8%
p€bp	mafic pillow lava	20.8%
€pv	quartzite	24.7%
€bi?	red sandstone	1.3%
	unknown	3.8%

Notes: Transport from west (Csu, €pv) and local.

7020b	Marystown-Creston	1M/3
p€mb(a)	epidotic mafic flow	13.5%
Csu	weathered fine grained granite	11.2%
?	quartzite	6.2%
p€mb(a)	weathered mafic flows	34.3%
p€m	red sandstone and siltstone	13.5%
p€mb	pyroclastics	20.2%

Source	Lithology	Percentage Composition
	unknown	1.1%

Notes: Very weathered clasts, may not be till - possible remnant of Spanish Room Formation?

7020c	Marystown-Creston	1M/3
p€mb(a)	black mafic flow	19.8%
p€la	rhyolite	10.5%
p€mb(b)	acidic pyroclastics	26.7%
p€mb(a)	epidotic mafic flows	7.0%
p€mb	red volcanic sediments	32.6%
	unknown	3.4%

Notes: P€mba reflects transport from west and local areas while p€la has an eastern source.

7021a	Salmonier Pond	1L/14
€bi	red and green mudstone	47.0%
p€la	hornfelsed basaltic flows	23.0%
€bv	quartzite	11.0%
p€w(a)	metagabbro	5.0%
p€bp	mafic flows	8.0%
€i	acidic pyroclastics	6.0%

Notes: All except p€w(a) are indicative of transport from the west. p€w(a) may indicate transport from the east, but local.

7021c	Salmonier Pond	1L/14
€pv	black shale	82.3%
€sp	red mudstone	8.9%
€bv	quartzite	3.3%
Csu	granite	1.1%
p€bp	mafic flows	4.4%

Notes: Intermediate colluvium. Possible upper till contaminant.

7021d	Salmonier Pond	1L/14
€bi	grey and red mudstone	25.8%
Csu	granite	2.2%
p€la	lithic tuff, acidic lapilli	32.0%
€i	quartzite	12.1%
p€w(a)	metagabbro	12.4%
€bv	micaceous siltstone	4.3%
€sp	green mudstone	5.2%
p€sa(a)	rhyolite flows	5.3%
	unknown	0.7%

Notes: CSu, p€la, €i from west. p€w(a) shows transport from local east. €bi is local bedrock.

Source	Lithology	Percentage Composition
7022	Corbin road	1L/14
p€la	rhyolite	4.7%
p€pab	agglomerate	23.5%
p€w(a)	metagabbro	58.9%
p€sa(b)?	mafic flows	7.1%
	unknown	5.8%

Notes: Transport local and from the west.

7024	Freshwater Pond Provincial Park	1M/3
€w	porphyritics	28.6%
€su	granite	14.2%
p€la	tuff and acidic pyroclastics	22.5%
p€g	mafic flows	5.1%
p€m	undifferentiated volcanics	2.2%
p€la	gabbro	16.1%
	unknown	11.3%

Notes: Transport from west, especially €w.

7026	Burin Arm-Mortier highway	1M/3
€bi	red and grey mudstones	28.0%
€sp	shaley, grey mudstones	13.0%
p€w	gabbroic sill	24.0%
p€la	acidic pyroclastics	35.0%

Notes: Transport local and from northwest.

7029	Garnish outwash plain	1M/3
p€b(c)	ignimbrite	22.2%
p€mb(a)	red pyroclastics	60.8%
p€mb(a)	mafic flows	14.8%
	unknown	1.9%

Notes: No evidence of flow from Widmer's (1950) "Lake Fortune". Local and eastern sources.

7032	Lannon Cove	1L/13
€d	quartzites	19.5%
€f	greywake	15.6%
€p	red limestone	18.2%
p€m	undifferentiated volcanics	36.3%
p€h	porphyritic volcanics	10.4%

Notes: Dominant transport from the north and northwest shown by p€m and p€h.

Source	Lithology	Percentage Composition
7037	Ben Hill (Taylor's Bay)	1L/13
p€t	conglomerate	8.7%
p€t	quartzite	6.6%
p€l	felsic lithic tuff	20.5%
p€tb	porphyritic basalt	5.4%
p€l	felsic pyroclastics	13.1%
p€l	vesicular basalt	32.6%

Notes: Transport of p€tb not differentiated so onshore movement cannot be substantiated. Sources to north and northwest.

7040	Great Lawn Harbour	1L/13
€su	granite	34.5%
p€m(a)	volcanics	38.6%
€i	shales	10.1%
€i(e)	argillite	16.0%
	unknown	0.8%

Notes: Dominant transport from northwest, €su.

7041a	Main Brook	1M/3
p€bh(c)	ignimbrite	16.5%
p€b(a)	coarse agglomerate	3.1%
p€br	acidic pyroclastics	25.4%
€su	granitic rocks	13.4%
p€bh(c)	tuff and rhyolitic flows	4.6%
p€s	gabbro	9.8%
p€br	mafic flows	19.0%
	unknown	8.2%

Notes: Shows dominant local sources and transport from northwest. Granite may be from distant northwest source. Stained clasts.

7041b	Main Brook	1M/3
€su	granitic rocks	73.8%
p€br?	undifferentiated volcanics	13.1%
p€bh	agglomerates	9.8%
p€br(a)	mafic flows	3.3%

Notes: Shows flow across €su, i.e., from south, p€br is local rock type.

7043	Clam Pond (water reservoir)	1M/3
pBmb(b)	red volcanic sediments	11.0%
p€mb(b)	grey-green acidic volcanics	33.8%
€su	granite	3.7%
€su	quartz	1.4%
p€mb(a)	mafic flows	36.0%
p€mb(a)	basalt	12.5%
	unknowns	1.6%

Notes: Transport shows local and northwest rock types.

Source	Lithology	Percentage Composition
7045	Winterland-Garnish Pond area	1M/3
p€b(c)	ignimbrite	13.3%
p€b(d)	spherulitic rhyolite, acidic tuff	22.9%
p€b(a)	coarse agglomerate	10.8%
p€g(b)	red sandstone and conglomerate	8.4%
p€mb(a)	mafic flows	8.4%
p€mb(b)	acidic pyroclastics	22.9%
	unknowns	13.3%

Notes: Local clasts with transport from the west (p€g(b) and east (p€m).

Source	Lithology	Percentage Composition
7046a	Spanish Room Point conglomerate	1M/3
p€mb(b)	red volcanic sediments	33.4%
p€mb(b)	light acidic volcanics	10.3%
p€mb(a)	mafic flows	17.7%
?	quartz	3.9%
p€mb(b)	porphyritics	15.4%
	unknown	19.3%

Notes: Not till. Transport local p€mb. Very weathered clasts.

Source	Lithology	Percentage Composition
7046b	Spanish Room Point	1M/3
p€mb(c)	acidic volcanics	28.6%
p€mb(b) (Cbv)?	red sandstone	21.4%
p€mb(a)	mafic flows	12.9%
?	quartz	1.4%
p€mb(a)	rhyolitic flows	25.7%
	unknown	10.0%

Notes: Sources appear to be local. Red sandstone may be from Bayview Formation and onshore, Placentia Bay ice.

Source	Lithology	Percentage Composition
7046c	Spanish Room Point	1M/3
p€mb(b)	rhyolitic pyroclastics	34.5%
Cbv	quartzite	15.6%
€bv	siltstone	7.8%
p€pa(b)	agglomerate	5.0%
p€w(a)	metagabbro	2.1%
?	quartz	2.0%
p€mb(a)	mafic flows	26.6%
	unknown	6.4%

Notes: 7046b and c are from the same unit, however 7046c is nearer surface. Transport similar to 7046b in that Bayview Formation is present in significant quantity.

Source	Lithology	Percentage Composition
7047	Highway 210, north of Jean de Baie	1M/3
p€mb(b)	red, green, grey acidic pyroclastics	60.9%
?	quartz	1.1%
€bv	quartzite, micaceous siltstone	14.8%

Source	Lithology	Percentage Composition
Unit 3	greywake conglomerate	8.2%
p€mb(a)	mafic flows	8.0%
	unknown	7.0%

Notes: Dominant sources are local. Cbv component may show onshore Placentia Bay push.

7051a	Shearstick Brook	1M/3
p€la	spherulitic rhyolite	21.7%
€su	granite	9.1%
p€bh(b)	rhyolite	15.7%
p€b?	red sandstone	22.8%
p€bh(c)	ignimbrite	28.4%
	unknown	2.3%

Notes: Part of two phase till units above Spanish Room Formation. Shows transport from local west.

7051b	Shearstick Brook	1M/3
€su	granite and granitic rocks	44.0%
€rr	ignimbrite	4.0%
p€la(a)	acidic pyroclastics	18.0%
p€br(b)	mafic volcanics	26.0%
p€la(b)	basaltic flows	8.0%

Notes: Upper phase of till unit 7051. Transport from west, but does not show distant transport. Granite is probably a component from the local south.

7052	Marystown, highway 210 by-pass	1M/3
p€mb(a)	mafic flows	60.8%
p€mb(b)	volcanic sediments	5.1%
p€mb(b)	acidic pyroclastics	32.5%
?	chert	0.8%
?	quartz	0.8%

Notes: All clasts are from local sources.

7053	Marystown, east side of harbour	1M/3
€bv	quartzite	4.9%
€bv	sandy, micaceous sandstone	6.8%
p€mb(a)	mafic flows	46.1%
p€la(c)	acidic pyroclastics	27.5%
p€mb(a)	volcanics sediments	14.7%

Notes: Dominant transport from the west, however, p€la(c) may be from hills to the east.

Source	Lithology	Percentage Composition
7055	Brown Ridge Pond	1M/3
Csu	granite and associated granitic rocks	67.1%
Crr	flow banded rhyolite	28.0%
	unknown	4.9%

Notes: Granite bedrock and local debris. Surface, frost shattered sample.

7057a	Little Dantzic Cove	1L/13
PPc	grey siltstone	81.6%
Cu	grey limestone	5.0%
Cb	quartzites	6.7%
PPc	red siltstone	4.3%
pCh	rhyolitic flow	0.8%
pCl	vesicular basalt	1.2%

Notes: Clasts dominantly local, however, Cu from northwest.

7057b	Little Dantzic Cove	1L/13
Cb	quartzite	16.0%
PPc?	red sandstone	7.0%
Cu	grey shale	14.0%
Csu	granite	9.0%
PPc	thinly bedded siltstone	36.0%
pCt	conglomerate	4.0%
pCm	agglomerate	1.0%
pChb	basalt	7.0%
pCh?	undifferentiated volcanics	6.0%

Notes: Transport from west (Cu) but dominant sources are to the east, i.e., from southern, onshore ice.

7059	Famine Back Cove	1M/4
Unit 3a	intrusive porphyritic rocks	23.1%
3a	red tuff	0.8%
3	red ash flow tuff	27.3%
3?	amygololoidal basalt	46.3%
3	vesicular basalt	2.5%

Notes: All units shown are local and indicate short transport to the west.

7066a	Lower Fortune coast	1M/4
Unit 4	red sandstone and pyroclastics	34.1%
17	granite	5.7%
5	quartzite	14.7%
12? (4?)	green-grey pyroclastics	6.8%
4	grey volcanics	38.7%

Notes: Granites and possibly some of the pyroclastics are from the Hermitage area and indicative of transport across Fortune Bay.

Source	Lithology	Percentage Composition
7066c	Lower Fortune coast	1M/4
Unit 4	volcanics and associated pyroclastics	39.3%
4	red sandstone	5.1%
5	white and pink quartzite	6.8%
6	grey sandstone and silty shale	40.2%
3	porphyritic felsite	6.0%
17	granite	2.6%

Notes: Dominant transport from the northwest through units 4 and 3a located to the east as well as to the northwest.

Source	Lithology	Percentage Composition
	Island Rock Point	1M/3
pCbr(b)	acidic pyroclastics	41.7%
pCbr(c)(a)	acidic flows-mafic flows	22.5%
pCbr(d)	ignimbrites	12.5%
pCbb	acidic agglomerates?	23.3%

Notes: Very few indicators of transport from the northwest. Most pronounced would be Anderson's unit 18 (conglomerate and slate), but none was found.

Source	Lithology	Percentage Composition
7078	Highway 210, south of Red Harbour	1M/6
Unit 4	red sandstone	4.7%
17	granite	10.0%
4	conglomerate	3.1%
3	porphyritic felsite	56.6%
4	grey siltstone	4.7%
4	pyroclastic rocks	20.9%

Notes: Transport from the west across units 17 and 4.

Source	Lithology	Percentage Composition
7079	Broad Cove Head	1M/3
Unit 3	schistose, green felsite	16.3%
3	basalt	11.7%
17	granite	13.0%
13	slate	1.8%
3	undivided felsite and tuff	57.2%

Notes: Dominant flow from northwest and west. Main flow from Newfoundland.

Source	Lithology	Percentage Composition
7080	Red Harbour	1M/7
Unit 17	granite and granodiorite	15.1%
4	slate	2.1%
3	schistose porphyritic felsite and tuff	41.7%
4	volcanic rocks and associated pyroclastics	42.5%

Notes: Major transport is from the immediate west and is indicated by units 4 and 17.

Source	Lithology	Percentage Composition
7081	East coast of Mortier Bay	1M/3
Unit 3	basalt	5.1%
3 (pCmb(c))	acidic flows	46.3%
3 (pCmb(b))	undifferentiated pyroclastics	27.9%
3 (pCmb(a))	mafic flows	20.7%

Notes: Local material and transport from the west.

Source	Lithology	Percentage Composition
7084	Tête du Petit Havre, St. Pierre	11I/16
Unit 10	rhyolite	7.7%
10	breccia and tuff	53.9%
10	agglomerate	27.4%
3	green phyllites	4.6%
2	quartzite	3.3%
10	basalt	3.0%

Notes: Sample shows transport from the northwest across Miquelon.

Source	Lithology	Percentage Composition
	Anse de Savoyard, St. Pierre	11I/16
Unit 5	red sandstone	4.5%
10	rhyolite and breccia	38.9%
10	agglomerates	22.4%
3	phyllites	6.0%
7	diabase	4.5%
10	basalt	9.0%

Notes: Most of the material in the esker is local, however, unit 5 shows initial transport across Miquelon.

Source	Lithology	Percentage Composition
7093	Creephole Point	1M/3
pCmb(a)	mafic flows	28.9%
pCmb(b)	undivided acidic pyroclastics	56.2%
Cbv	quartzite	5.0%
Cbv	grey siltstone	3.3%
Csu	granite and granodiorite	5.0%
Cbv	red sandstone	1.6%

Notes: Possible onshore Placentia Bay ice. Csu and pCmb(a)(b) are local and show transport from the west. Cbv may indicate onshore push.

Source	Lithology	Percentage Composition
7090a	Long Beach	1M/6
Unit 3a	intrusive porphyritic rocks	77.4%
4	red sandstone	3.2%
18	brown conglomerate	3.2%
3	felsite and greywake	15.1%
5	quartzite	1.1%

Notes: Most of the clasts originate on the Burin Peninsula, however, units 4 and 18 are located to the northwest on the Hermitage Peninsula.

Source	Lithology	Percentage Composition
7090b	Long Beach	1M/6
Unit 3	greywake and basalt	8.1%
17 (19)	granite and granodiorite	2.0%
3a	porphyritic rocks	37.8%
3	felsite	43.9%
18	brown conglomerate	3.1%
5	quartzite	4.1%
6	siltstone	1.0%

Notes: Ablation facies. Predominantly local material. Similar Hermitage sources as 7090a.

Source	Lithology	Percentage Composition
7095	Near Bay de l'Eau River and Bay l'Argent highway	1M/7
U3	green schistose tuff	98.6%
?	grey-green sandstone	1.4%

Notes: Iron stained bedrock in stream bed.

Source	Lithology	Percentage Composition
7099	East coast of Shoal Cove	1L/14
Csu	granite and associated rocks	66.1%
Ci (Cbv?)	micaceous siltstone	20.9%
Ci	quartzite	1.7%
pCm	lithic tuff	4.3%
pCm	basaltic flows	7.0%

Notes: Transport is from the north northwest. Mostly local material.

Source	Lithology	Percentage Composition
7102	Baine Harbour	1M/7
Unit 3	basalt	7.5%
15	hornblende-biotite granite	4.3%
13	green, tuffaceous slate	6.5%
4	grey siltstone	7.5%
3	felsite and tuff	74.2%

Notes: Most of the clasts have western sources, however, unit 4 may indicate a target to the east in Placentia Bay.

Source	Lithology	Percentage Composition
7103	Rattle Creek-Bay l'Argent highway	1M/7
Unit 13	green, varved, tuffaceous slate	19.0%
3	green felsite and tuff	78.9%
17	granite	1.6%
	unknown	0.5%

Notes: Granite seems to indicate transport from northwest, but targets also located towards the southeast.

Source	Lithology	Percentage Composition
7109	Lower Little Bay	1M/10
Units 17	granite	6.8%
3	greywake conglomerate	16.2%
3(12?)	basalt	17.1%
3	felsites	32.5%
12(14?)	red, green, purple siltstone	6.0%
13	schistose, tuffaceous slate	20.5%
15	foliated granite	9.0%

Notes: Units 17, 12, and 14 show transport to the southeast from the Hermitage Peninsula.

7110	Bay l'Argent highway	1M/10
Unit 17	granite	2.1%
13	green, varved, tuffaceous slate	12.9%
3	basalt and felsite	68.1%
3 (13?)	greywake	9.1%
3	undifferentiated volcanics	7.8%

Notes: Local material, but also from the Burin Peninsula west coast.

7111	Western Feeder Point	1M/7
Unit 3	schistose tuff	69.1%
13	basalt and tuffaceous slate	12.7%
3	schistose felsite	14.0%
15	hornblende-biotite granite	0.7%
3	mineralized basalt	0.7%
	unknown	2.8%

Notes: Transport is from the northwest, but dominantly local material.

7112	Bay de l'Eau River	
Unit 15	granite	9.1%
3	schistose tuff	3.3%
13	basalt and tuffaceous	30.2%
3	felsite	57.1%

Notes: Unit 13, 15 indicative of transport from the west; remainder of the clasts are local.

7113a	Bay de l'Eau River	1M/7
Unit 3	green, schistose tuff	81.3%
15	hornblende-biotite granite	6.7%
13	basalt	4.4%
3	felsites	7.6%

Notes: Clasts are dominantly local material with northwestern sources shown by units 15 and 13.

Source	Lithology	Percentage Composition
7113b	Bay de l'Eau River	1M/7
Unit 3	schistose tuff and felsite	68.8%
3	greywake	5.6%
15	granite	8.1%
17	granite	2.2%
3	basalt	12.1%
	unknown	3.2%

Notes: Clasts are very iron stained. High percentage of local felsite and tuff. Granites are from the west.

7117	Paradise River drumlinoid	1M/9
Unit 17	granite and granodiorite	29.8%
9	lithic tuff	11.4%
3	felsite	33.5%
3	basalt	15.3%
3	greywake	7.0%
13	tuffaceous slate	3.0%

Notes: Transport from the west and northwest - strongly directed.

7118	Old Terrenceville road	1M/10
Unit 17	coarse grained granite and granodiorite	29.1%
9-13-3?	basalt	10.2%
9-13-3?	greywake conglomerate	32.8%
13	varved, tuffaceous slate	2.2%
3	green-grey felsite	22.8%
12	green, red, purple siltstone	2.9%

Notes: Southeast transport strongly reflected by unit 13.

7120	Dunn's Pond	1M/10
Unit 9	chert	0.9%
17	granite and granodiorite	8.1%
9	basalt	2.7%
3	schistose tuff	10.8%
9	brown, crystal lithic tuff	1.8%
3	green felsite	75.7%

Notes: Sub-esker till. Clasts are dominantly local but show major northwest component.

7123	Drift limit	1M/15
Unit 12	basalt	5.3%
17	granite and granodiorite	23.5%
6	grey sedimentary rock	50.7%
8	granite gneiss	2.3%
12	felsite, andesite and pyroclastics	18.2%

Notes: Shows south-southeast transport from Gisborne Lake area.

Source		Lithology	Percentage Composition
7126		North of Grand le Pierre	1M/10
Unit 17		granite	11.8%
9		brown, lithic tuff	14.7%
9		chert	8.3%
6		siltstone, sandstone	7.8%
9		basalt	2.8%
12	(9?)	felsite	32.6%
12		pyroclastic rocks	22.0%

Notes: Dominant transport from the immediate north.

Source		Lithology	Percentage Composition
7127		Near Swift Current	1M/16
Unit 17		granite and granodiorite	16.4%
4		red sandstone	4.9%
3		schistose felsite and tuff	45.1%
4		pyroclastic rocks	30.8%
4		conglomerate	2.8%

Notes: All units show transport from the west northwest.

Source		Lithology	Percentage Composition
7128		Garden Cove highway	1M/16
Unit 17		granite	36.5%
16		diabase and gabbro	12.5%
1	(2a?)	chlorite and sericite schist	14.6%
3		felsites	31.3%
3		greywake	5.1%

Notes: All material was transported from the northwest. Local rock types are units 1 and 3.

Source		Lithology	Percentage Composition
7130		North of North Harbour	1M/16
Unit 1		chlorite and sericite schist	16.9%
4		green, grey, red sandstone	16.2%
17		granite and granodiorite	20.0%
1		acidic, basic volcanics	50.0%
1		conglomerate	2.2%

Notes: Local transport from the northwest.

Source		Lithology	Percentage Composition
7131		Paradise Sound	1M/9
Unit 17		granite and granodiorite	9.9%
6		siltstone	15.9%
6		limestone	2.0%
13		tuffaceous slate	7.2%
3		basalt	7.9%
4		pyroclastic volcanics	4.6%
3		undifferentiated volcanics, felsite and tuff	52.6%

Notes: Transport is from the surrounding highlands, east and west.

Source	Lithology	Percentage Composition
7134	South of Swift Current	1M/16
Unit 17	granite	15.7%
3	basalt	25.2%
4	grey and green sandstone	11.0%
4	pyroclastic rocks	32.5%
3	felsite	15.6%

Notes: Flow dominantly from the northwest.

