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QUATERNARY STUDIES IN NEWFOUNDLAND: A SHORT REVIEW

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INTRODUCTION

During the past century and a half, a considerable body of knowledge has been amassed on the Quaternary epoch of Newfoundland. Until recently, studies were of a reconnaissance nature, generally incidental to bedrock mapping projects or regional prospecting. No new information is contained in this paper; rather, the purpose is to provide an extensive, if not complete, list of reference for the area and to summarize the salient points presented in the literature. It is hoped that a historic approach will shed light on how specific theories developed and were maintained, while at the same time re-emphasizing problems that still exist in determining the scope and sequence of Quaternary events. Many original ideas such as those of Murray (1864, 1883), Fernald (1911, 1930), and Coleman (1926) have been obscured by more recent work, but in spite of improved logistics and research methods, several questions originally raised by the authors have yet to be resolved. Except for coastal events, the Quaternary of Newfoundland is, still, little understood.

EARLY APPLICATION OF GLACIAL THEORY

As was common for 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's topography its characteristic northeast-southwest lineation. Submergence was assumed to have been followed by local glaciation, which would explain anomalous radial striae and roches perchees that were recorded by Jukes (1843) on his excursions through Newfoundland. In 1876, referring to 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. This, he envisaged from the "scooping out of great holes" in Humber Arm and supposed terminal and lateral moraines found along its banks. 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. 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 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 workers in Newfoundland, Murray did more to interpret field data on the Quaternary in a manner that has some validity, even today.

THE OPPOSING THEORIES

In 1911, Fernald reported on an expedition to Newfoundland and Labrador. In it, he proposed that the island had remained unglaciated during the Wisconsinan. His argument (1925) was 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 theories

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were to be debated in the literature for the next two decades, though not from a botanical viewpoint. 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 were in agreement with Fernald's since peripheral upwarping 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 he could find no evidence for glaciation of the southern part of the Long Range Mountains during the Pleistocene; further, ice that 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. Coleman, as did his predecessors, reported locations of buried and raised Pleistocene shells, many of which have since been re-discovered and variously dated as being 15,000 to 11,000 years old.

Little information was added to knowledge of the Quaternary for the next decade until, with the aid of a Penrose Bequest from the Geological Society of America, a series of research projects was completed in the summer of 1939 that effectively established the basis for all future studies. R.F. Flint (1940) attempted to resolve the problem of post-glacial crustal warp on the west and north-central coasts of the island. He determined (Fig. 1) that isostatic rebound increases to the northwest 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 does note that Widmer (pers. comm.) recorded elevated deltas in Belle Bay, Fortune Bay. Flint interprets these 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. The Bay of Islands Surface, stretching from Port au Port Bay northward to Bonne Bay, was described as resulting from a lengthy stand-still during deglaciation, which allowed bench-cutting in sedimentary rock through widths of more than 60 m. Although it is not placed specifically within a rebound sequence, Flint envisages a time span of at least 5,000 years to cut the prominent surface.

McClintock and Twenhofel (1940) alternately co-authored two papers, financed from the Penrose Bequest, in which they devised a series of three levels of planation and proposed that the island had, in fact, been completely glaciated during the Wisconsinan. They concluded that:
1. Newfoundland may have been glaciated by Labrador ice during the Wisconsinan.
2. In a late phase of the Wisconsinan, 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 the Annieopsquotch Mountains and the Red Indian Lake area.
3. A slight deglaciation occurred along the southwest coast which allowed deposition of fines and glacio-marine sediment.
4. Following this, a slight re-advance in St. George's Bay deposited till and gravel (Robinson's Head Drift) over marine beds and earlier drift, and formed a "strong continuous moraine from the Anguille Mountains to Port au Port".

Tanner (1940) while enroute to Labrador, 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.