Source	Lithology	Percentage Composition
M7002a	Petit Barachois, Langlade	11I/16
Unit 2	quartzites	26.5%
5	red sandstone	42.0%
(Nfld.)	fine grained granite	2.1%
11 (Nfld.)	coarse grained granite	4.3%
5	phyllites	6.2%
5	grey sandstones	12.1%
	pebble conglomerate	2.4%
	agglomerate	4.4%

Notes: Most of the clasts are local, however, similar targets may be found to the northwest in Newfoundland. Units 12 and 11 outcrop along the Cape la Hune area of Newfoundland.

APPENDIX 3

GRAIN SIZE ANALYSES

Dry sieve and pipette analyses were completed on selected till samples. The objective was to present a general, quantitative description of the various deposits, not a detailed sedimentological-environmental analysis. Although many of the samples are discussed at length in Chapter 3, their organization is fragmented. Therefore, a complete description of the textures is provided here along with the statistical parameters, which followed the methods of Inman (1952) and Folk (1968).

TABLE A3.1

Sediment Textures, Percentage Composition

SAMPLE NO.	% GRAVEL	% SAND	% SILT	% CLAY
7001a x	29.546	37.360	22.970	10.124
7001c*	38.574	37.908	18.521	4.997
7004a x	26.684	34.755	23.713	14.849
7004c*	26.063	51.945	19.166	2.826
7019 †	33.228	36.845	24.688	5.239
7021a x	29.156	28.348	31.089	11.407
7021d*	25.542	45.290	22.446	6.723
7032 *	44.966	32.326	15.438	7.270
7037 *	43.684	38.663	15.441	2.212
7040 *	66.439	20.704	11.812	1.046
7041a†	75.717	14.801	7.245	2.236
7041b x	35.852	39.648	19.076	5.424
7046b x	28.724	34.551	26.396	10.328
7046c x	31.454	35.240	21.480	11.826
7051b x	22.436	33.076	28.002	16.486
7057a x	35.410	48.741	10.166	5.683
7057b*	17.200	34.221	32.323	16.256
7066a x	25.211	32.997	33.145	8.647
7066c*	29.137	53.617	13.685	3.561
7078 *	32.145	45.004	19.043	3.808
7079 †	14.022	39.839	32.895	13.244
7081 †	34.185	42.550	14.127	9.138
7084 *	38.110	40.800	17.827	3.264
7089 *	71.299	24.446	2.712	1.543
7090a x	5.175	22.987	58.702	13.136
7090b*	32.430	49.518	12.677	5.376
7092 x	2.953	41.445	38.429	17.173
7099 *	23.897	46.944	25.570	3.590
7102 *	20.586	45.339	25.104	8.971
7103 *	57.391	32.613	6.356	3.640
7109 *	26.293	43.732	23.737	6.238
7113a*	37.601	43.182	17.281	1.937
7113b*	59.744	30.227	6.489	3.589
7117 x	24.698	53.916	19.741	1.646
7118 *	21.941	46.480	29.515	2.064
7120 x	40.916	43.136	13.967	1.982
7123 *	12.309	53.248	30.284	4.159
7126 *	43.904	41.245	12.150	2.700
7127 *	17.790	38.404	34.254	9.551

TABLE A3.1 (cont'd)

SAMPLE NO.	% GRAVEL	% SAND	% SILT	% CLAY
7128 *	26.651	42.489	24.352	6.508
7130 *	30.931	47.165	20.139	1.765
7131 *	57.718	26.688	11.606	3.988
7134 *	43.108	43.744	11.724	1.423

* Upper, sandy till

x Fortune Bay event, silty till

† Indurated, stained till

TABLE A3.2

Inman (1952) Statistical Parameters

SAMPLE NO.	MEDIAN (φ UNITS)	MEAN (φ UNITS)	SORTING (φ UNITS)	SKEWNESS	KURTOSIS
7001a[x]	02.45	01.54	04.52	-0.20	–
7001c*	00.15	01.25	03.99	00.28	00.50
7004a[x]	02.45	02.52	05.18	00.01	–
7004c*	01.82	00.98	03.63	-0.23	–
7019 †	01.04	01.39	04.37	00.08	–
7021a[x]	02.36	02.20	05.18	-0.03	–
7021d*	00.97	01.93	04.04	00.24	00.48
7032 *	-0.23	00.72	04.26	00.22	–
7037 *	-0.25	00.32	03.90	00.15	–
7040 *	-2.18	-0.55	03.41	00.48	–
7041a†	-3.79	–	–	–	–
7041b[x]	00.78	01.06	04.20	00.07	–
7046b[x]	01.75	01.96	04.72	00.05	–
7046c[x]	01.43	02.18	05.09	00.15	00.30
7051b[x]	02.96	03.02	05.11	00.01	00.29
7057a[x]	00.36	00.67	03.30	00.09	00.82
7057b*	03.81	03.40	04.64	-0.09	00.42
7066a[x]	02.89	01.89	04.70	-0.21	–
7066c*	00.43	00.84	03.36	00.12	00.59
7078 *	00.75	00.92	03.90	00.04	–
7079 †	03.35	03.44	04.18	00.02	00.50
7081 †	00.65	01.36	04.31	00.17	–
7084 *	-0.03	01.07	03.72	00.30	–
7089 *	-2.47	–	–	–	–
7090a[x]	04.96	05.08	02.47	00.05	01.15
7090b*	00.65	00.66	03.64	00.00	00.62
7092 x	04.32	04.87	03.42	00.16	00.50
7099 *	01.53	01.73	03.82	00.05	00.45
7102 *	02.03	02.65	04.17	00.15	00.46
7103 *	-1.59	-0.92	02.71	00.25	–
7109 *	01.59	01.80	04.23	00.05	–
7113a*	00.35	00.64	03.78	00.08	–
7113b*	-1.53	-1.31	02.05	00.10	–
7117 x	01.16	01.23	03.21	00.02	00.50
7118 *	02.48	01.34	03.82	-0.30	–
7120 x	-0.36	00.42	03.56	00.22	–
7123 *	02.67	02.50	02.98	-0.06	00.69
7126 *	-0.47	-0.29	03.51	00.22	–
7127 *	02.96	02.86	04.12	-0.02	00.52
7128 *	01.41	01.92	04.29	00.12	–
7130 *	00.46	01.12	03.49	00.19	–
7131 *	-1.73	–	–	–	–
7134 *	-0.60	-0.01	03.17	00.18	–

TABLE A3.3

Folk (1968) Statistical Parameters

SAMPLE NO.	MEDIAN (ϕ UNITS)	MEAN (ϕ UNITS)	SORTING (ϕ UNITS)	SKEWNESS	KURTOSIS
7001a x	02.45	01.84	-	-	-
7001c*	00.15	00.88	03.81	00.29	00.84
7004a x	02.45	02.49	-	-	-
7004c*	01.82	01.26	-	-	-
7019 †	01.04	01.27	-	-	-
7021a x	02.36	02.25	-	-	-
7021d*	00.97	01.61	03.83	00.25	00.88
7032 *	-0.23	00.40	-	-	-
7037 *	-0.25	00.13	-	-	-
7040 *	-2.18	-1.10	-	-	-
7041a†	-3.79	-	-	-	-
7041b x	00.78	00.97	-	-	-
7046b x	01.75	01.89	-	-	-
7046c x	01.43	01.93	04.55	00.18	00.75
7051b x	02.96	03.00	04.55	00.02	00.78
7057a x	00.36	00.56	03.48	00.22	01.09
7057b*	03.81	03.54	04.32	-0.10	00.83
7066a x	02.89	02.23	-	-	-
7066c*	00.43	00.70	03.30	00.18	01.02
7078 *	00.75	00.86	-	-	-
7079 †	03.35	03.41	04.00	00.00	00.83
7081 †	00.65	01.13	-	-	-
7084 *	-0.03	00.70	-	-	-
7089 *	-2.47	-	-	-	-
7090a x	04.96	05.04	02.85	-0.04	01.47
7090b*	00.65	00.65	03.61	00.15	00.99
7092 x	04.32	04.69	03.27	00.11	00.96
7099 *	01.53	01.67	03.59	00.07	00.85
7102 *	02.03	02.44	03.92	00.15	00.88
7103 *	-1.59	-1.14	-	-	-
7109 *	01.59	01.73	-	-	-
7113a*	00.35	00.54	-	-	-
7113b*	-1.53	-1.39	-	-	-
7117 x	01.16	01.20	03.07	00.05	00.89
7118 *	02.48	01.72	-	-	-
7120 x	-0.36	00.16	-	-	-
7123 *	02.67	02.55	03.01	-0.03	01.03
7126 *	-0.47	00.04	-	-	-
7127 *	02.96	02.90	03.96	-0.01	00.85
7128 *	01.41	01.75	-	-	-
7130 *	00.46	00.90	-	-	-
7131 *	-1.73	-	-	-	-
7134 *	-0.60	-0.21	-	-	-

APPENDIX 4

TILL FABRIC ANALYSES

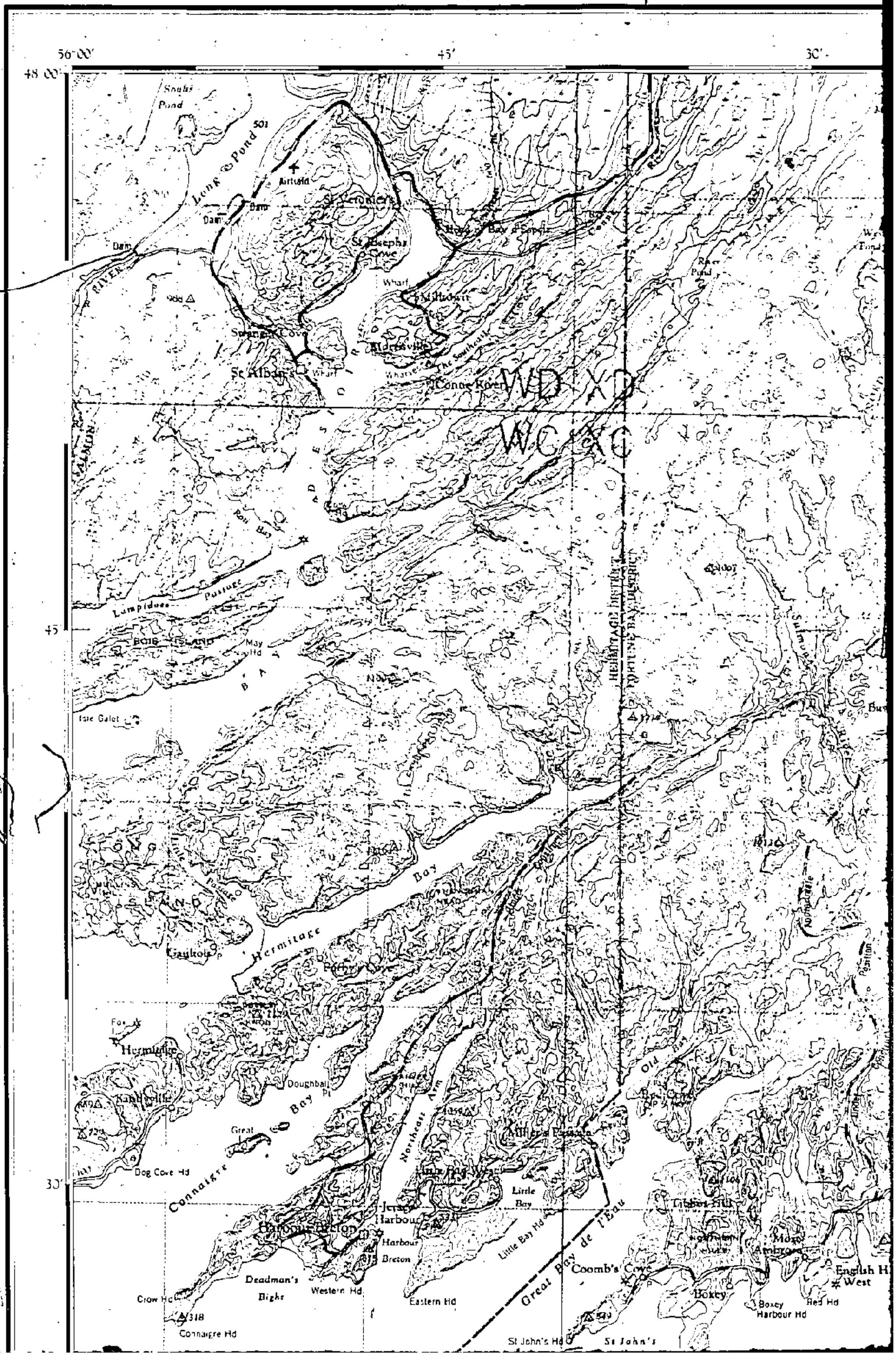
Table A4.1 provides a summary of orientation and orientation strength data. Initially, clast orientation and dip measurements were plotted on polar equidistant projections from which the rose diagrams shown in Chapter III were derived. To calculate the moment mean and moment standard deviation (Krumbien, 1939) without the negating effect of a 360 degree plot, points included in an arbitrarily decided minor half of the projection were rotated 180 degrees and then grouped into nine, 20 degree classes. Two dimensional chi-square values were calculated, and levels of significance using K-2 degrees of freedom, after Cowan (1968) and Andrews (1971), were obtained. The null hypothesis, that the distribution of pebbles in a fabric is uniform, is rejected at the 95% level when $x^2 \geq 14.07$ and at 99% when $x^2 \geq 18.48$.

TABLE A4.1

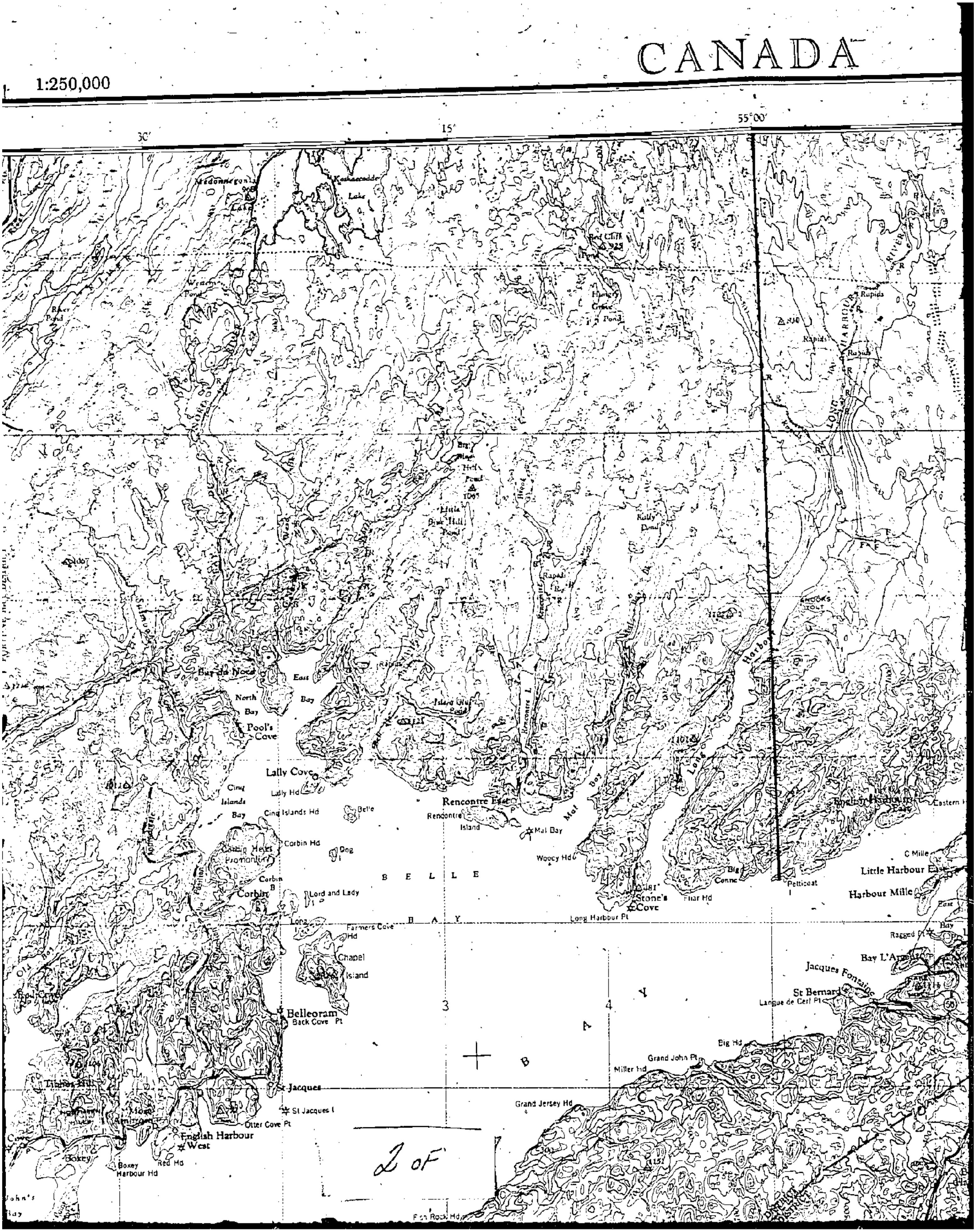
Till Fabric Analyses Statistical Data (±5°)

SAMPLE NUMBER	PRIMARY MODE	MOMENT MEAN	MOMENT STANDARD DEVIATION	CHI-SQUARE	x^2 SIGNIFICANCE (K-2)
7001C	080	075-265	41	10.34	N.S.
7004C	350	350-170	34	27.90	99%
7019	280	270-090	41	30.40	99%
7020A	090	095-275	50	14.33	95%
7020B	290	280-110	31	48.97	99%
7041A	130	130-310	41	10.40	N.S.
7041B	150	135-315	38	16.47	95%
7050	080	060-240	41	15.04	95%
7057A	020	050-230	39	23.97	99%
7057B	300	295-115	46	7.19	N.S.
7066A	300	320-140	41	5.76	N.S.
7066C	140	130-310	41	15.72	95%
7077	290	260-080	42	24.33	99%
7079	360	360-180	51	10.09	N.S.
7080	260	195-015	48	7.18	N.S.
7081	200	205-025	38	35.04	99%
7114	340	340-160	36	35.04	99%
7116	140	155-335	38	30.75	99%
7117	180	185-005	30	33.95	99%
7127	040	055-235	45	10.76	N.S.

1 M 1:250,000

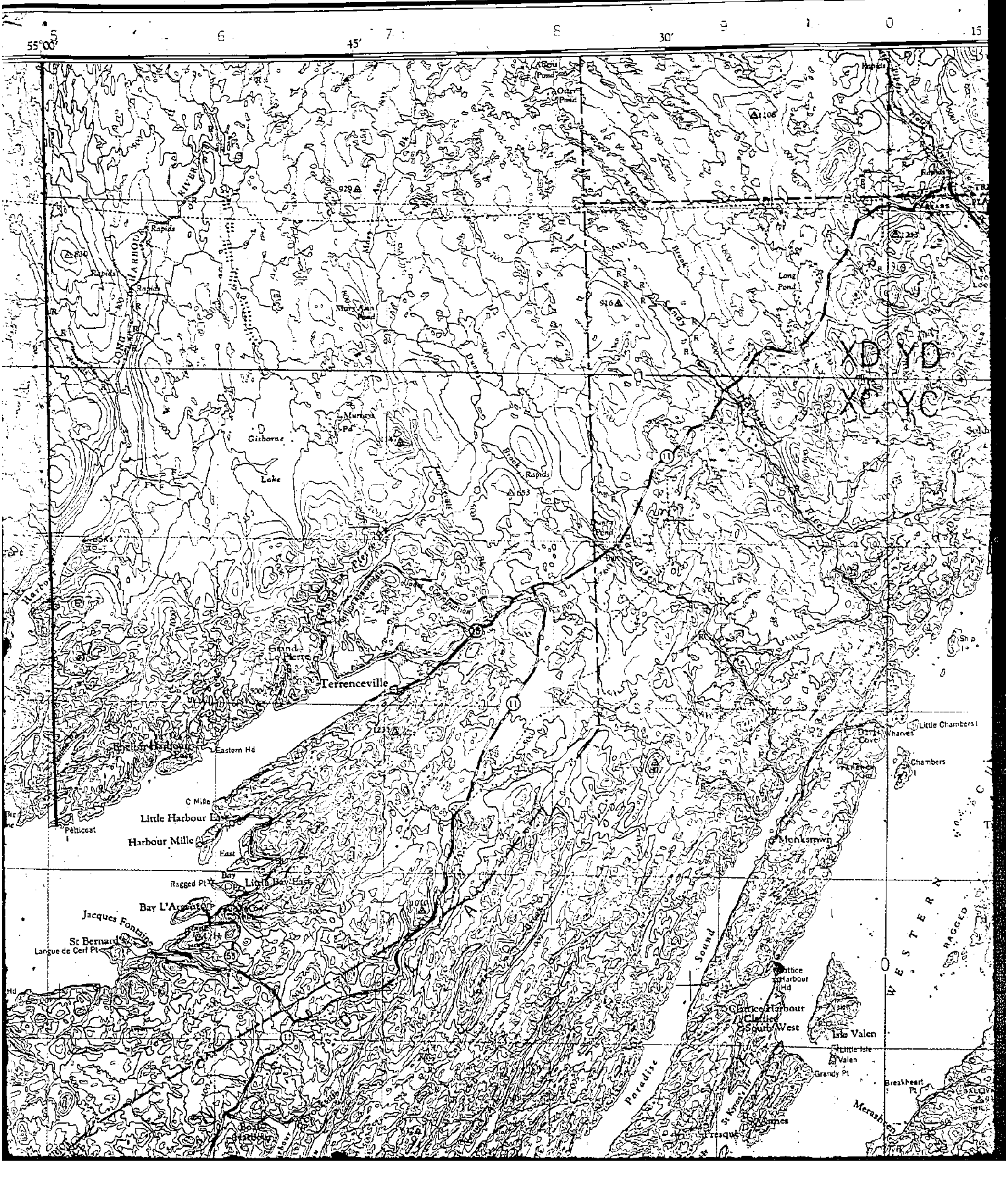


56°00'
45'
30'
48°00'
45
30
South Pond
Long Pond
Airfield
Dam
St Veronica's
St Joseph's Cove
Milltown
Morrisville
Swanger Cove
St Alban's
Wharf
Conne River
Bay d'Espoir
WD XD
WC XC
Lampidoes Passage
BOIS ISLAND
Isle Galet
Little Passage
Gaultois
Hermitage Bay
Hermitage
Sandyville
Fox
Doughball Pt
Great
Dog Cove Hd
Connaigre Bay
Northeast Arm
Miller's Passage
Little Bay West
Little Bay
Little Bay Hd
Jersey Harbour
Harbour Breton
Deadman's Bight
Western Hd
Eastern Hd
Crow Hd
318
Connaigre Hd
Great Bay de l'Eau
Coomb's Cove
St John's Hd
St John's
Old Bay
Tibbo's Hill
Boxey
Boxey Harbour Hd
Red Hd
English Harbour West
Mose Ambrose
Salmon
HERMITAGE DISTRICT
FORTUNE BAY DISTRICT



CANADA
1:250,000
30'
15'
55°00'
Kaskaecodde Lake
Bell Cliff
Hungry Grove Pond
Rapids
LONG HARBOUR RIVER
Little Bell Hill Pond
Rally Pond
Rapids
Bay du Nord
East Bay
North Bay
Pool's Cove
Lally Cove
Lally Hd
Cinq Islands Bay
Cinq Islands Hd
Belle
Rencontre East
Rencontre Island
Mal Bay
Woody Hd
Corbin Hd
Dog
Corbin
Lord and Lady
B E L L E
B A Y
Stone's Cove
Friar Hd
Long Harbour Pt
Big Conne
Petticoat
C Mille
Little Harbour East
Harbour Mille
Eastern
English Harbour East
Ragged Pt
Bay L'Argent
Jacques Fontaine
St Bernard's
Langue de Cerf Pt
Farmers Cove Hd
Long
Chapel Island
Belleoram
Back Cove Pt
3
4
Big Hd
Grand John Pt
Miller Hd
St Jacques
St Jacques I
Otter Cove Pt
Grand Jersey Hd
English Harbour West
Boxey
Boxey Harbour Hd
Red Hd
Fish Rock Hd
Tibbos Hill
Coomb's Cove
2 of

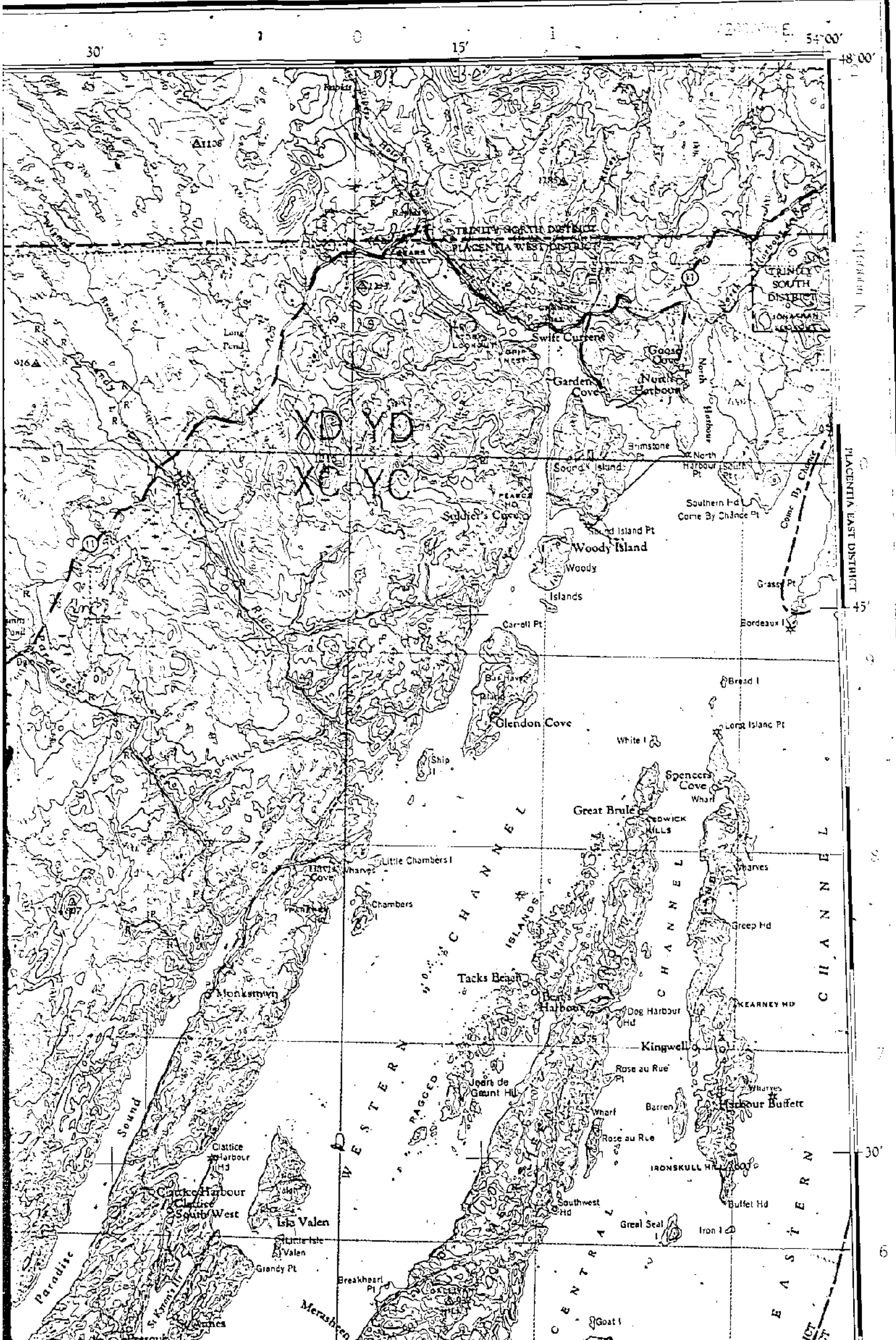
NADA 30F EDITION 2



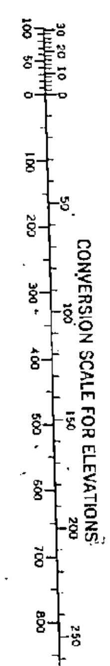
EDITION 2

Refer to this map as:	1 M EDITION 2 MCE SERIES A 501

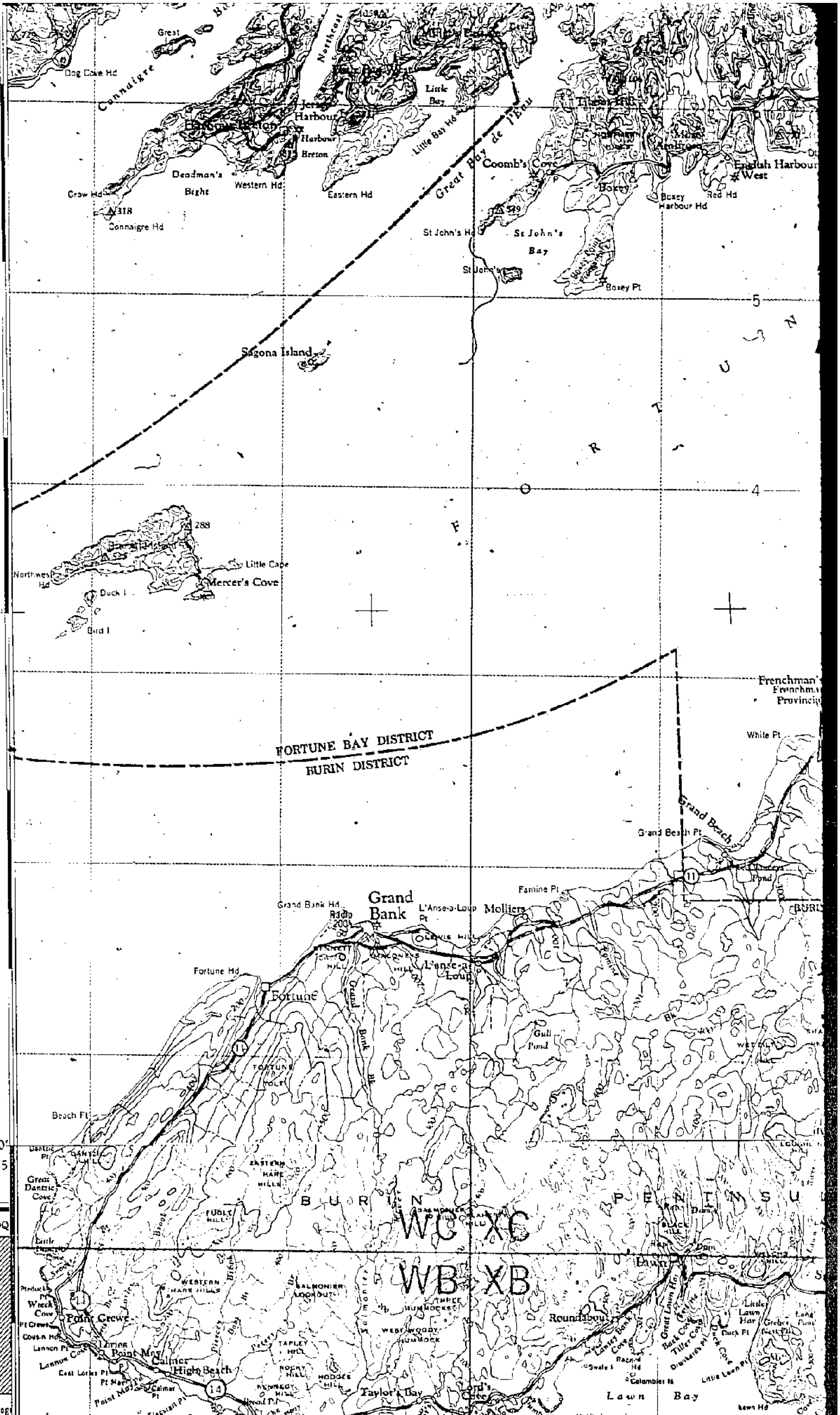
1 M



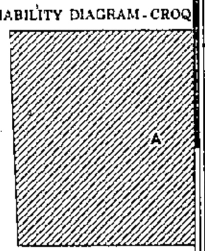
4 of



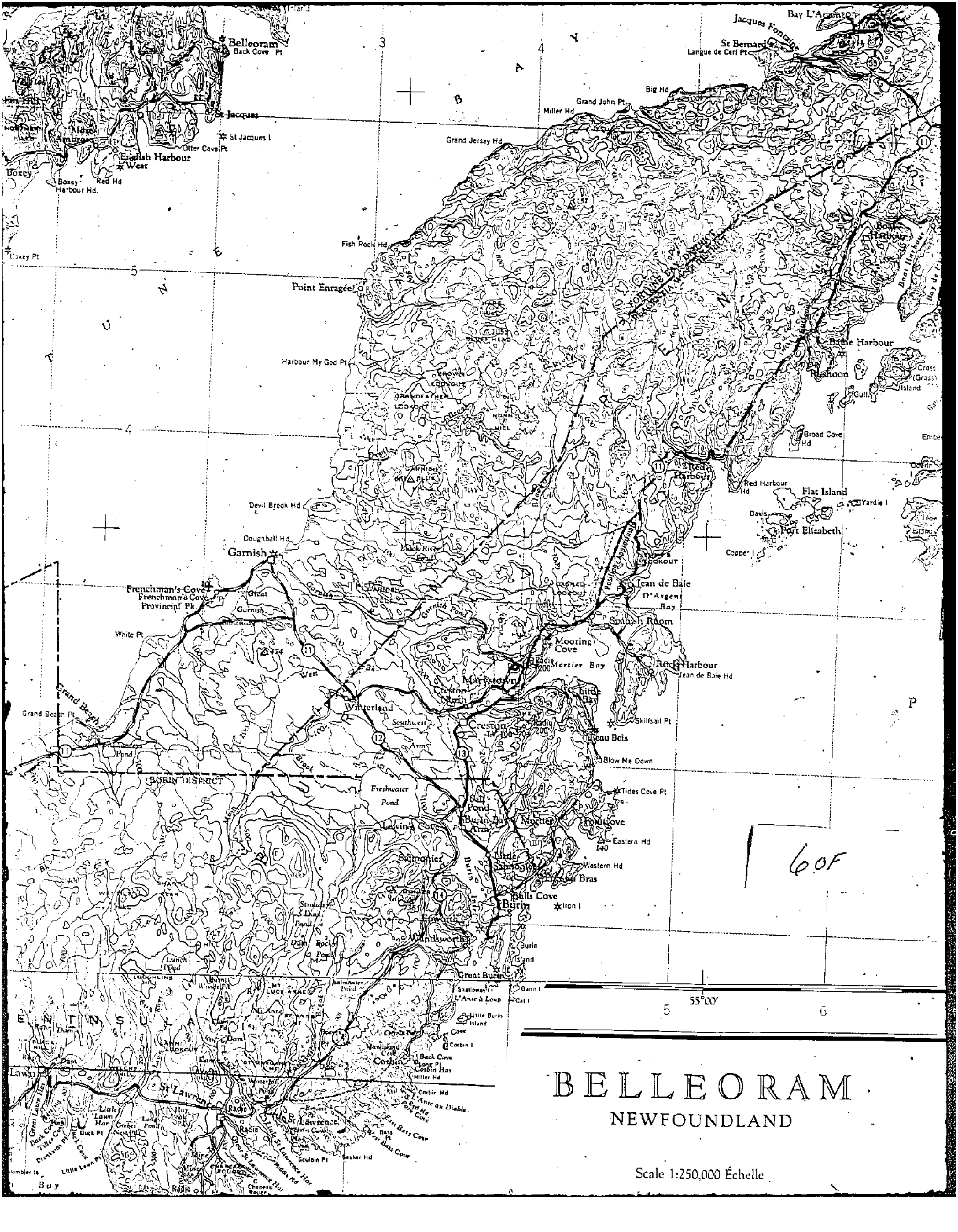
50F



RELIABILITY DIAGRAM - CROQ



A Large scale mapping photog
from 1966 aerial photograph



BELLEORAM
NEWFOUNDLAND
Scale 1:250,000 Échelle
Belleoram
Back Cove Pt
St Jacques
St Jacques I
Otter Cove Pt
English Harbour West
Boxey
Boxey Harbour Hd.
Red Hd
Boxey Pt
Bay L'Argent
Jacques Fontaine
St Bernard's
Langue de Cerf Pt
Big Hd
Grand John Pt
Miller Hd
Grand Jersey Hd
Fish Rock Hd
Point Enragée
Harbour My God Pt
Devil Brook Hd
Doughball Hd
Garnish
Frenchman's Cove
Frenchman's Cove Provincial Pk
White Pt
Grand Beach
Grand Beach Pt
Winterland
Freshwater Pond
Salt Pond
Burin Bay Arm
Lewin's Cove
Salmonier
Mortier
Fox Cove
Eastern Hd
Western Hd
Port au Bras
Bulls Cove
Burin
Iron I
Epworth
Burin Island
Great Burin
Shalloway I
Cat I
L'Anse à Loup
Little Burin Island
Corbin I
Silver Cove
Corbin
Back Cove
Corbin Har
Miller Hd
Corbin Hd
L'Anse au Diable
Red Hd
Lawn
St Lawrence
Little St Lawrence
Sculpin Pt
Little Lawn Pt
Duck Pt
Chambers Is
Bay
Jean de Baie
D'Argent Bay
Spanish Room
Mooring Cove
Mortier Bay
Marystown
Creston North
Creston
Rock Harbour
Jean de Baie Hd
Little Bay
Skiffsail Pt
Beau Bois
Blow Me Down
Tides Cove Pt
Baine Harbour
Rushoon
Cross (Grass) Island
Gull I
Broad Cove Hd
Red Harbour
Red Harbour Hd
Flat Island
Yardie I
Davis
Port Elizabeth
Copper I
Boat Harbour
BURIN DISTRICT
FORTUNE BAY DISTRICT
PLACENTIA WEST DISTRICT
55°00′
60F

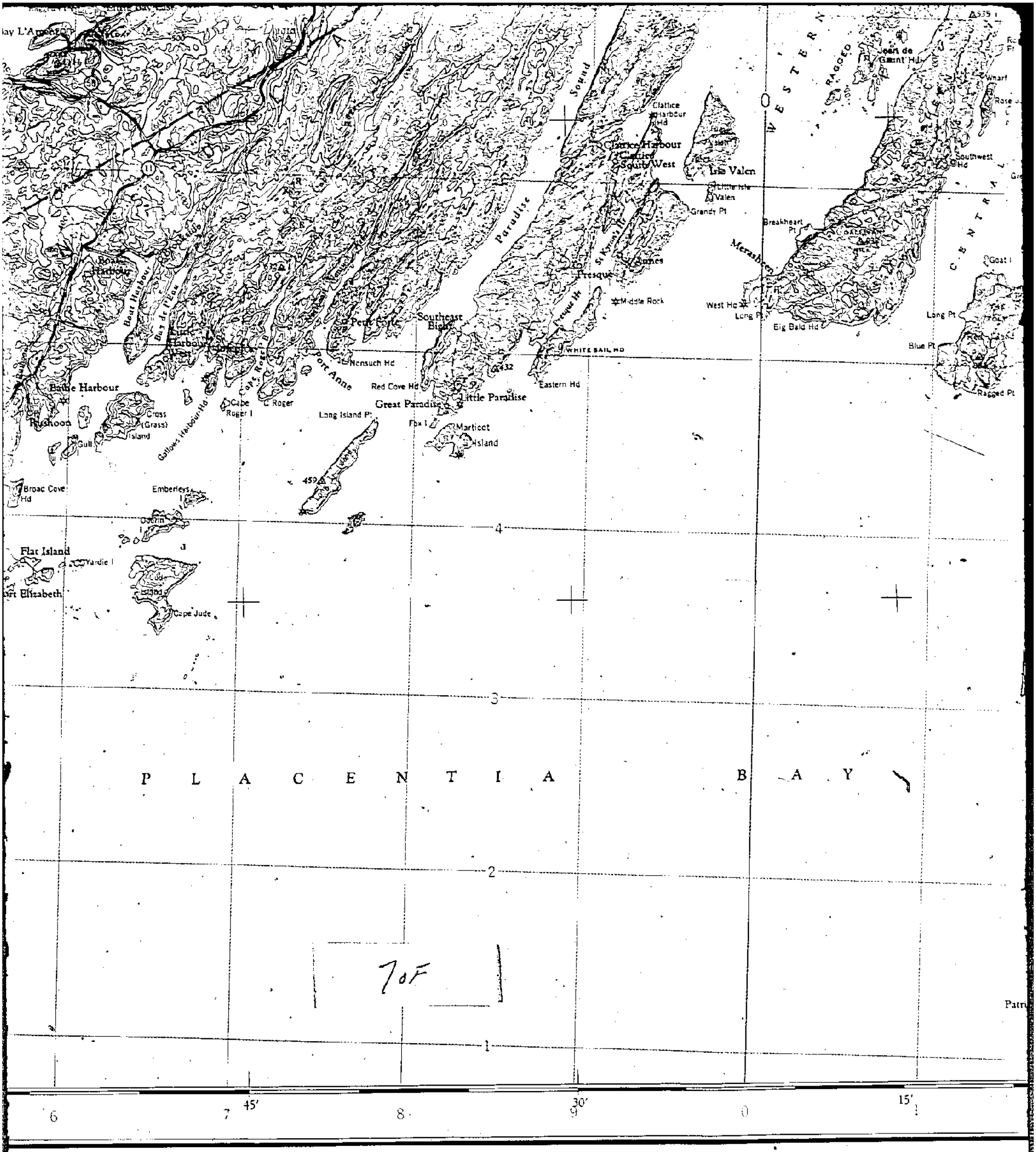
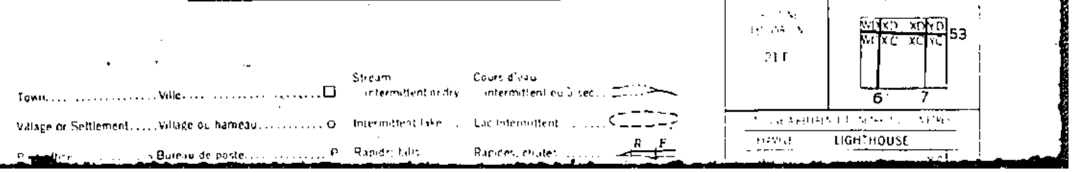
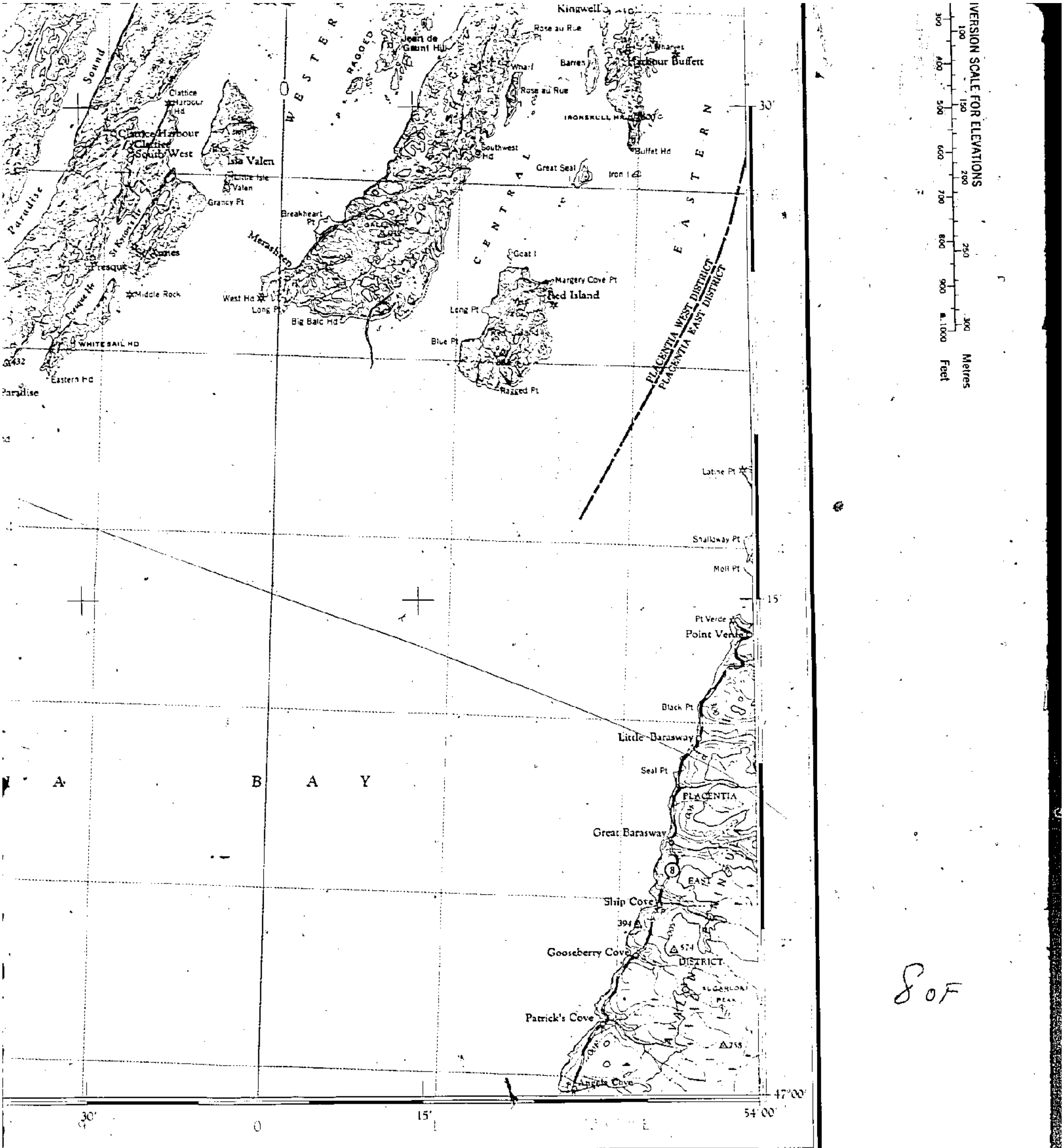


Figure 1.9: Place names and topography.