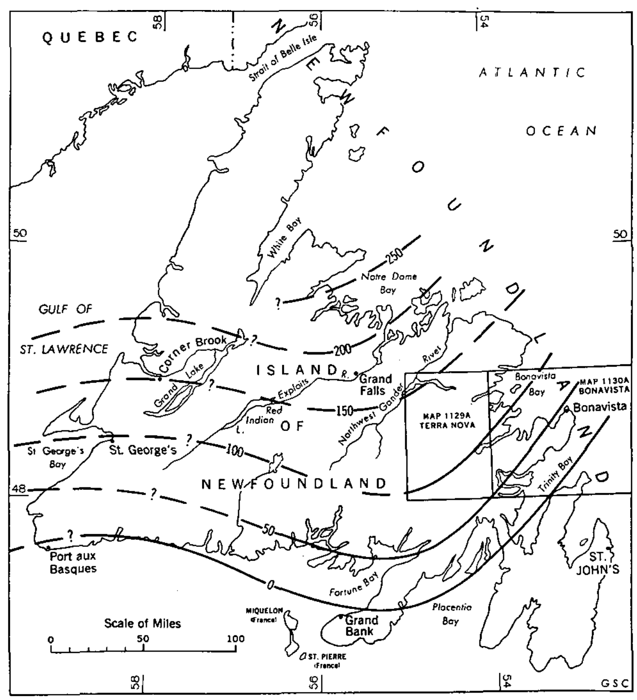

Fig. 1. Isobases of the island of Newfoundland, based on upper levels of outwash deltas. (Data for west coast from Flint 1940). Source; Jenness (1963).

RECENT INVESTIGATIONS

Following the 1940 Princeton-Yale field work, little else was published until the end of the decade though, when research resumed, studies had shifted from the northwest coast to the south and east coasts. Summers (1949), following the lead of MacClintock and Twenhofel, submitted an M.Sc. thesis to McGill University on the physical geography of the Avalon Peninsula in which he proposed a series 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 interglacial, wave-cut benches were formed at two levels (the relationships of which are unclear).
2. The Wisconsinan 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 Wisconsinan culminated in a stand north of Fortune Bay.
4. A late Wisconsinan 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, standlines 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. 2). The system of lakes was

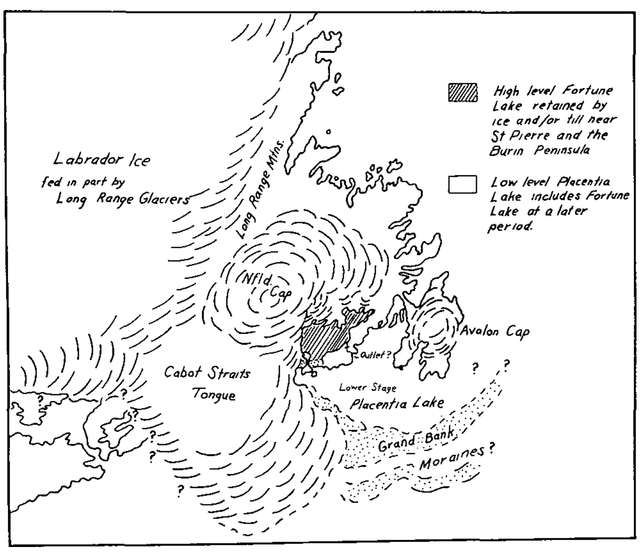

Fig. 2. Glacial lakes Fortune and Placentia. Source; Widmer (1950).

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. Grant (1975b) reported the occurrence of multidirectional striae on the Burin Peninsula that he interpreted as suggesting an initial ice flow south-southeast from the island followed by a period of intensive weathering and flow to the north and west from ice centered over the Burin Peninsula-Grand Banks area. He also noted the presence of northward-stossed hills on the Hermitage Peninsula coast (Fig. 3), and several sitings of till overlying glaciofluvial deposits. This new evidence would seem to complicate, or require significant modification to the deglacial chronology proposed by Widmer.

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 Murray concluded that the Annieopsquotch Mountains acted as a centre of accumulation during the Wisconsinan and agreed with MacClintock and Twenhofel that the assignment of glacial deposits in central Newfoundland to that stage seemed valid.

Several years later, S.E. Jenness (1960) published a 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:

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 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. 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 unwarping towards the northwest. Isobases drawn on the upper levels of deltaic sediments associated with outwash are concave towards the northwest (Fig. 1).