8 oF

names and topography.

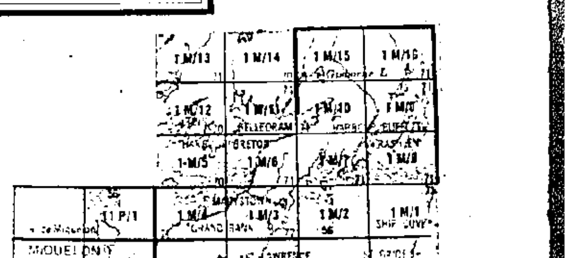
Stream / Cours d'eau

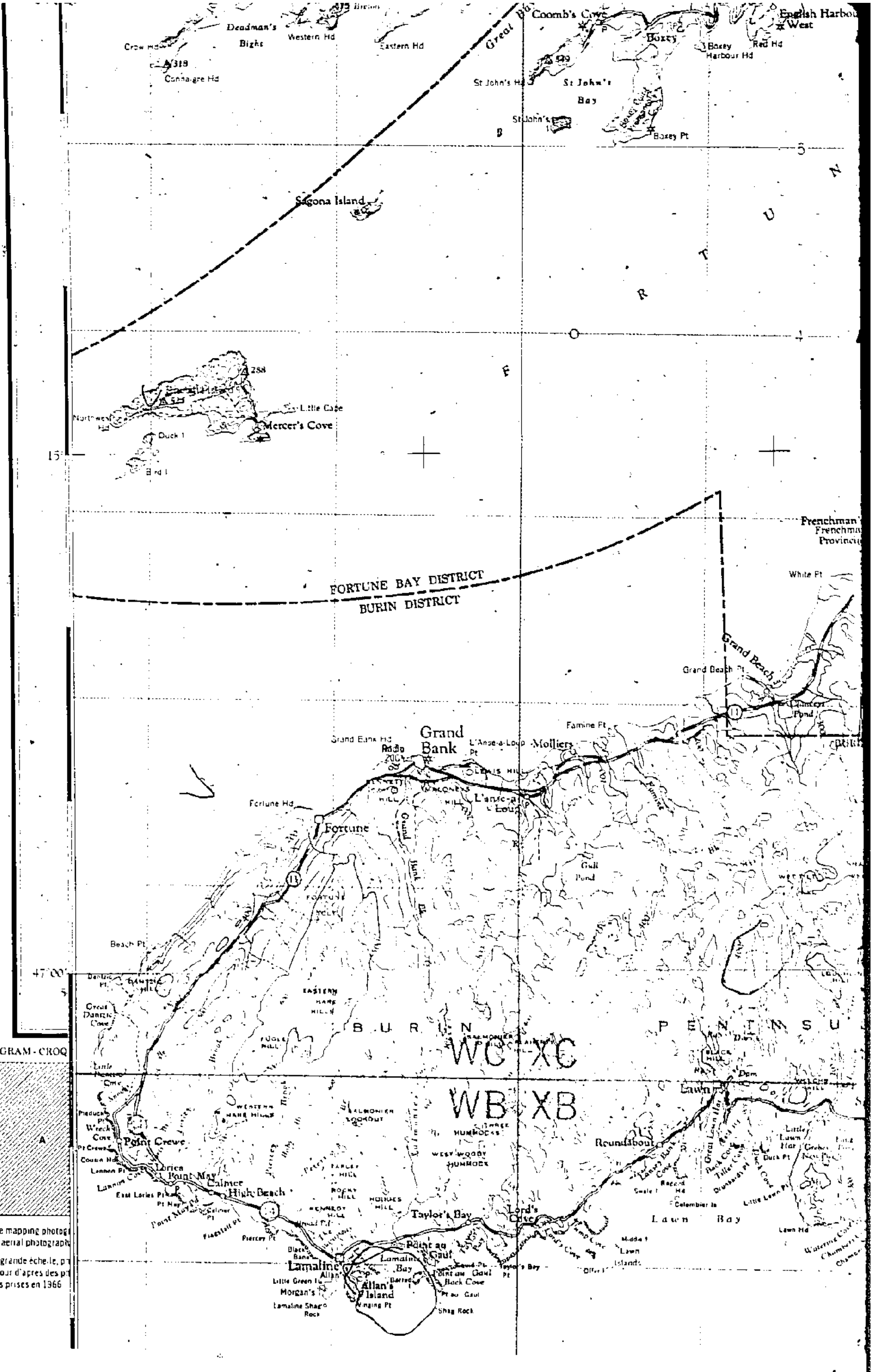
Intermittent lake / Lac intermittent

Rapids, falls / Rapides, chutes

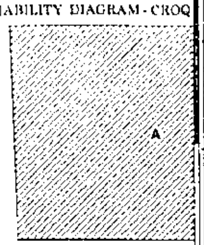
21 T

LIGHTHOUSE





RELIABILITY DIAGRAM - CROQ



A Large scale mapping photog... from 1966 aerial photograph...

A Cartes à grande échelle, p... mises à jour d'après des p... aériennes prises en 1966

9oF

English Harbour West
Point Enragée
Harbour My God Pt
Devil Brook Hd
Doughball Hd
Garnish
Frenchman's Cove
Frenchman's Cove Provincial Pk
White Pt
Grand Beach
BURIN DISTRICT
Winterland
Freshwater Pond
Marystown
Creston North
Creston
Mooring Cove
Mortier Bay
Spanish Room
Rock Harbour
Jean de Baie
Lean de Baie Hd
Little Bay
Beau Bois
Blow Me Down
Skiffsail Pt
Tides Cove Pt
Salt Pond
Burin Bay Arm
Mortier
Fox Cove
Eastern Hd
Western Hd
Little Salmonier
Salmonier
Bulls Cove
Burin
Epworth
Wandsworth
Burin Island
Great Burin
Corbin
St Lawrence
Little St Lawrence
Lawn
Red Harbour
Flat Island
Port Elizabeth
Copper I
Baine Harbour
Rushoon
Cross (Grass) Island
Gull I
Broad Cove Hd
Ember
Yardie I
Davis
Red Harbour Hd
Fish Rock Hd
55°00'
BELLEORAM
NEWFOUNDLAND
Scale 1:250,000 Échelle
CONTOUR INTERVAL 100 FEET
Elevations in Feet above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection
ÉQUIDISTANCE DES COURBES 100 PIEDS
Élevations en pieds au-dessus du niveau moyen de la mer
Système de référence géodésique nord-américain, 1927
Projection transverse de Mercator
Copies may be obtained from the Map Distribution Office, Department of Energy, Mines and Resources, Ottawa
Ces cartes sont en vente au Bureau de distribution des cartes, ministère de l'Énergie, des Mines et des Ressources, Ottawa.
10 of

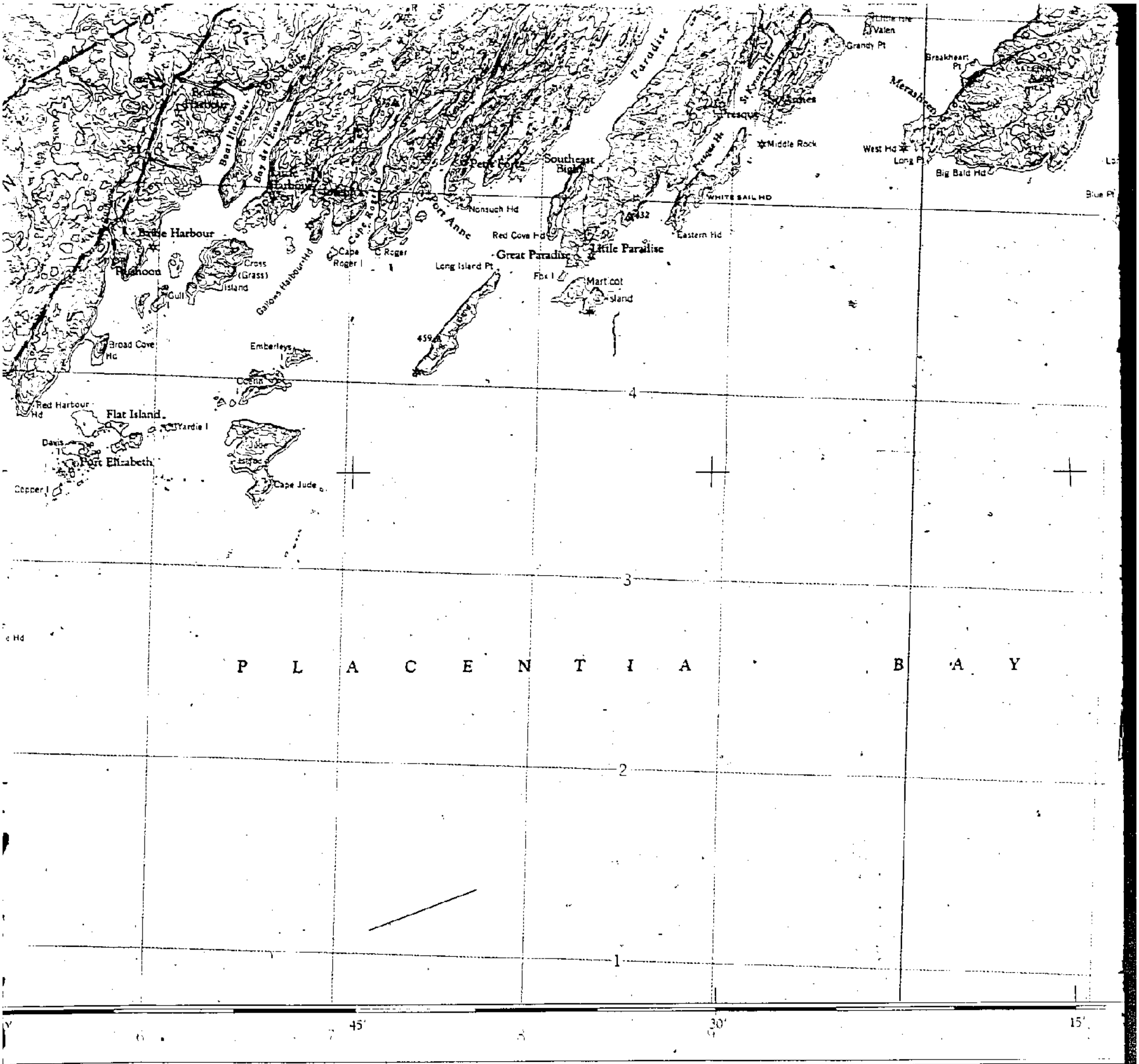
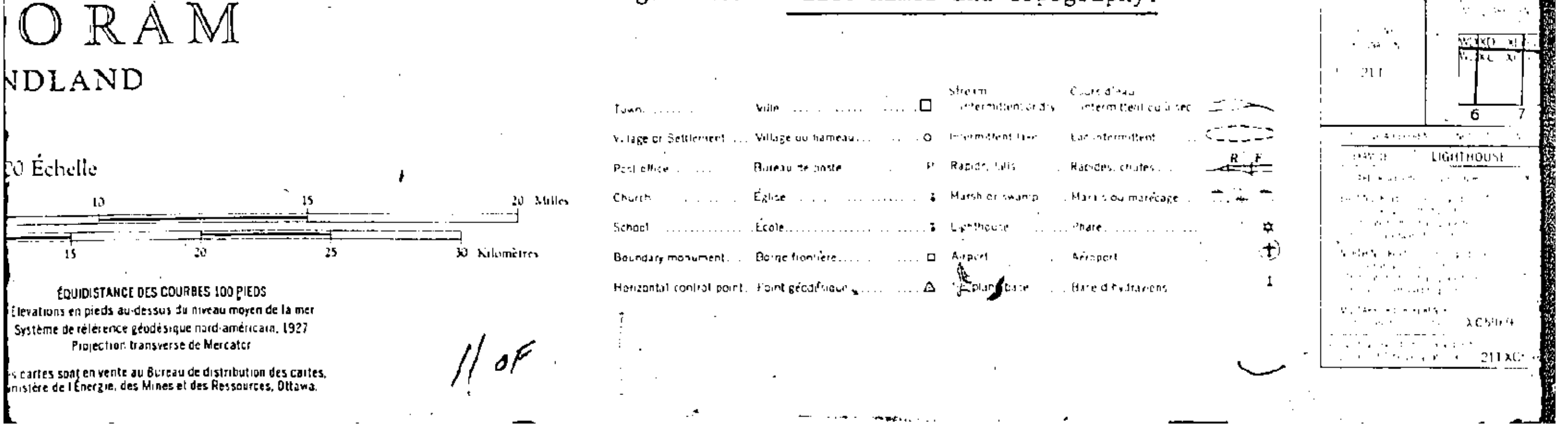
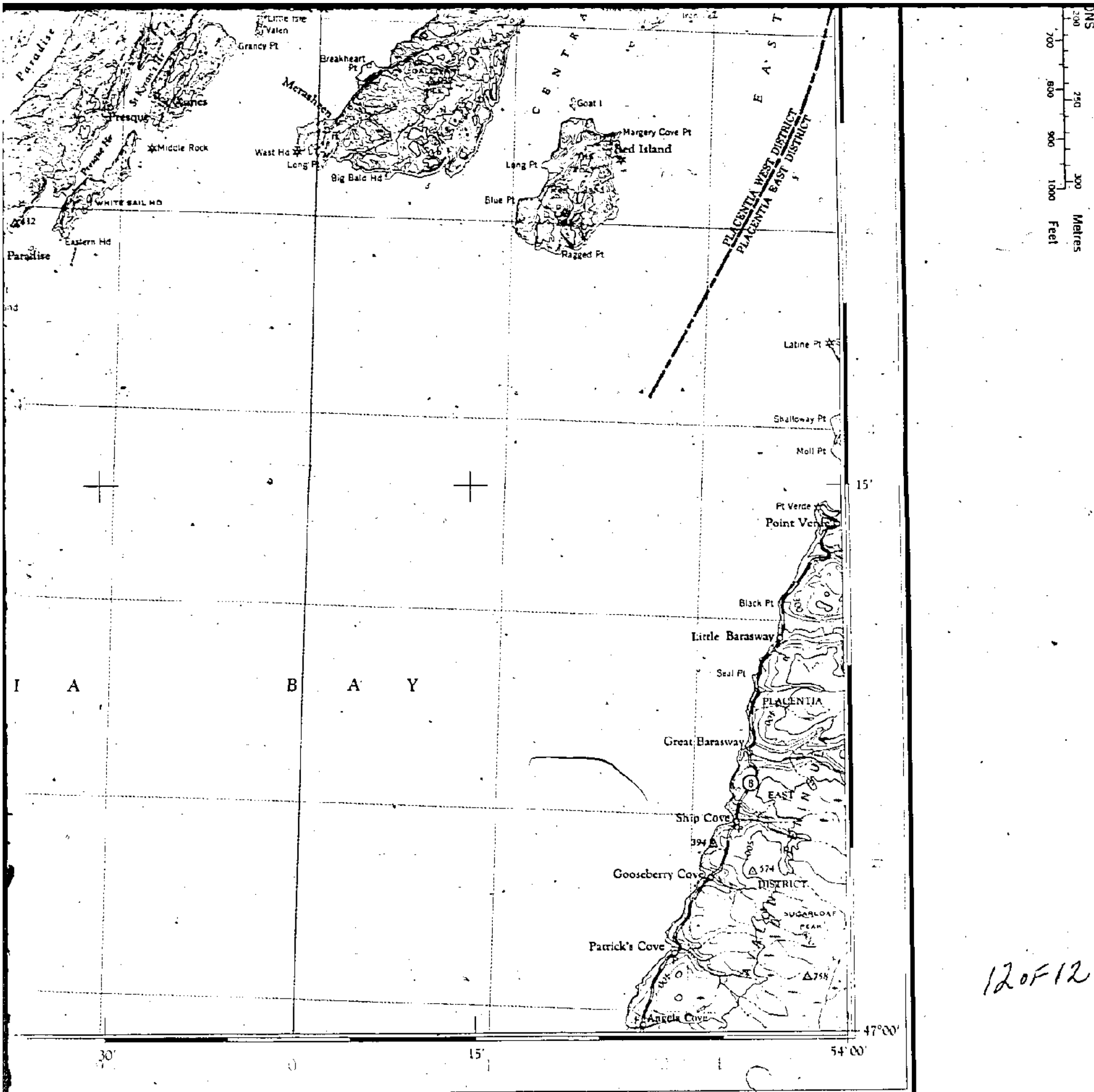


Figure 1.9: Place names and topography.





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names and topography.

Stream, intermittent stream	Cours d'eau, cours d'eau intermittent	
Intermittent lake	Lac intermittent	
Rapids, falls	Rapides, chutes	R F
Marsh or swamp	Marais ou marécage	
Lighthouse	Phare	
Airport	Aéroport	
Seaplane base	Base d'hydravion	