Lundqvist (1965) attempted to trace the Jenness inner-outer drift zone boundary in north-central Newfoundland (Fig. 4). A discrepancy between the two systems was obvious since Lundqvist proposed

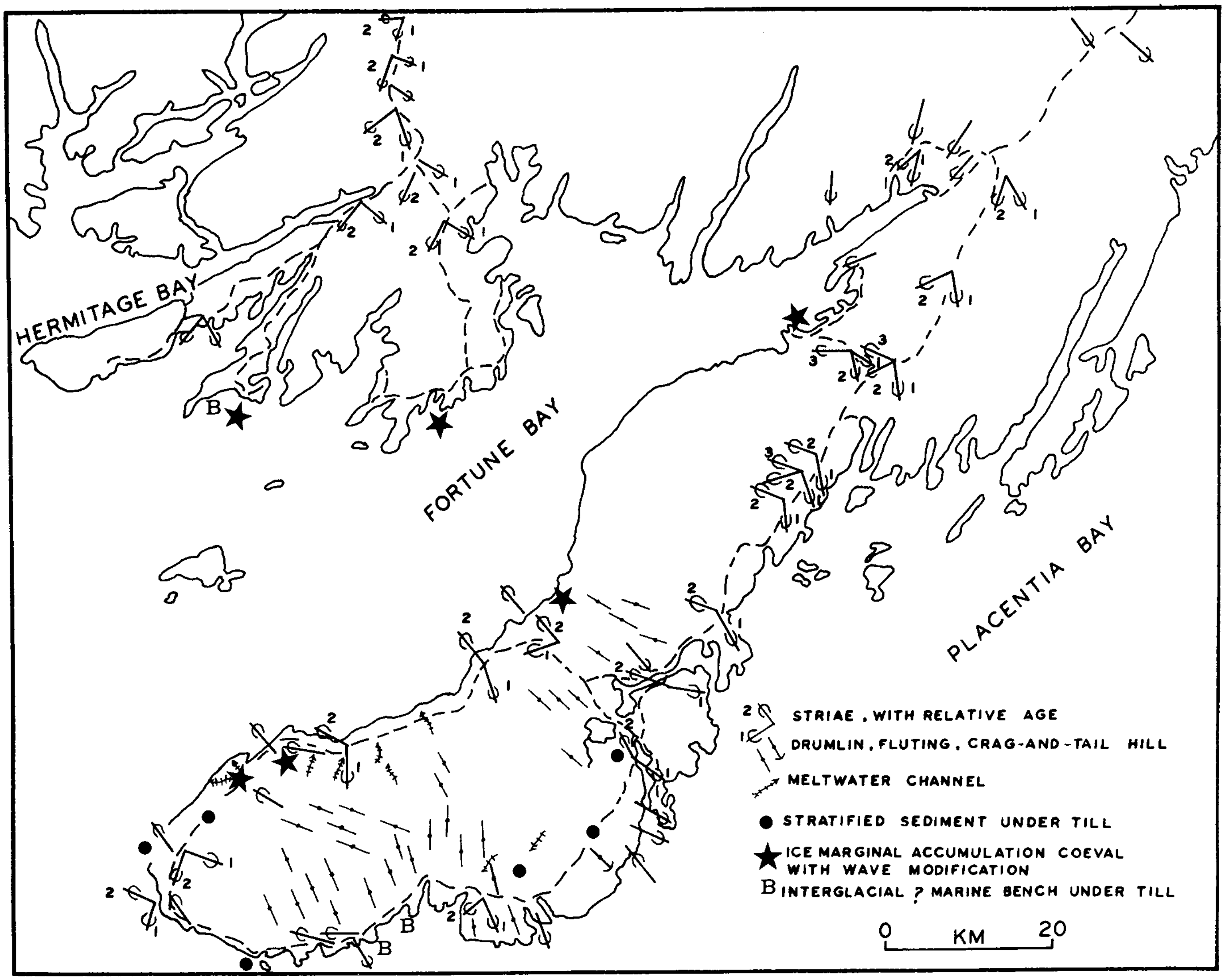

Fig. 3. Glacial features of the Hermitage-Burin Peninsula area. Modified from Grant (1975b).

that the ice margin in north-central Newfoundland be positioned at the delta interfaces in Halls Bay. Dyke (1972) took issue with Jenness's proposals and determined that the Eastport Bonavista Bay delta was, a) glaciomarine in origin and, b) formed when the ice front was less than 2 km from the marine limit and not at the position of the inland terminal moraine. Lundqvist also suggested that the Halls Bay deltas were glaciolacustrine, however, Tucker (1974a) concluded that the features were in fact glacio-marine. As a point of interest, the idea of glacio-lacustrine 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 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 (1974, 1975, 1976) did discoverer 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 and C^{14} dates obtained over the previous decade (Fig. 5). The sequence of events proposed by Brookes was roughly similar to that described by MacClintock and Twenhofel (1940). 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 (Fig. 6).

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. Subsequent 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

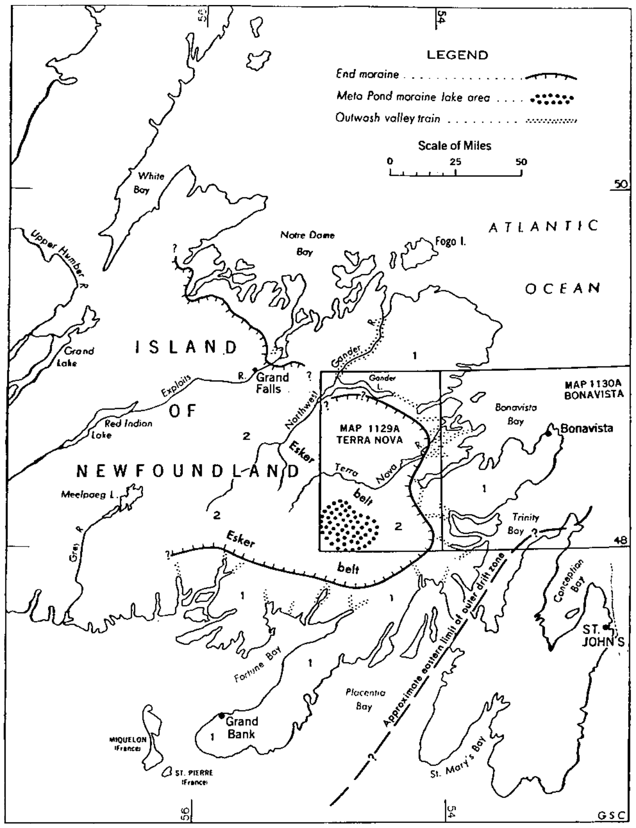

Fig. 4. General distribution of glacial deposits in eastern Newfoundland. Inner-outer drift zone continued in West-central Newfoundland from Lundqvist (1965). Modified from Jenness (196~).