21 I

WD YD XD YD 53

6 7

LIGHTHOUSE

XC

5

9

59

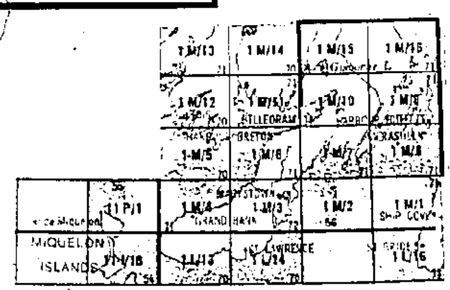
6

9

69

XC5969

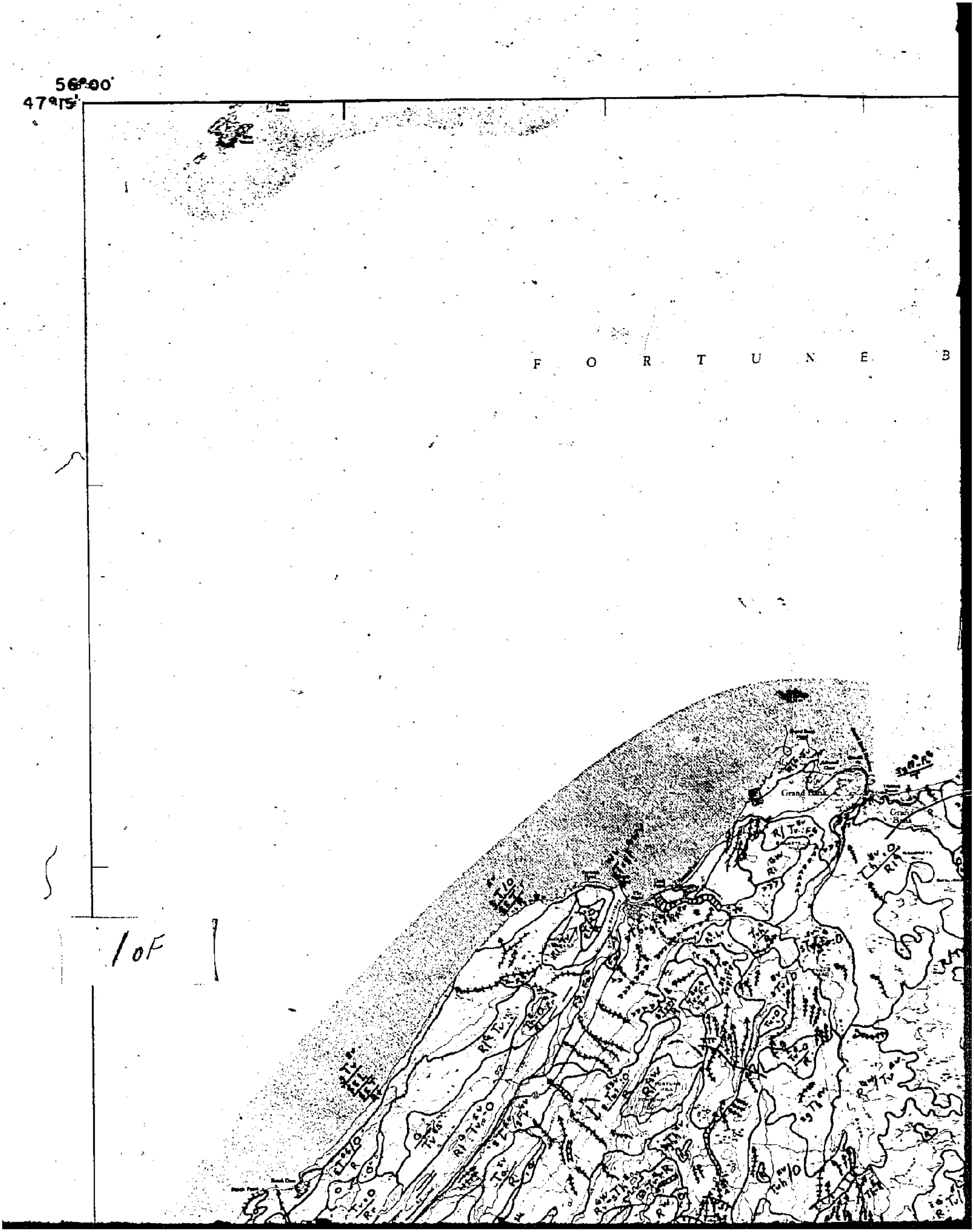
21 XC5969

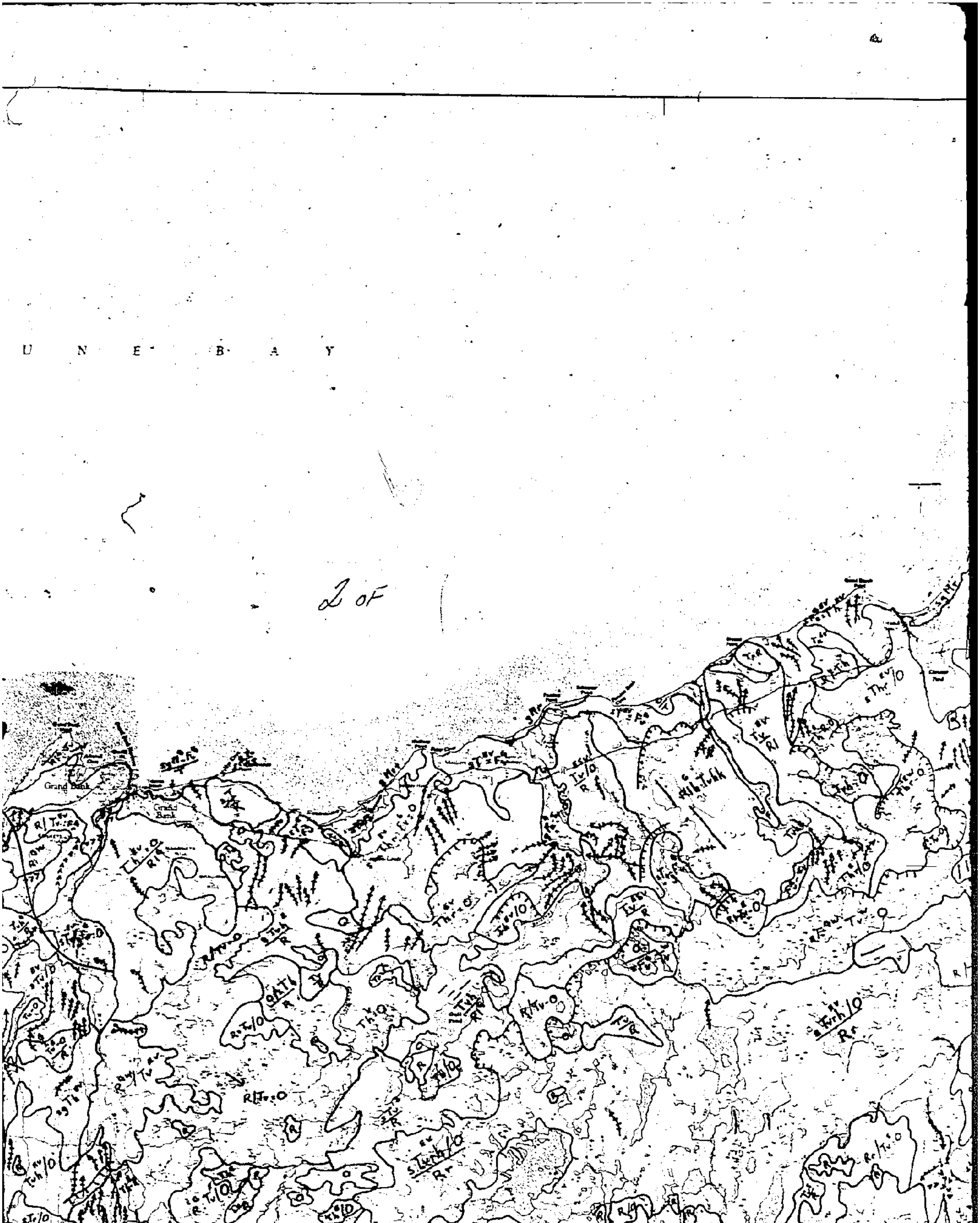


Index to adjoining Maps of National Topographic System
Tableau d'assemblage du Système National de Référence Cartographique