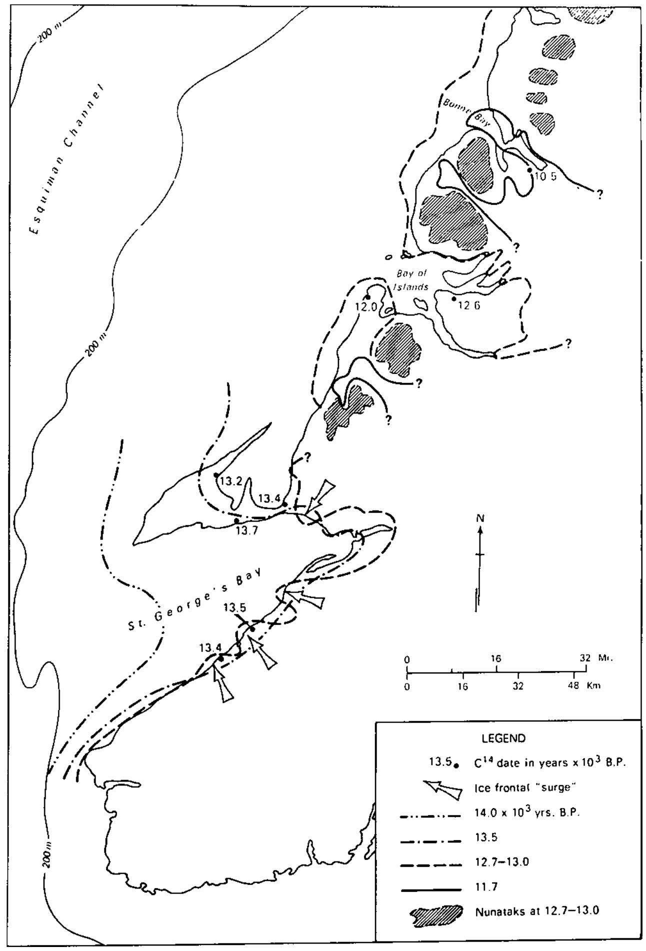

Fig. 5. Speculative ice-marginal positions during deglaciation of south-western Newfoundland. Source; Brookes (1974).

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-Wisconsinan ice is afforded by the presence of old cirques that appear to have been over-ridden and not re-occupied by glaciers.

Subsequently, Grant (1970, 1971, 1972a,b,c, 1973a,b,c, 1974a,b, 1975a) published notes that detailed Quaternary events on the Northern Peninsula as far south as Bonne Bay.

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 he revised his ideas and proposed (Fig. 7) that:

1. At the glacial maximum southward flow of ice centered 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 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 on the Trepassey Peninsula highlands.

The same year Slatt (1974) 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 now covered by more than 90 m of water, reworked glacio-fluvial sediments, defined a Wisconsinan ice limit at somewhat less than 150 km from the present coastline.

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,

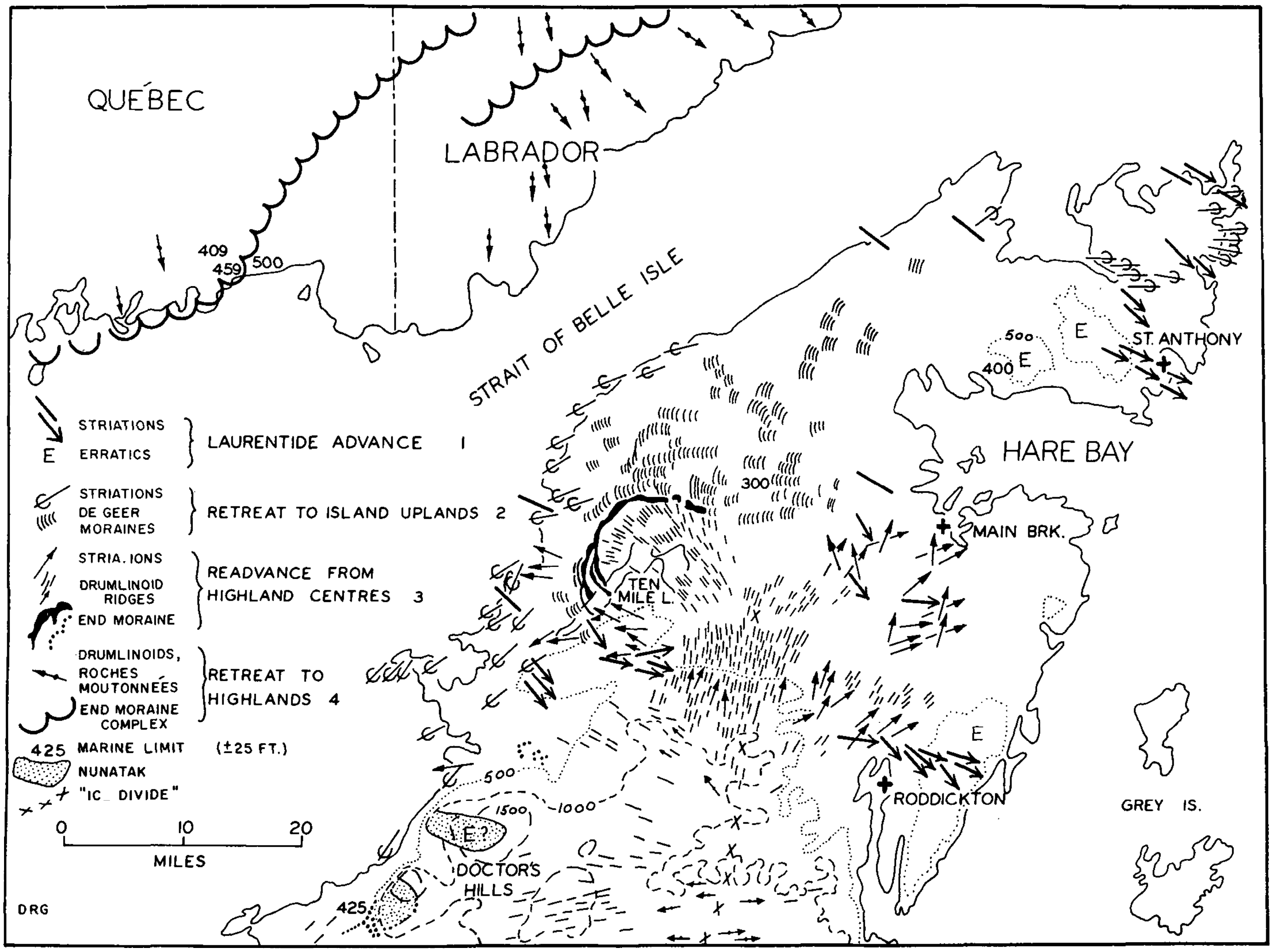

Fig. 6. Glacial features, Northern Peninsula of Newfoundland, and adjacent Quebec Labrador. Re-drafted from Grant (1969a).

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, Annieopsquotch Mountains and 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 and increases 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.

DISCUSSION

Due to the nature of the present publication and multitudinous references, a synthesis of Quaternary events may seem fragmented. Generally, it is known that:

1. At sometime during the Pleistocene, possibly before the Wisconsinan maximum, ice invaded the Northern Peninsula from Labrador.
2. During the Wisconsinan, Newfoundland supported its own ice cap which was domed over the central part of the island and the Avalon Peninsula. From the south coast, and the Avalon, ice advanced at least 150 km onto the Grand Banks.
3. Ice retrated from the southwest coast about 13,700 B.P., probably later further north. A readvance occurred about 12,750 B.P. near St. Georges' Bay and about 10,900 B.P. near Ten Mile Lake at the northern extremity of the Peninsula. Deglaciation from a calving ice front took place about 12,000 B.P. on the north-central coast and as much as 1500 years earlier on the south coast.
4. Ice culminated as minor independent ice caps (Fig. 8) as determined by Grant 1974a).
5. Postglacial vegetation was present on the Avalon Peninsula about 8,400 B.P. (Terasmae 1963) following a pronounced and extensive period of periglacial activity (Henderson 1968, MacPherson 1973).