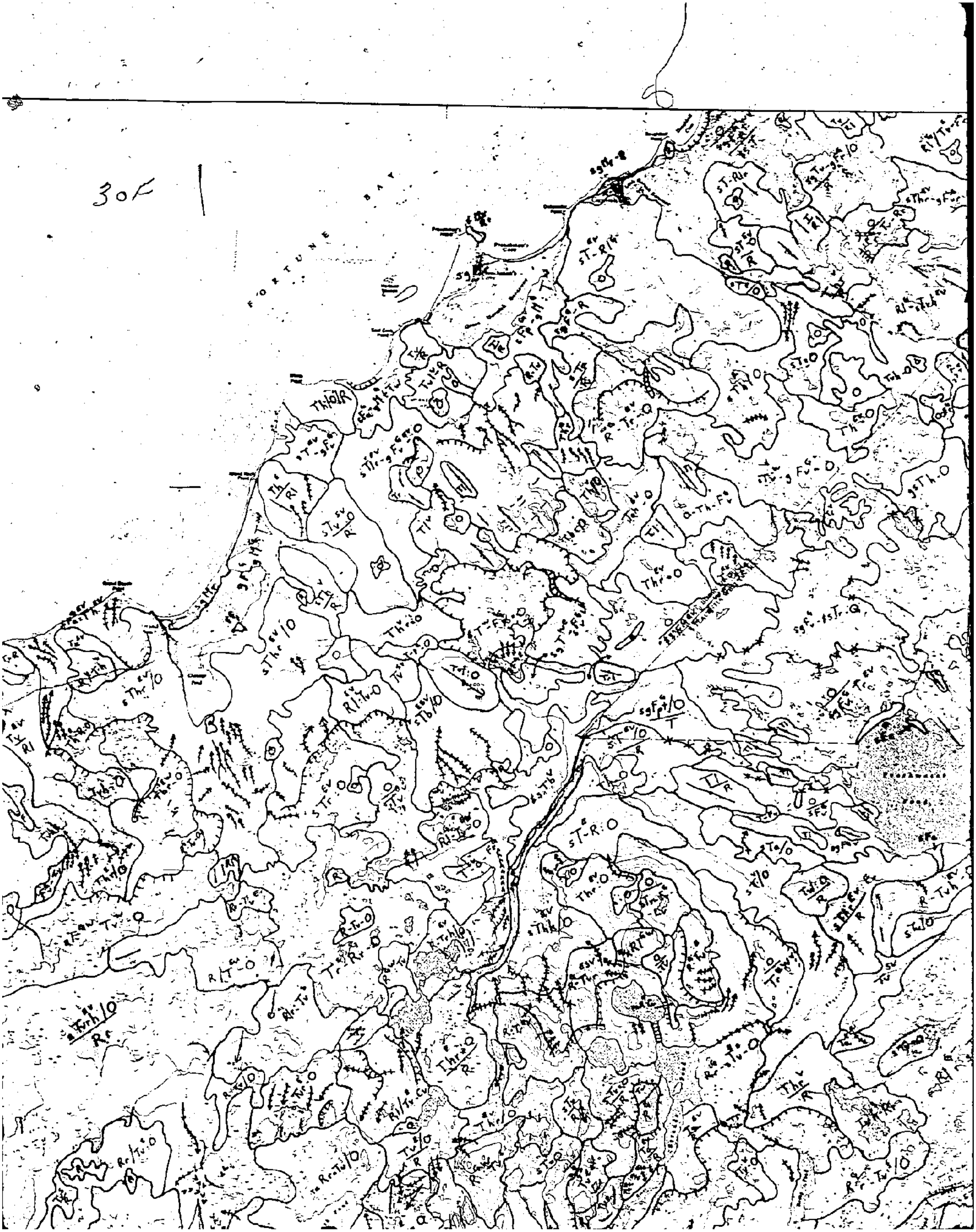
TEN THOUSAND METRE
UNIVERSAL TRANSVERSE MERCATOR GRID
ZONE 21

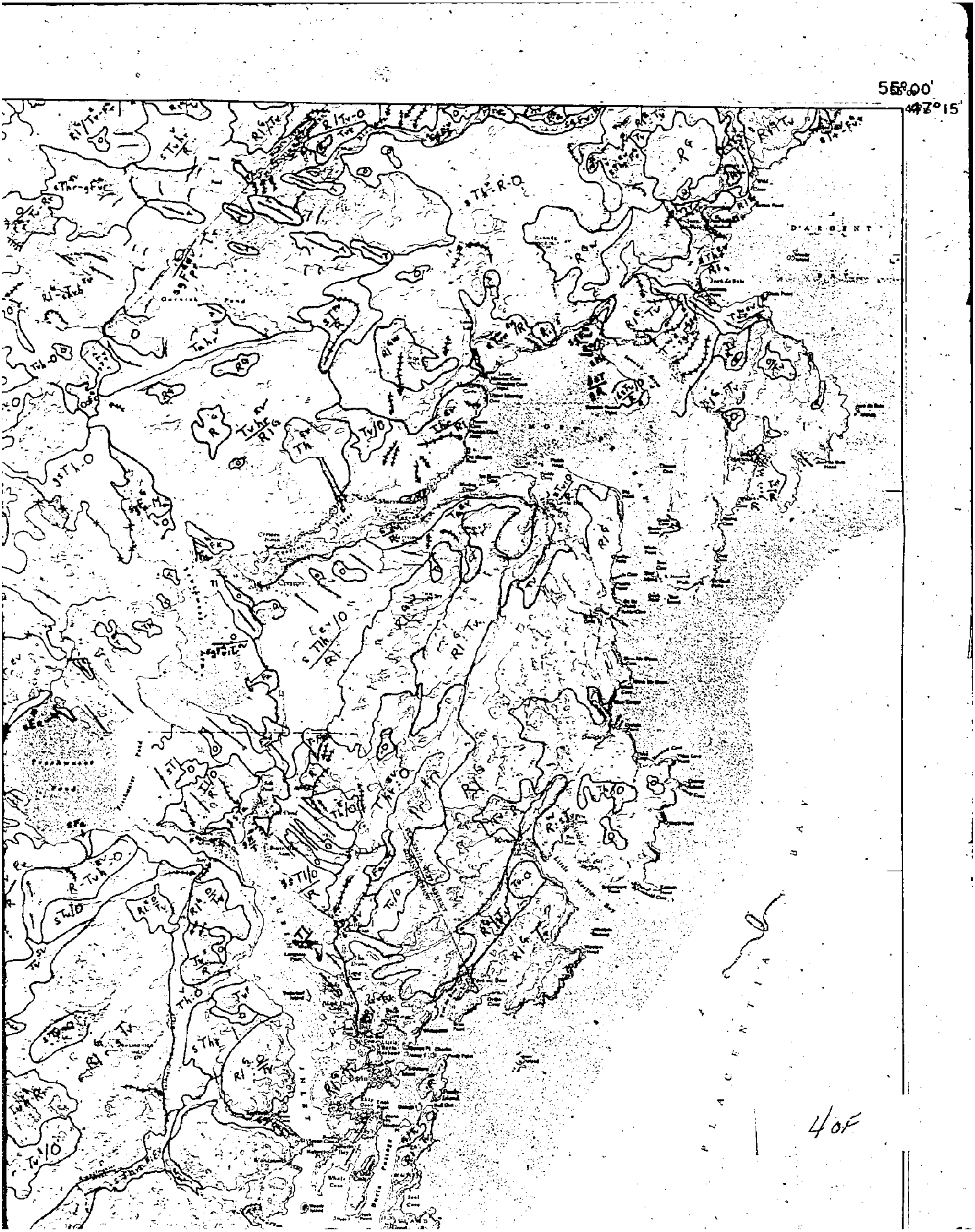
BELLEORAM
1 M
EDITION 2

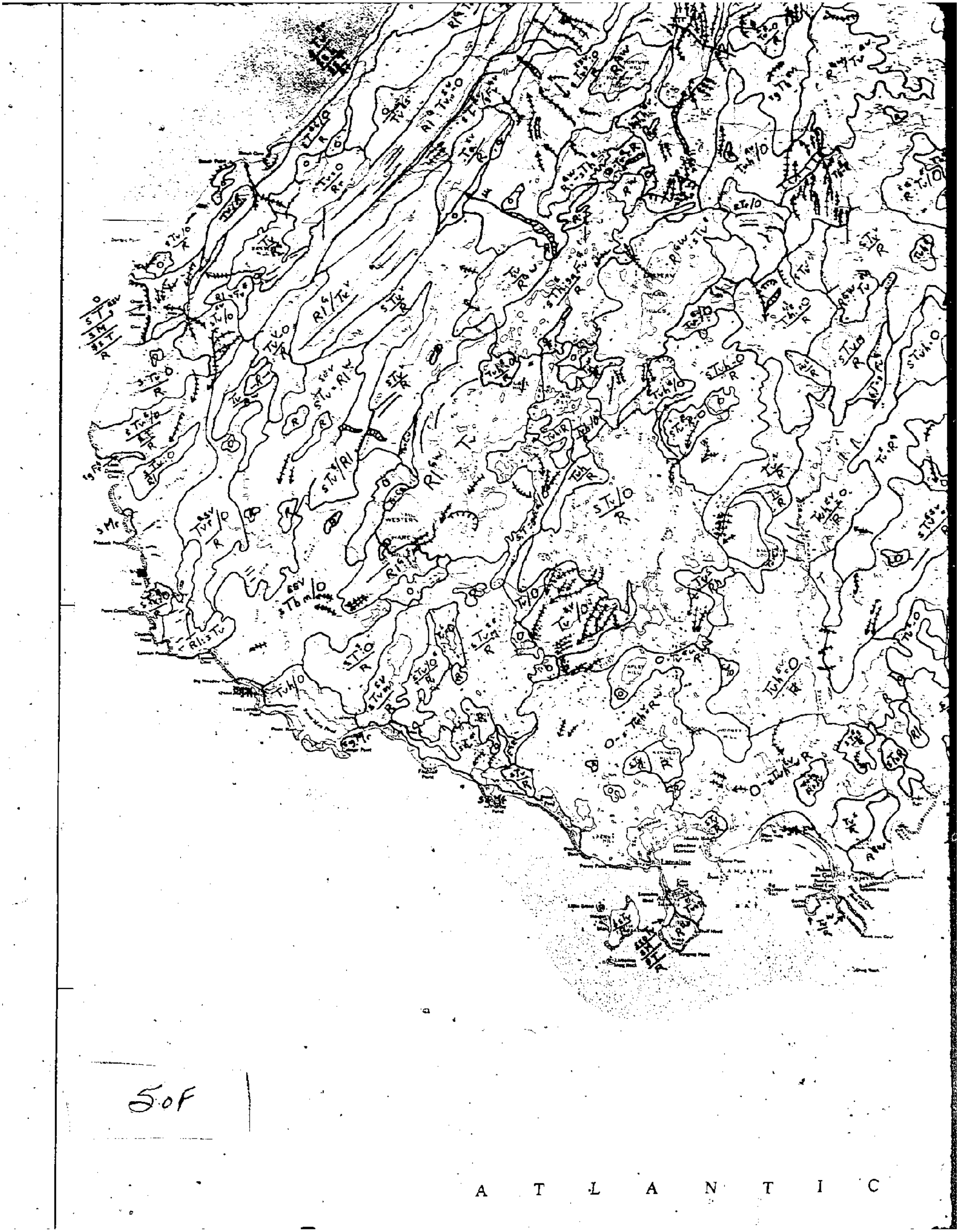

56°00'
47°15'
F O R T U N E B
Grand Bank
1 oF



U N E B A Y
Grand Bank
Grand Bank
2 OF

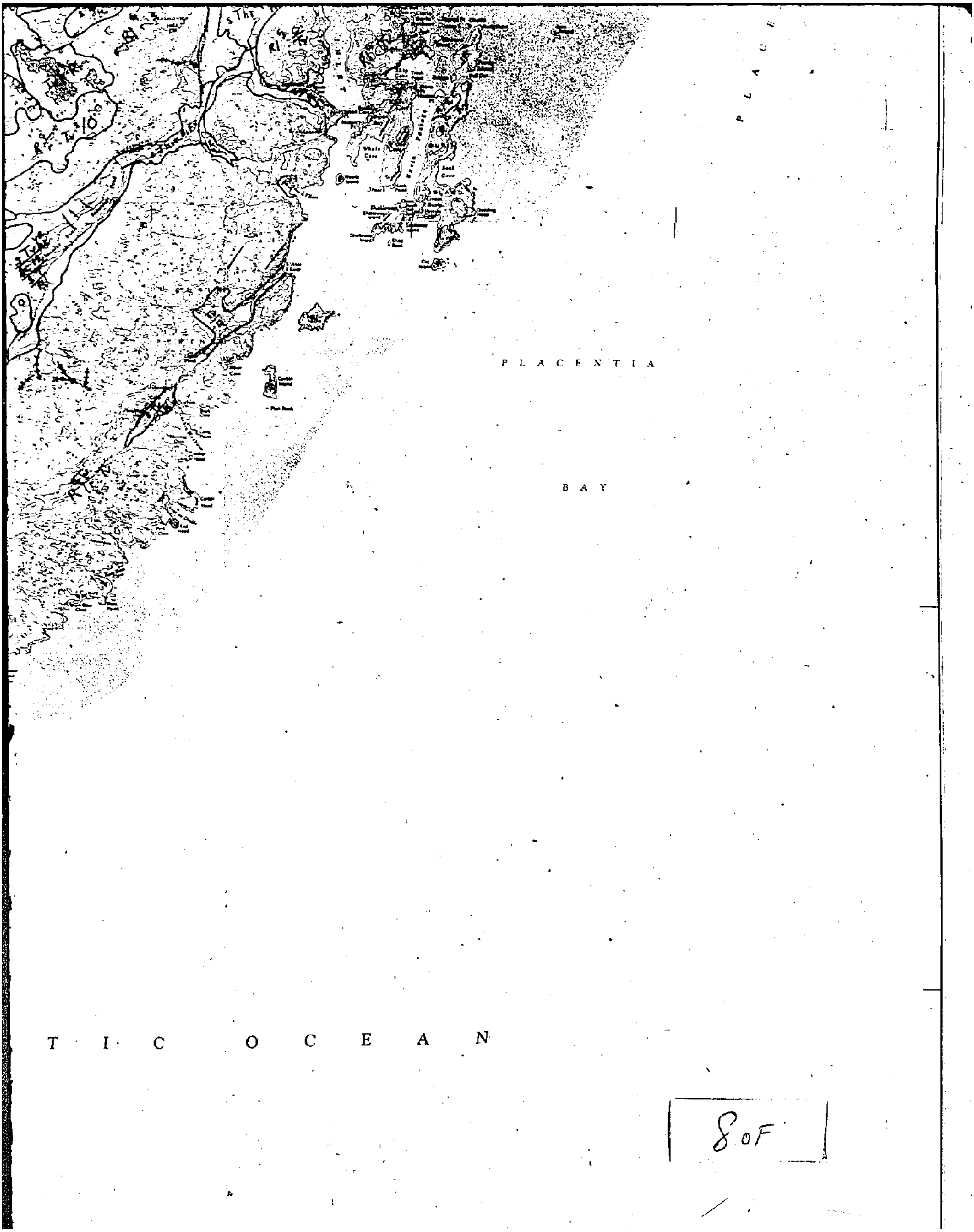

FORTUNE BAY

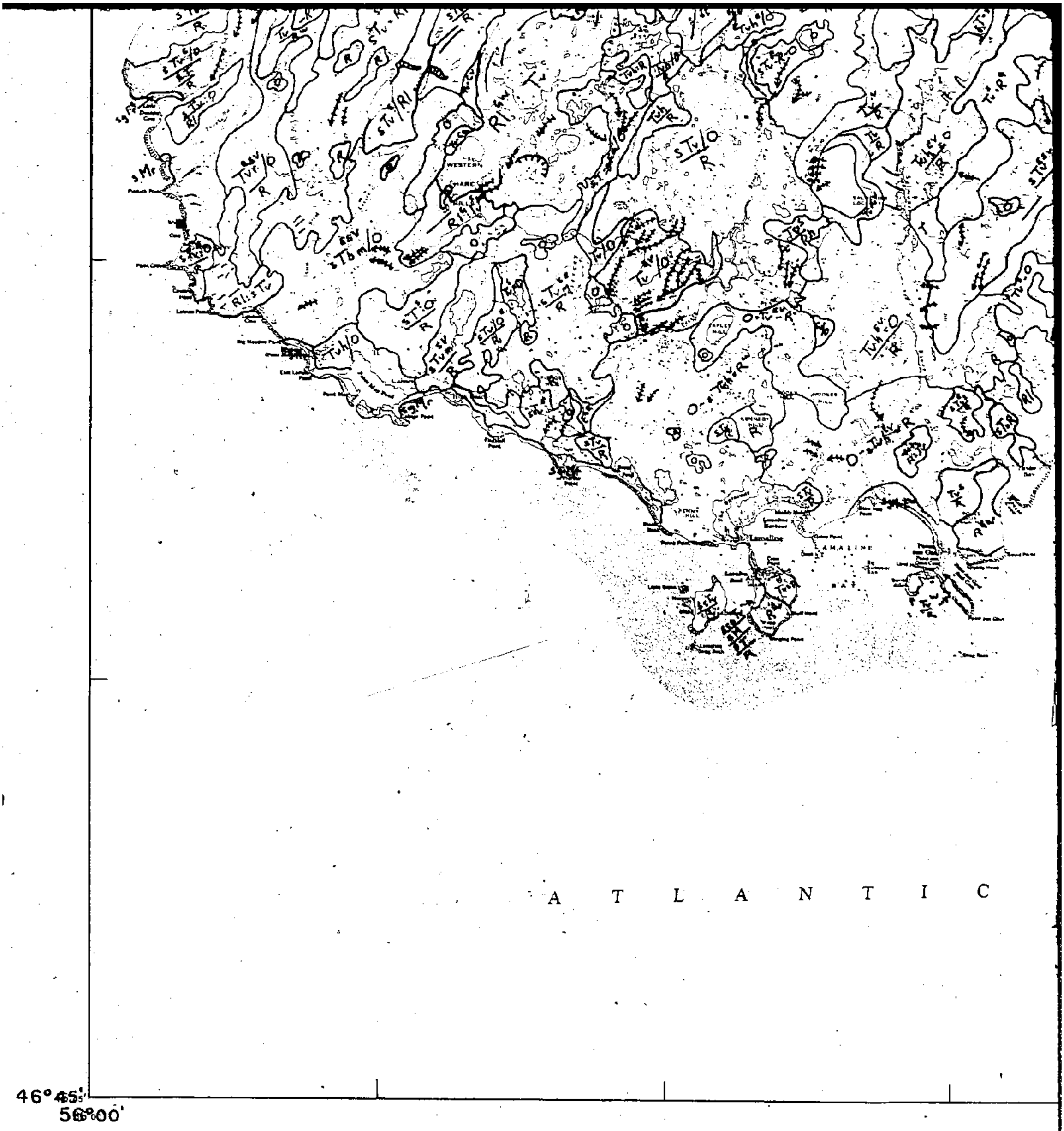

55°00'
47°15'
PLACENTIA BAY
4OF


Lamaline
5 of
ATLANTIC

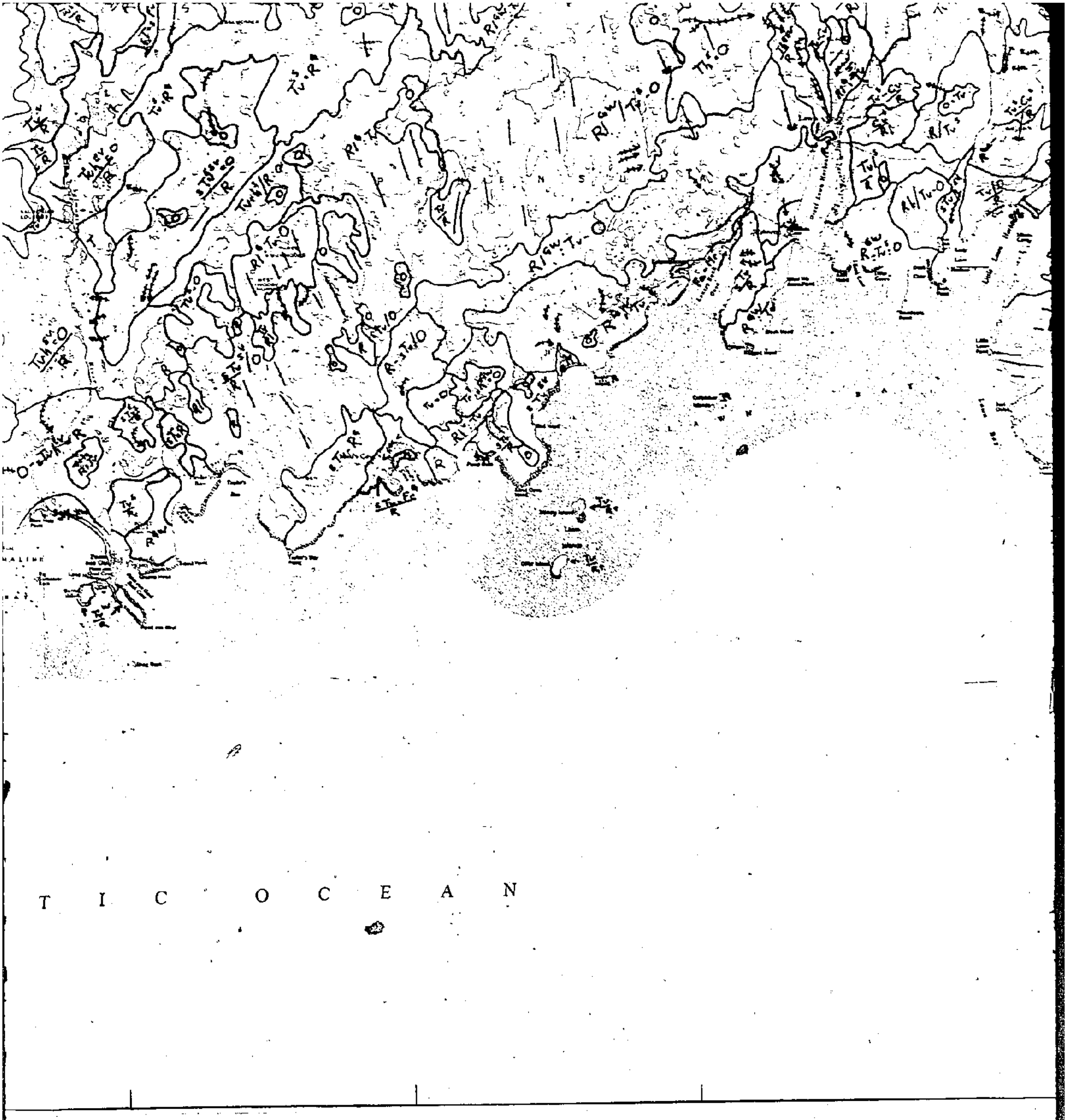

T I C   O C E A N
6 of

70F


P L A C
P L A C E N T I A
B A Y
T I C O C E A N
8 OF

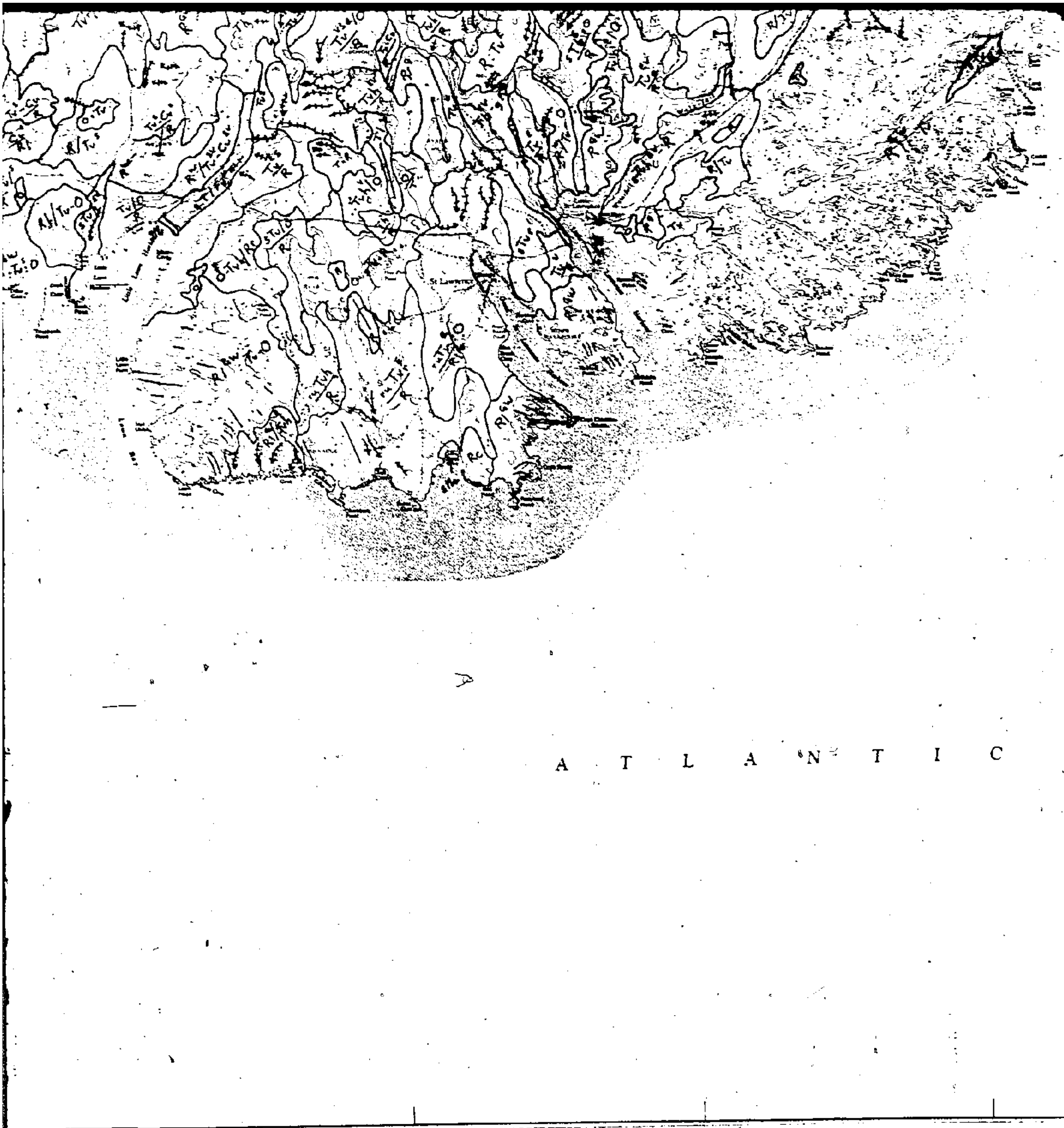


9 of



10 of

I M-3,4 & L-13,1

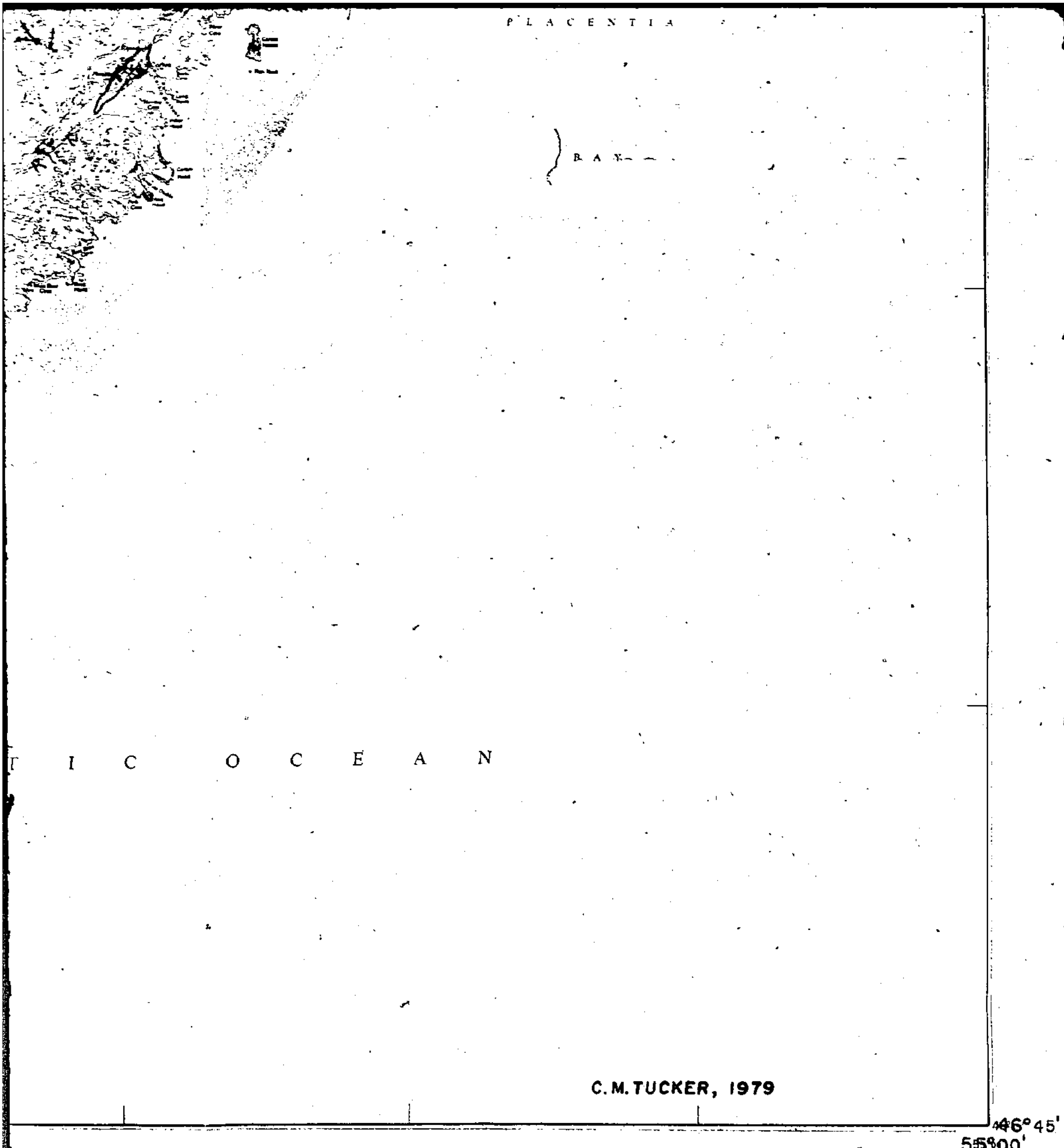


I M-3,4 & L-13,14

// of

BURIN PENINSULA, N

SCALE 1:100,0



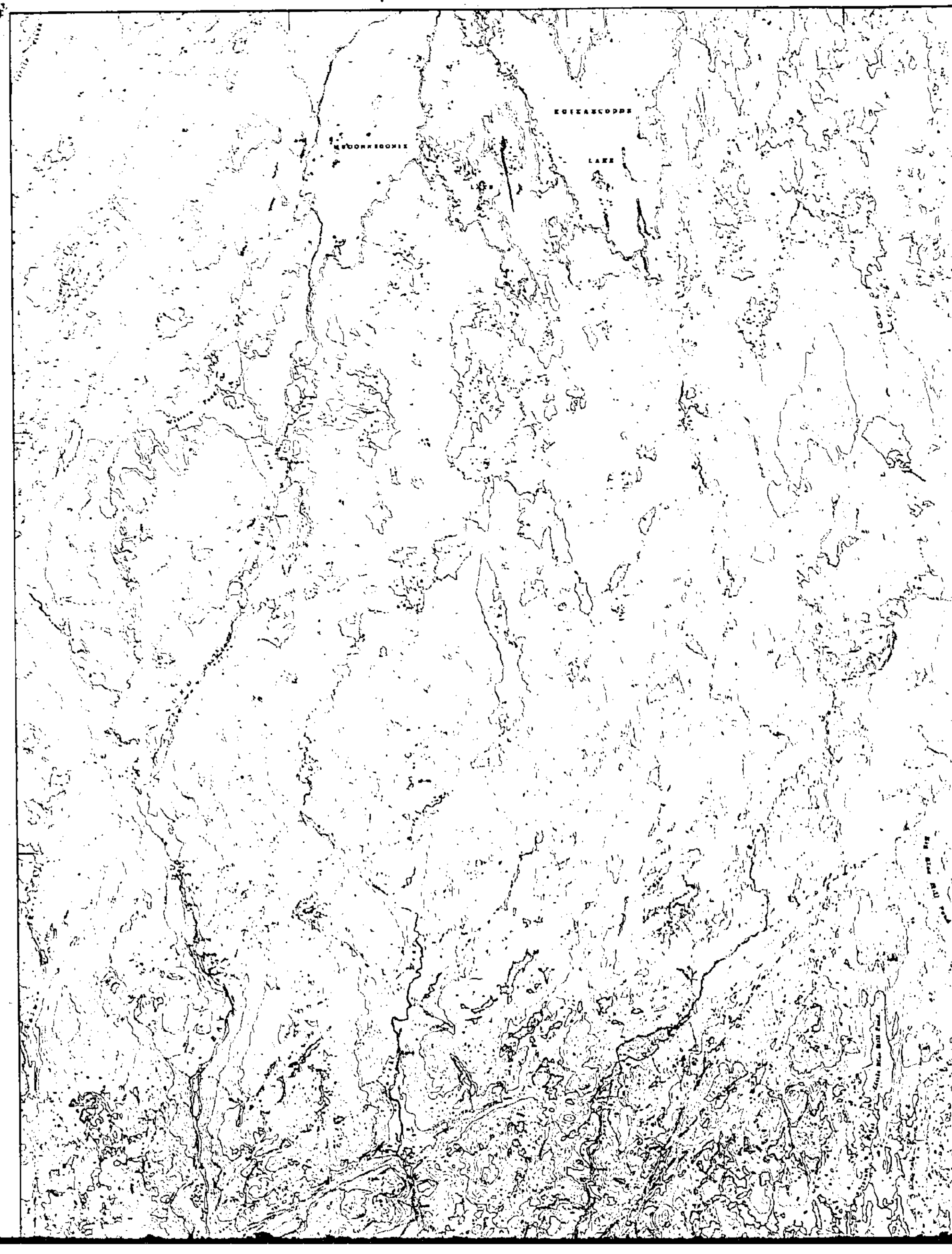
NSULA, NEWFOUNDLAND

SCALE 1:100,000

12 OF 12

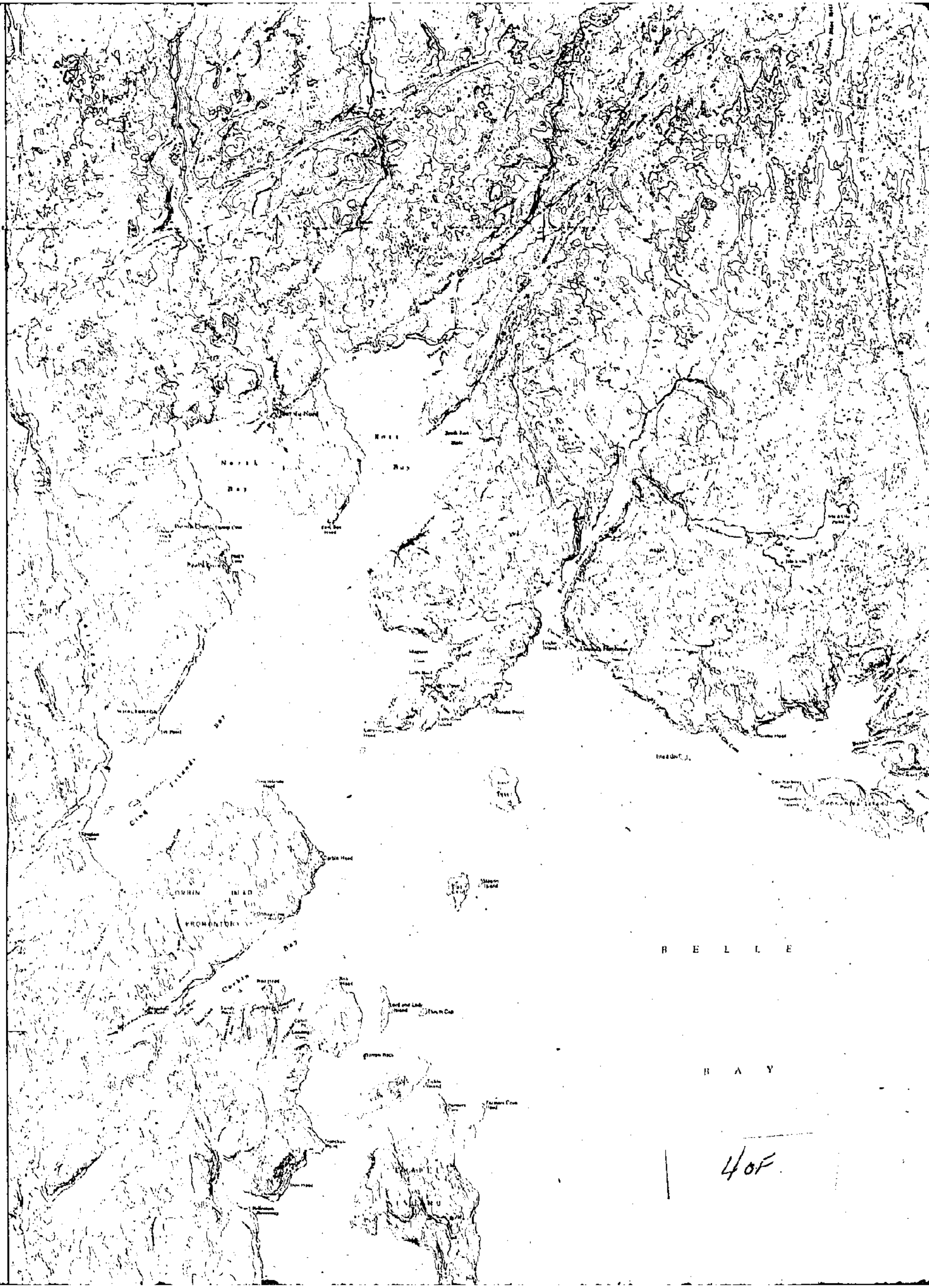
1oF

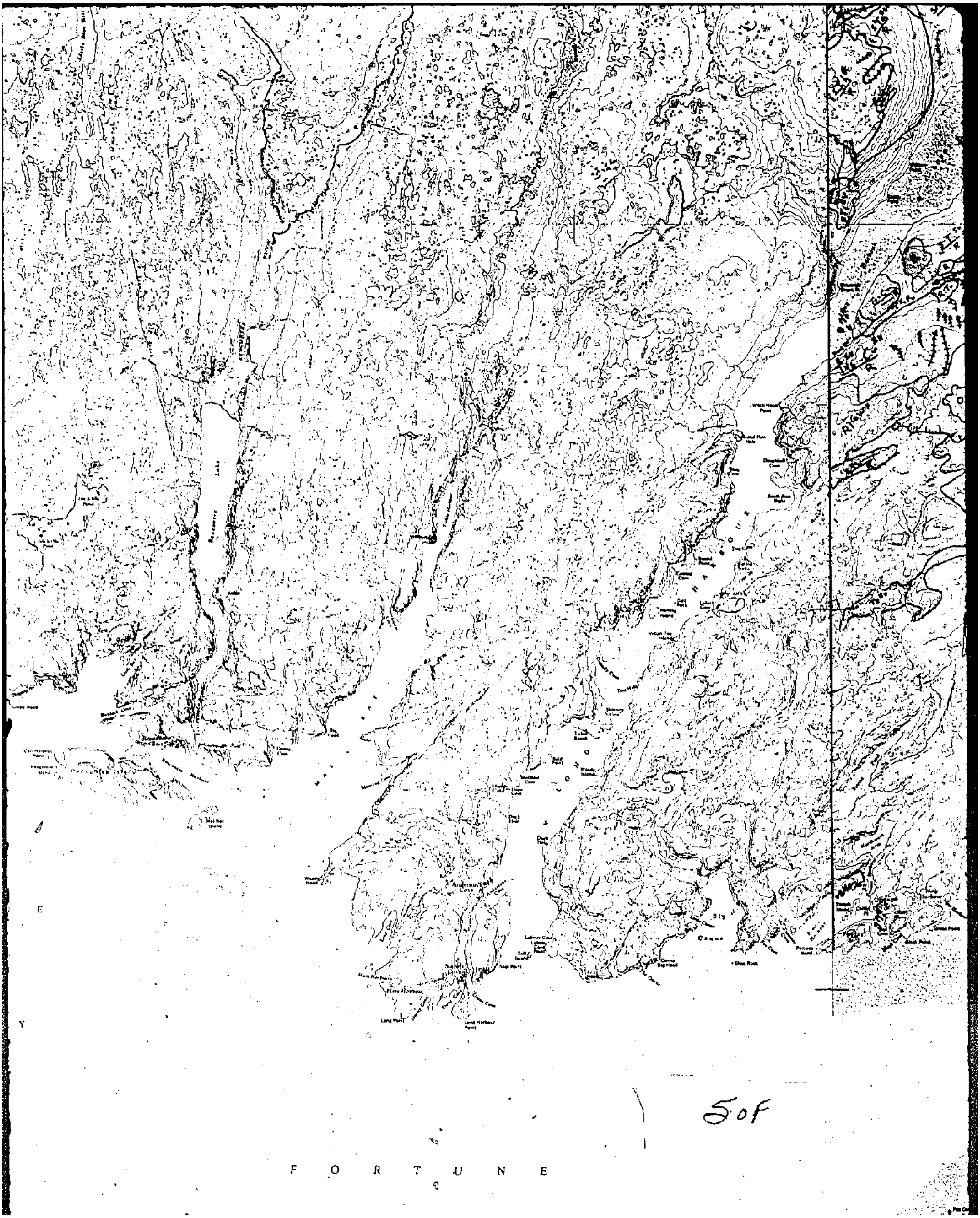
55°30'
48°00'