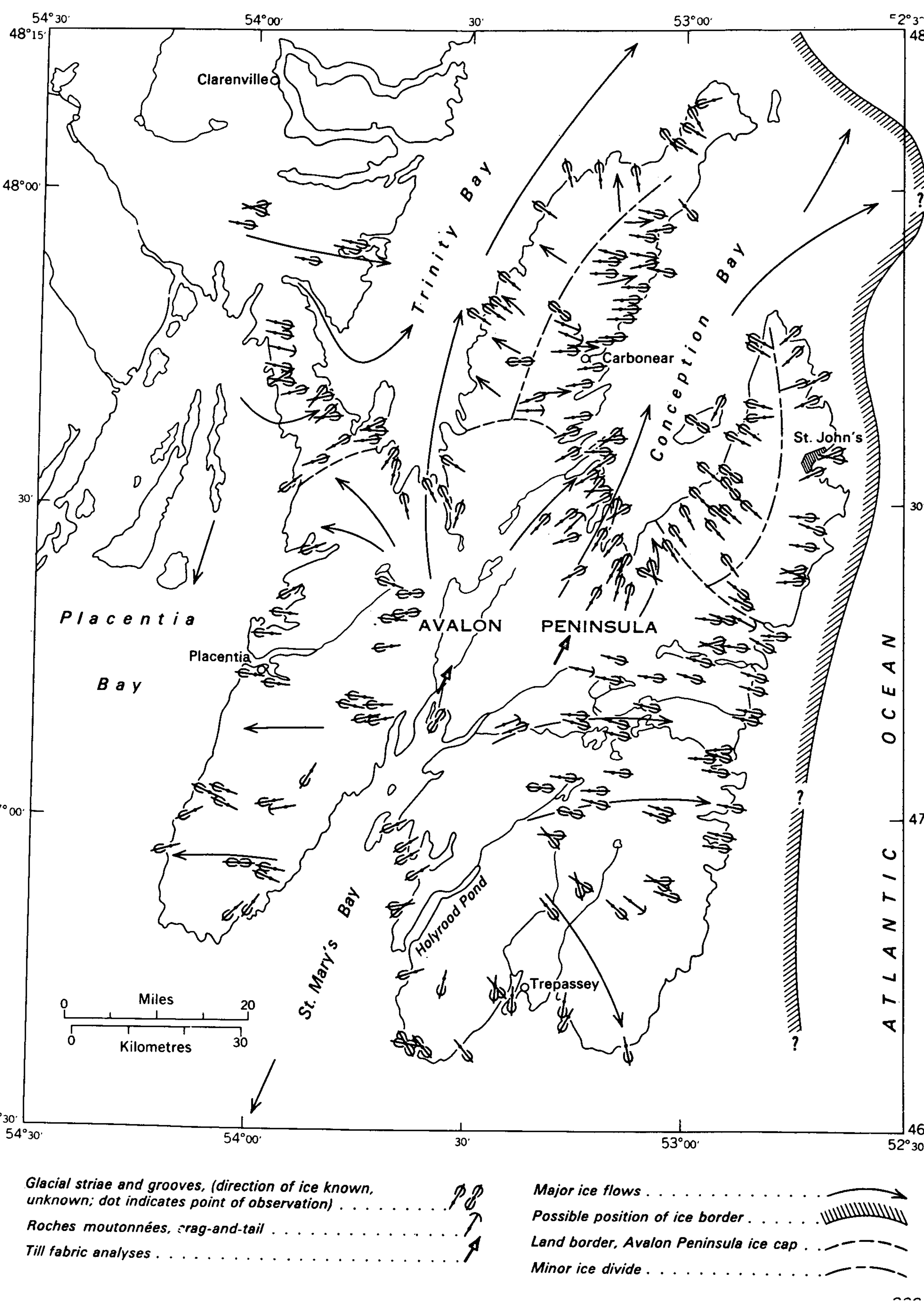

Fig. 7. Orientation of ice-flow indicators and probable extension of ice at the Wisconsinan glacial maximum. Source; Henderson (1972).