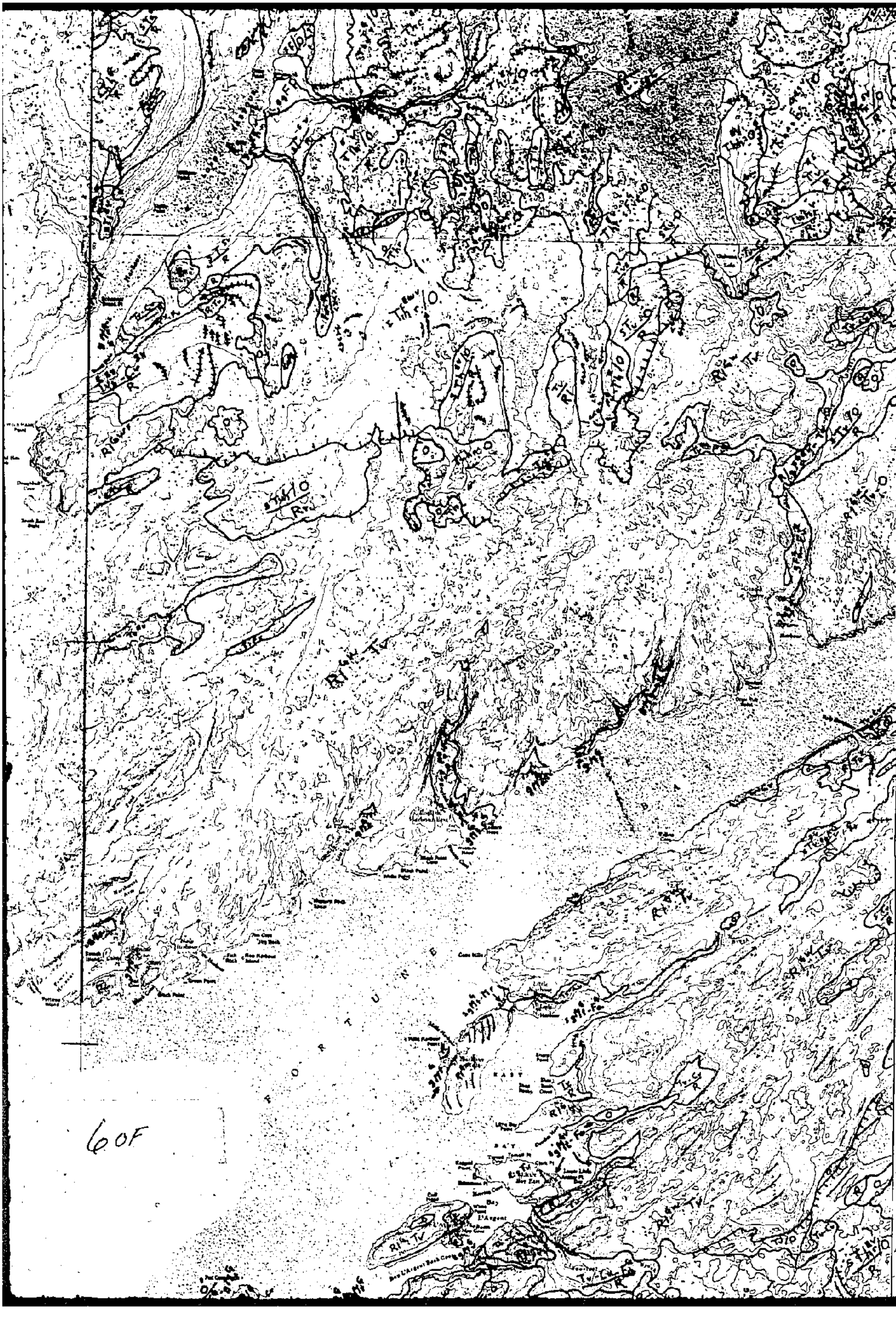


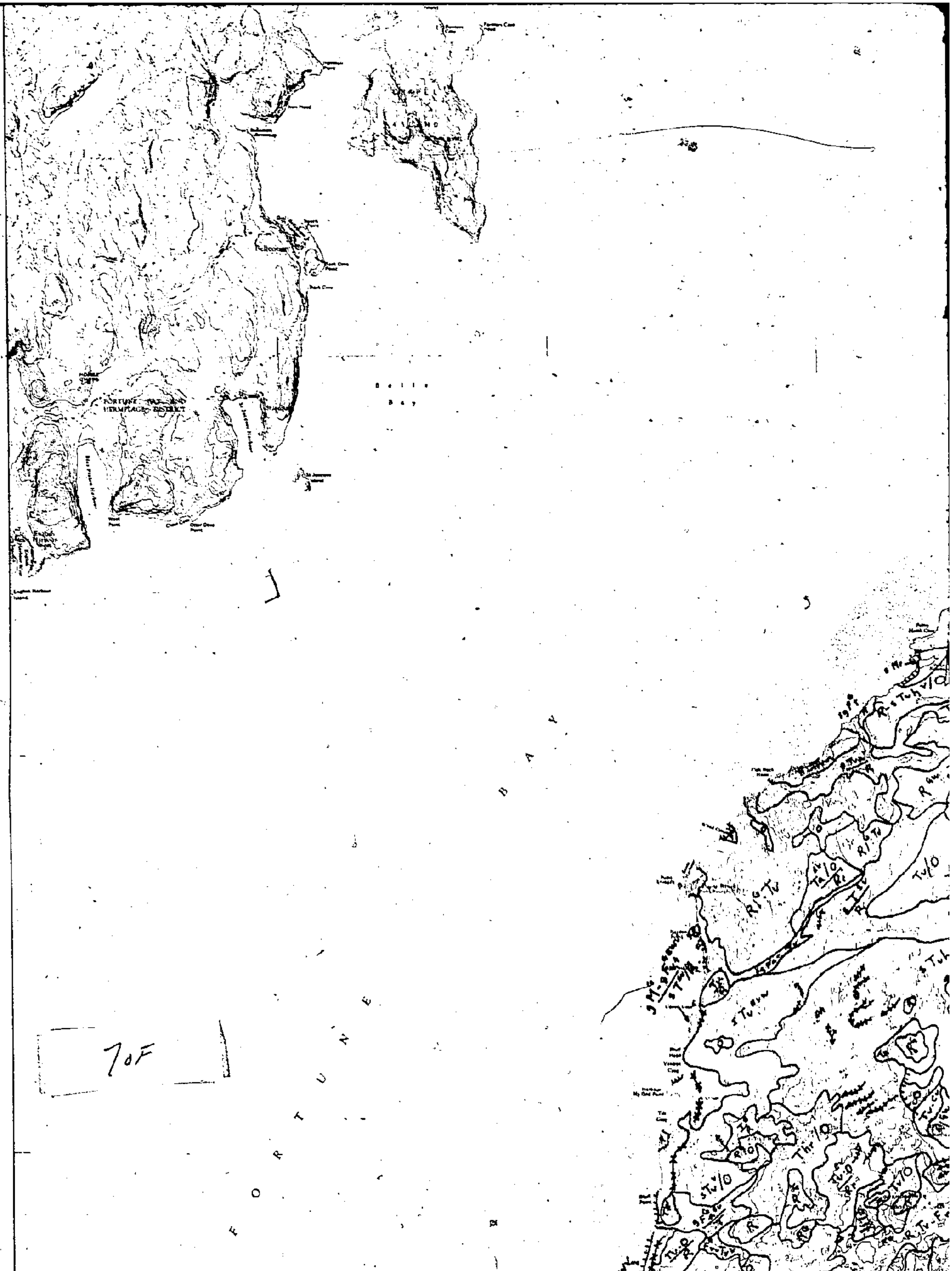
2 of

30K


North Bay
East Bay
CORBIN HEAD PROMONTORY
Corbin Head
BELLE BAY
4OF

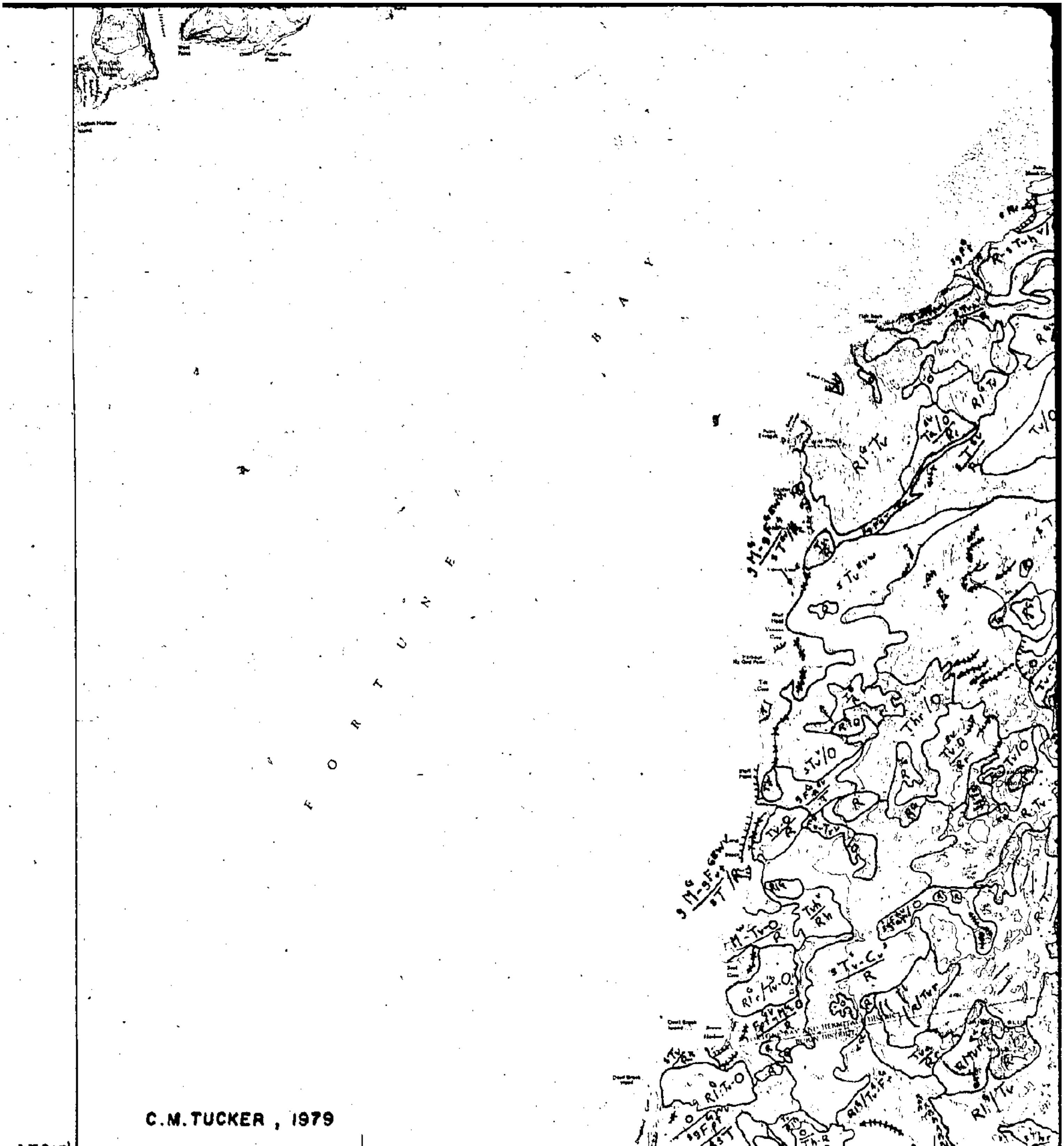

F O R T U N E
5oF


F O R T U N E
60F


Belle Bay
FORTUNE BAY
70F


F O R T U N E
B A Y
8 OF


L'Argent
9 of



47°15'
55°30'

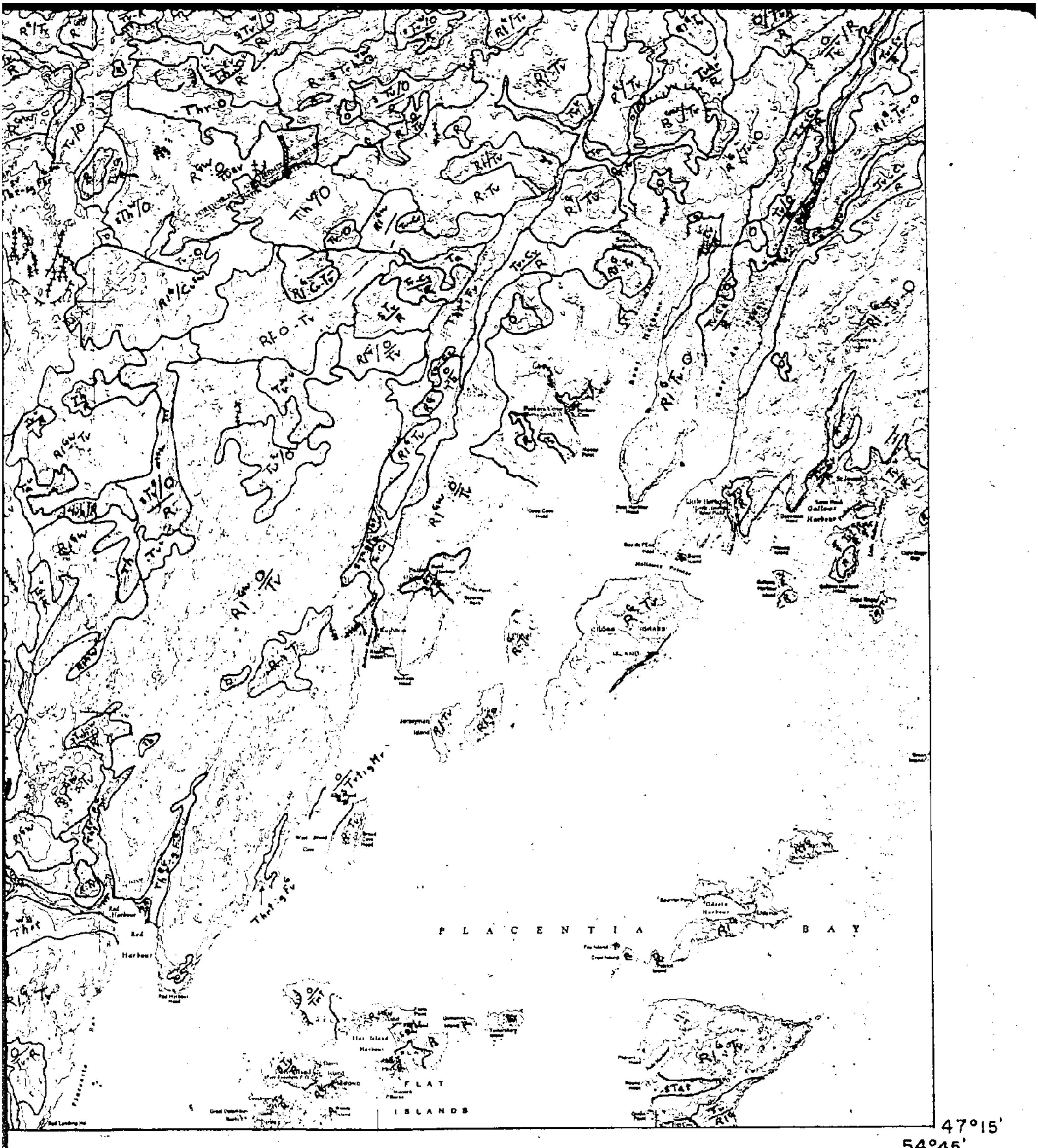
1 of

BURIN PENINS

I M-6,7,10,11,14,15

11 of

SCAL



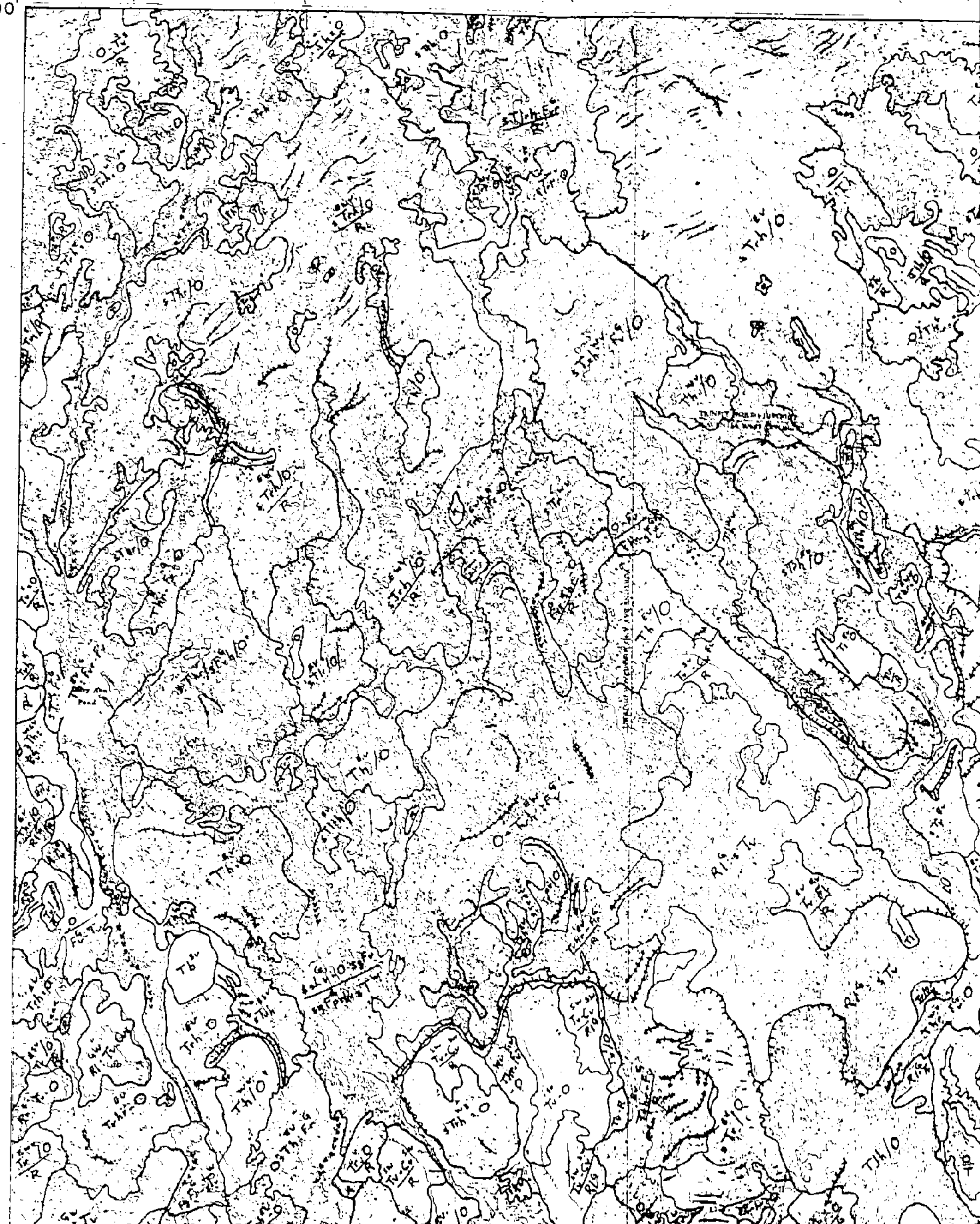
BURIN PENINSULA, NEWFOUNDLAND

SCALE 1:100,000

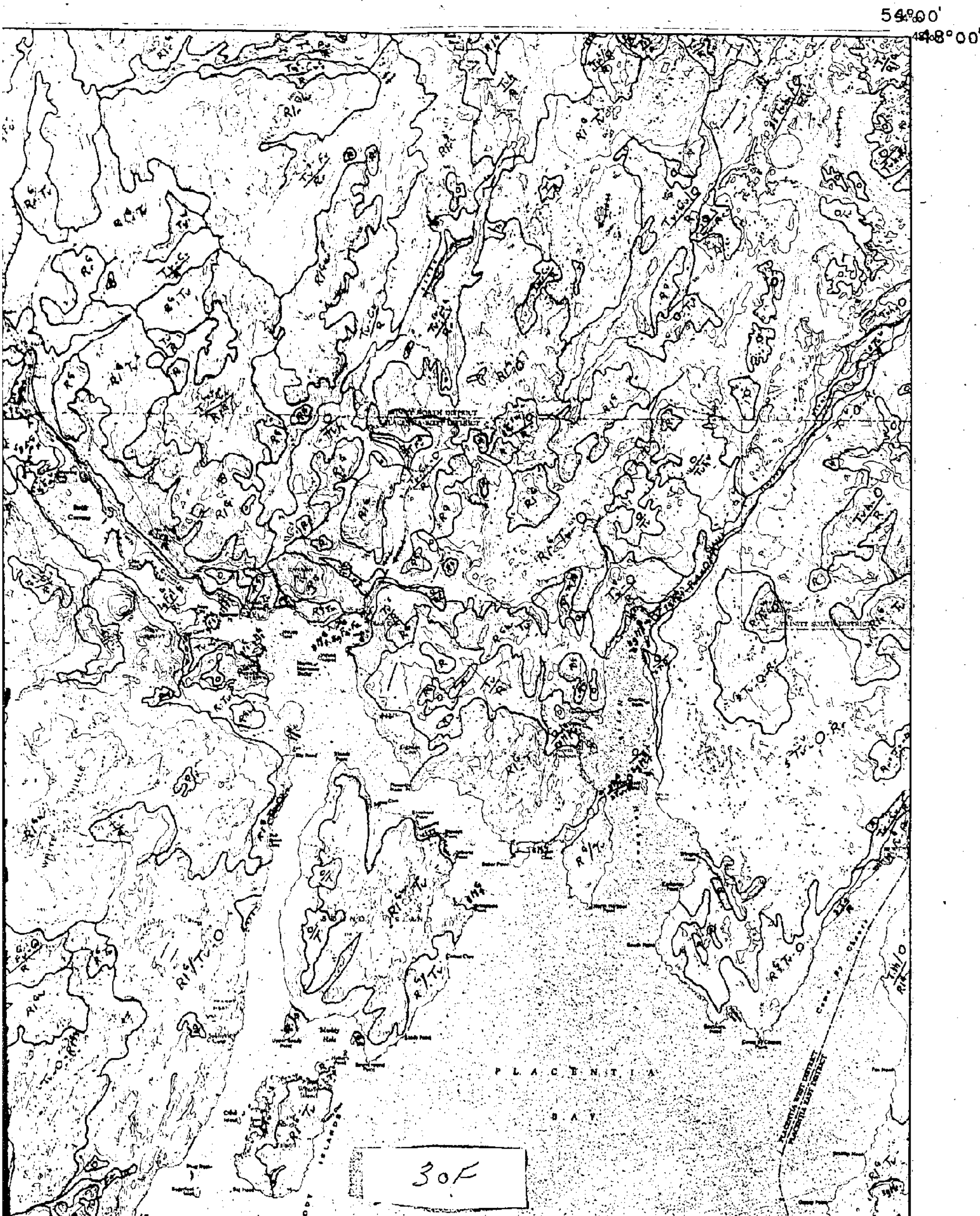
1 of

54°45'