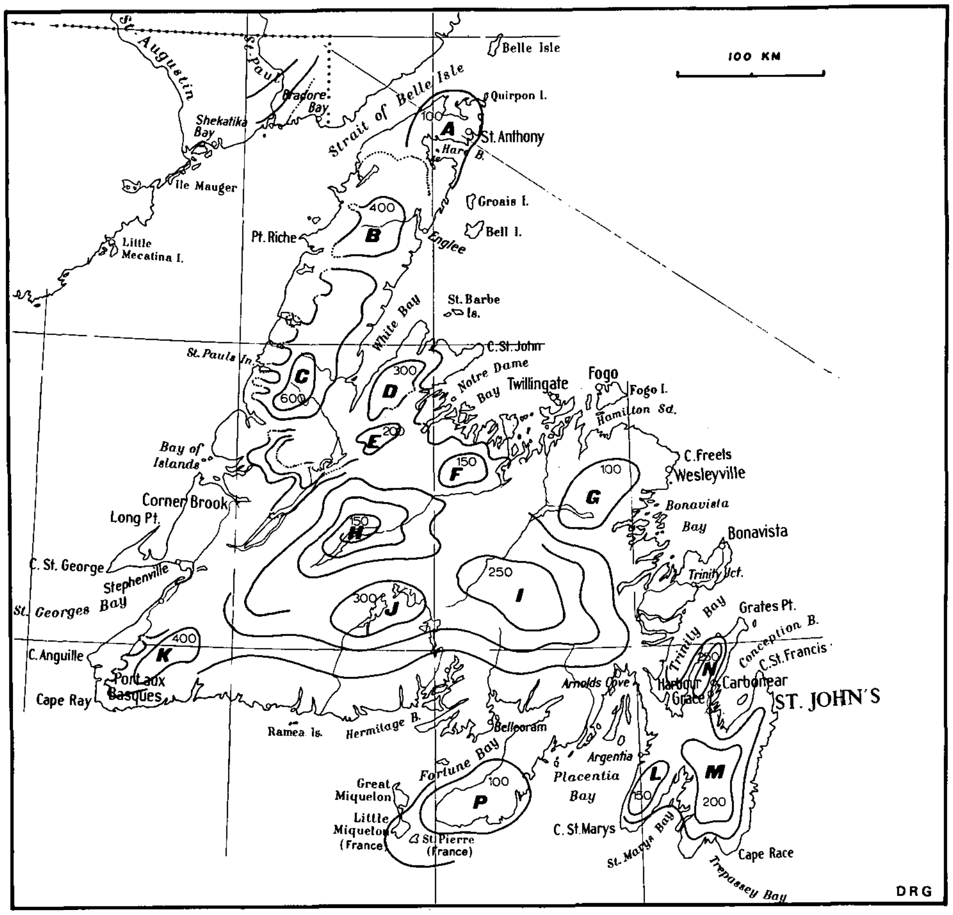

Fig. 8. Approximate location of remnant ice caps during deglaciation of Newfoundland. (Dotted lines mark end moraines and other ice-marginal features; figures are average ground elevations in m). Source; Grant (1974c).

Some of the unknowns are:

1. How far south did Laurentide ice advance on the Northern Peninsula and were there long-term glacial refugia in the southern Long Range Mountains? Fernald's argument has never been clearly refuted. It is possible though, for vegetation to exist near a temperate ice margin and this may have allowed migration of species from the west to east coast of the continent. Lindroth (1963) attempted to resolve the problem by study of the dispersal and variants of Carabid beetles in Newfoundland. He concluded that a noted tendency towards subspeciation was unlikely to have occurred in the short postglacial period; thus, adding further support to the idea of glacial refugia. Recent work by Ives (1975) and the Institute of Arctic and Alpine Research, Colorado has revived interest in limited ice extent during the Late Wisconsinan. It seems clear that ice coverage may not have been as pronounced as had been formerly thought.

2. What are the ages of previous Pleistocene glaciations? Coleman (1926) probably misinterpreted intensive periglacial weathering of granite and granodiorite as being proof of ice-free areas during the Wisconsinan. It was commonly believed by his contemporaries that the Wisconsinan stage was an entity and not a series of retreats and advances as we now know. Recorded multidirectional flow indicators, multiple till sheets and buried organics (Van Alstine 1948, Henderson 1972, Alley 1975, Alley and Slatt 1974, 1975, 1976, Grant 1975b, and Grant and Tucker 1976) imply that stratigraphy on the island is complex and ice-flow patterns, unrelated to final flow, are present.

3. How did ice advance and retreat on the Grand Banks? The questions posed by Widmer (1950) have not been resolved, and deglacial chronology of the western south coast is unknown.

4. Was there a significant pause of ice inland (Jenness 1960, 1963 and Lundqvist 1965) which post-dates deposition of the north-central and northeast coast deltas and, if such a stand existed, how did it relate to other halts such as at the Kitty's Brook moraines on the west coast (MacClintock and Twenhofel 1940, Prest 1970 and Tucker 1974b)?

5. What is the pattern of isostatic rebound on the south coast of the island and can any of the benches mentioned by Widmer (1950) be related to the Bay of Islands Surface described by Flint (1940)?

The first two points listed are inter-related and merit attention as such. One hopes that future research may unravel some of the questions more rapidly than has occurred in the past.

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