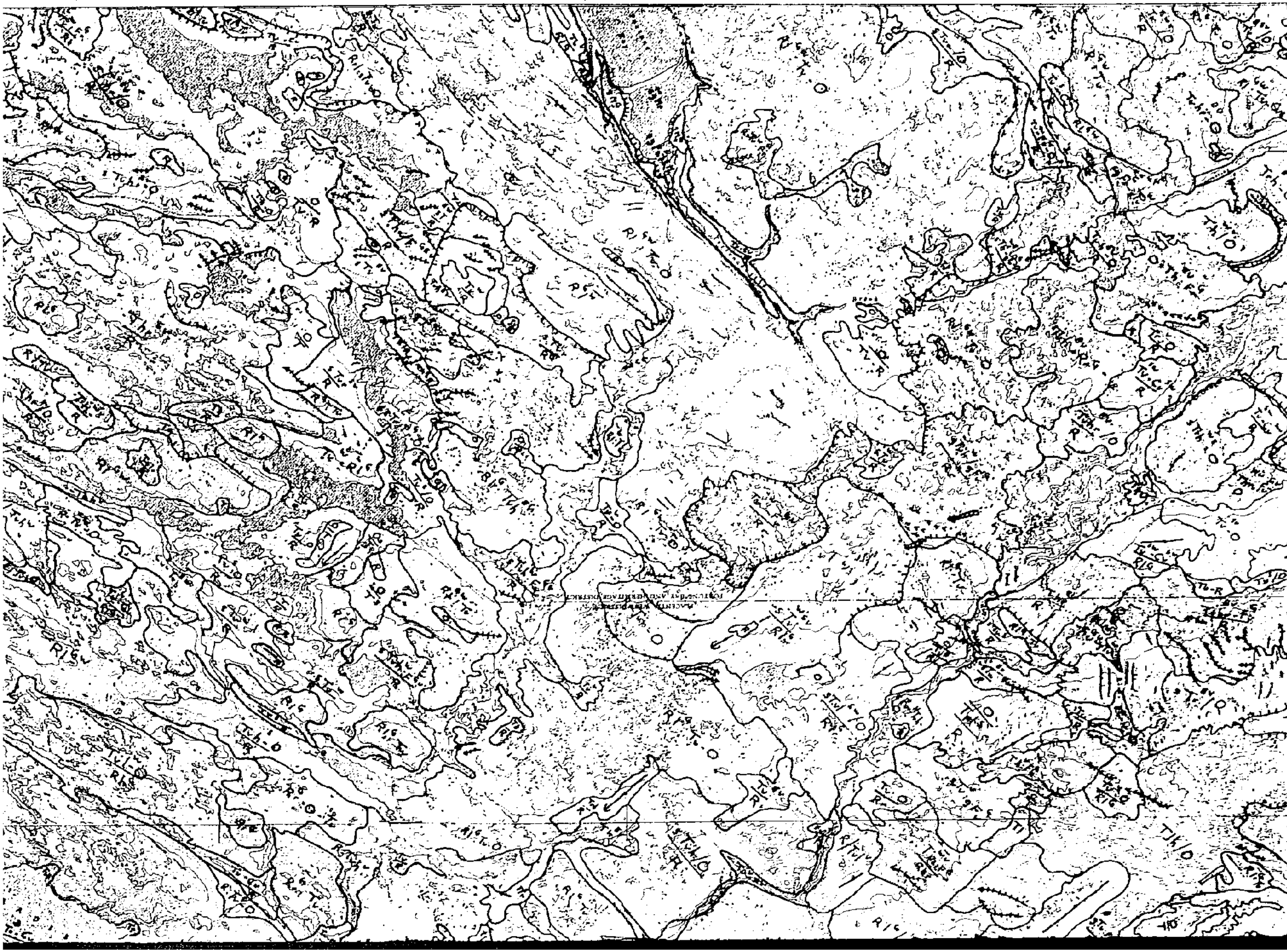
48°00'



2 OF

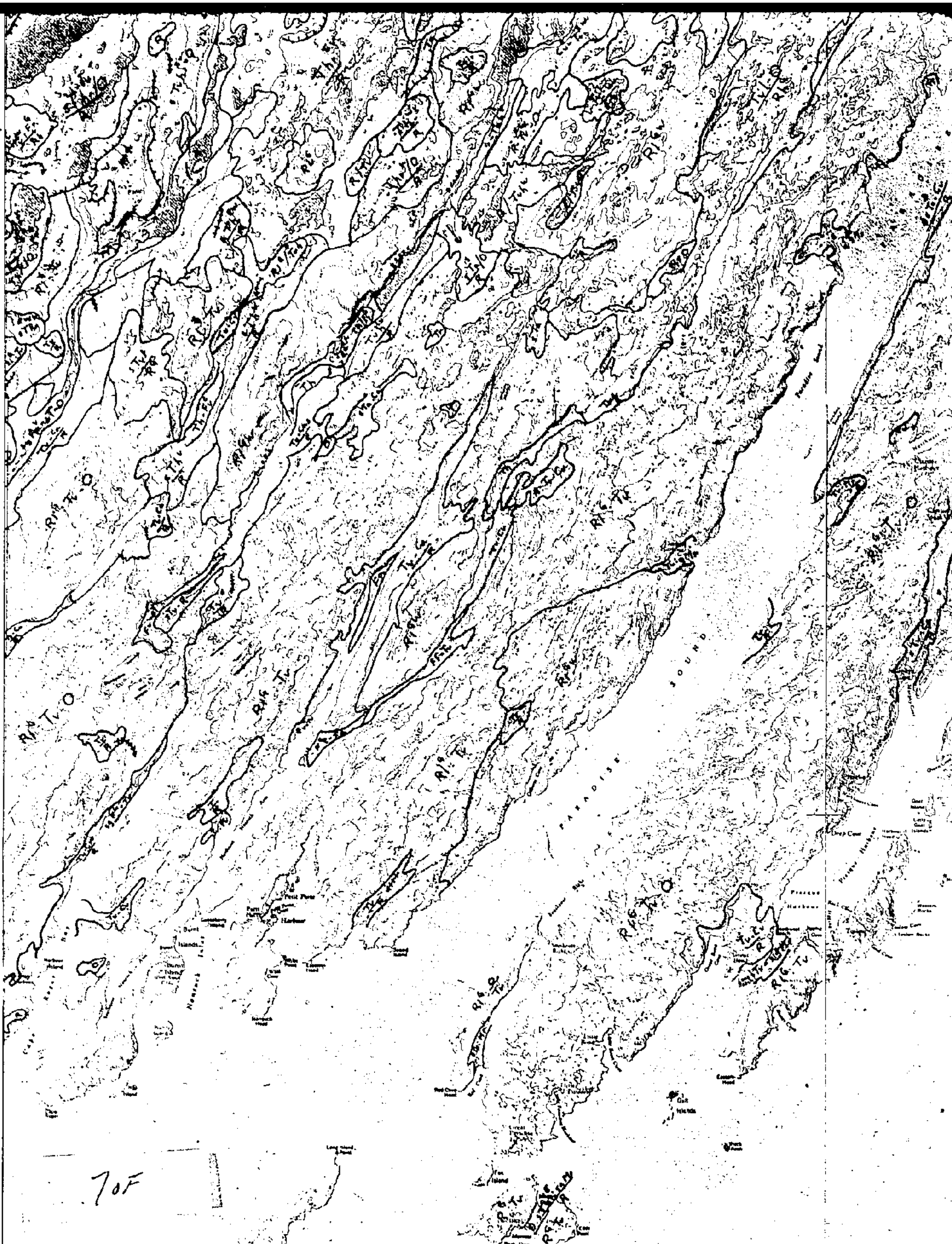

54°00'
48°00'
P L A C E N T I A
B A Y
30F

4 of



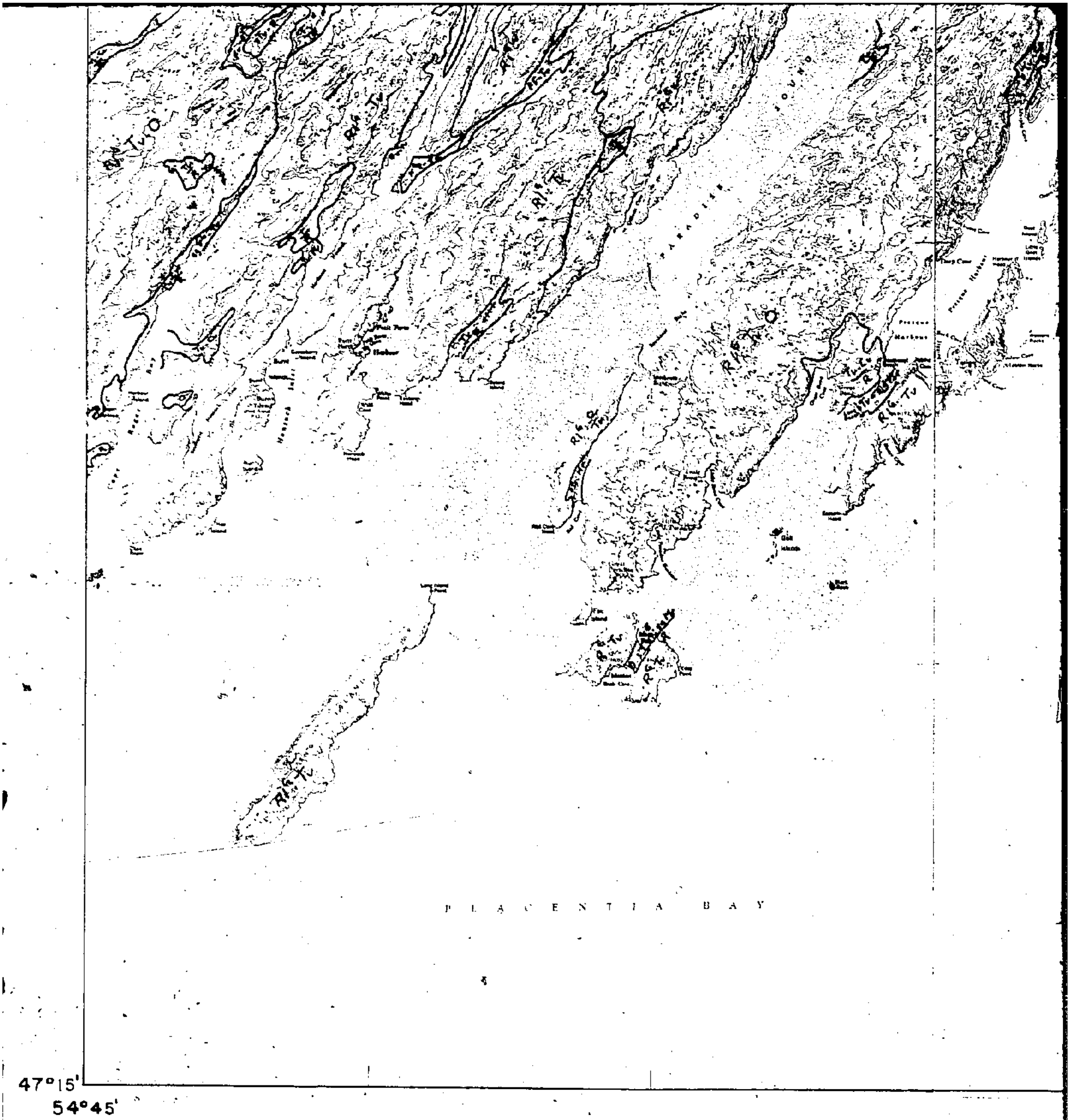

PLACENTIA
ISLANDS
5.0F


P L A C E N T I A
B A Y
P L A C E N T I A
RAGGED
ISLANDS
B A Y
E A S T E R N C H A N N E L
60F

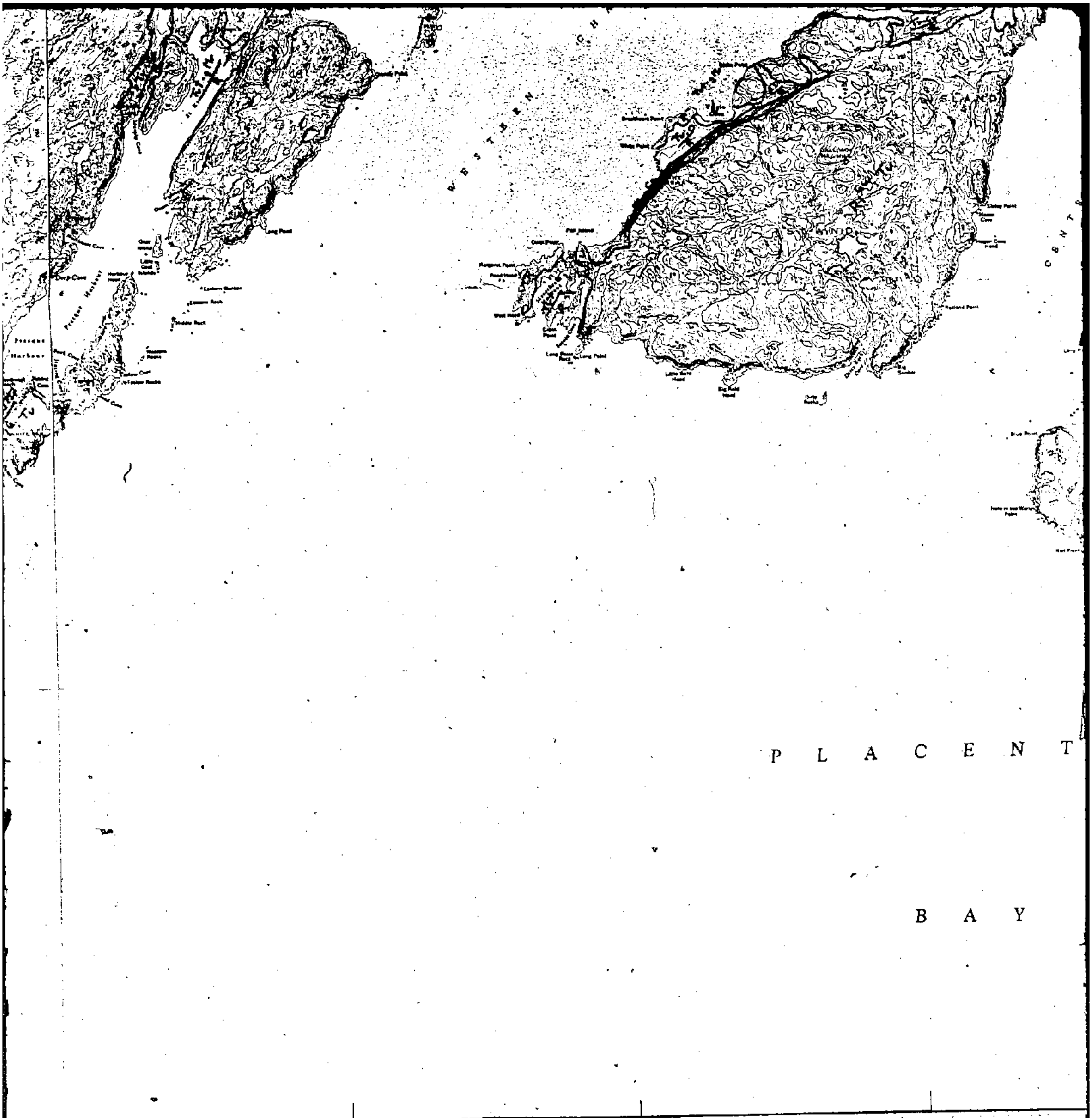

PARADISE SOUND
Petit Forte
Harbour
7oF

8 OF


CENTRAL CHANNEL
EASTERN CHANNEL
9 of



10 of

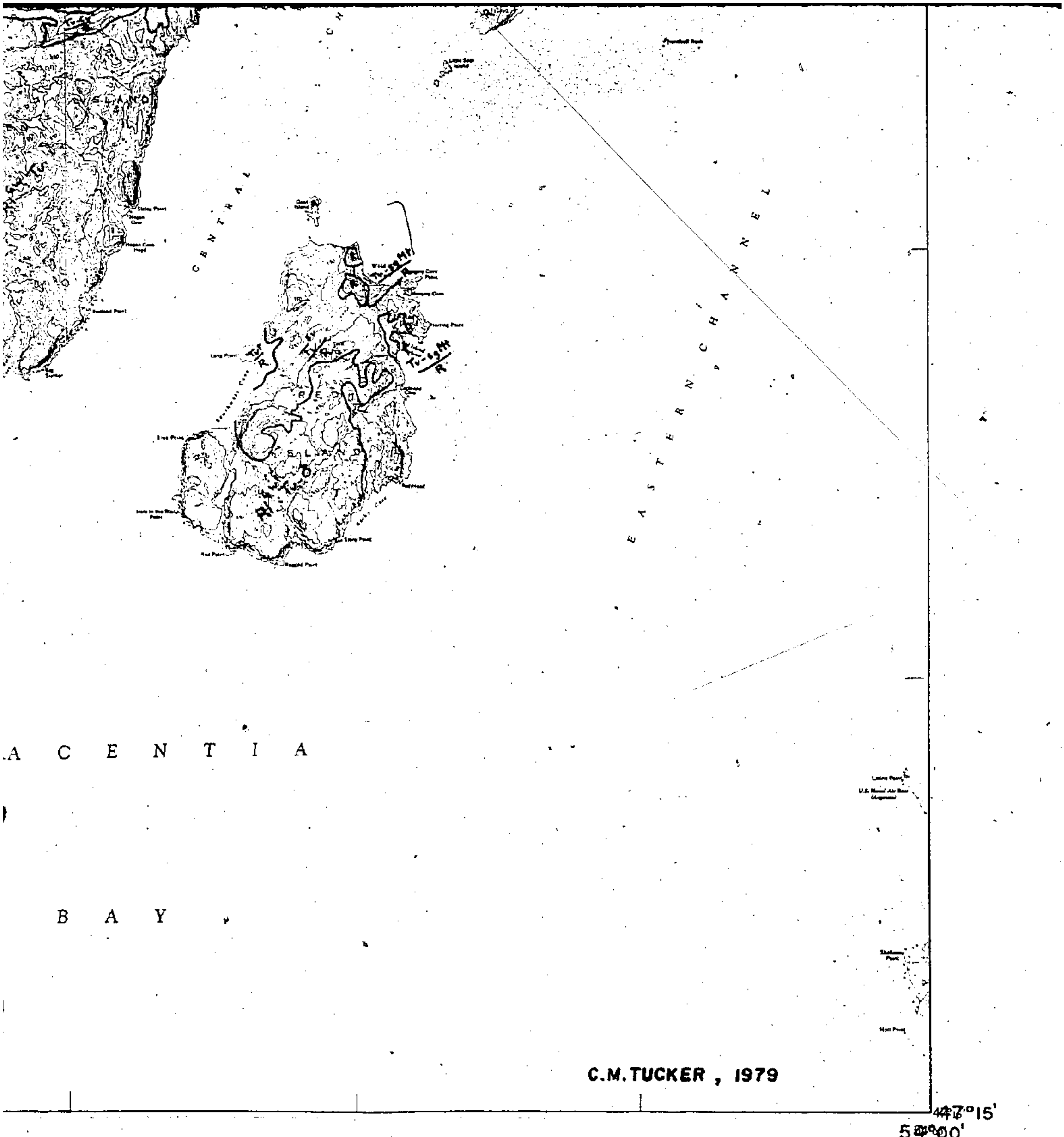


BURIN PENINS

SCAL

I M-7,8,9,10,15,16

11 of



RIN PENINSULA , NEWFOUNDLAND

SCALE 1:100,000

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